Stretto di Messina

Concessionaria per la progettazione, realizzazione e gestione del collegamento stabile tra la Sicilia e il Continente Organismo di Diritto Pubblico
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EurolinK

PONTE SULLO STRETTO DI MESSINA

PROGETTO DEFINITIVO

EUROLINK S.C.p.A.

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Abbreviations

AC	Alternating Current - corrente alternata
AID	Automatic Incident Detection - sistema di identificazione automatica
ALPR	Automatic Licence Plate Recognition (Targa di riconoscimento automatico)
ANSI	American National Standards Institute (istituto nazionale americano per gli standard)
ASTM	American Society for Testing and Materials
AVC	Automatic Vehicle Classification (classificazione automatica del veicolo)
BAN	Bridge Area Network
Bridge	Messina Strait Bridge
BS	British Standard
CCD	Charged Coupled Device
CCITT	*Comité Consultatif International Téléphonique et Télégraphique*(4) , livello mondiale
CCTV	Closed Circuit TeleVision-(televisione/telecamera a circuito chiuso)
CEI	Comitato Elettrotecnico Italiano
CEN	*Comité Européen de Normalisation*, livello europeo
CMS	Control and Monitoring System
CSP	Computing, Simulation & Prediction
dB	deciBel
dBi	Gain relative to isotropic antenna
dBm	Power level relative to 1 mW
DC	Direct Current - corrente continua
EBB	Equipotential Bonding Bar -Barra equipotenziale

EMC	ElectroMagnetic Compatibility-Compabilità elettromagnetica
EN	Europa Norm
ENEL	Italian Electrical Power Utility
ETSI	Europeam Telecommunications Standard Institute

GBIC	Gigabit Interface Converter
General Contractor	Eurolink
HMI	Human-Machine-Interface
HV	High Voltage
IR	Infra Rossi
IEC	International Electrical Commission
IMS	Incident Management System
kA	kilo Ampere
kV	kilo Volt
LAN	Local Area Network - (rete ad estensione locale)
LCC	Life Cycle Cost
LCS	Roadway Lane Control Signals (Lanterne semaforiche veicolari di corsia).
LPL	Lightning Protection Level-Livello di protezione
LPS	Lightning Protection System - Sistema di protezione contro i fulmini
LPZ	Lightining Protection Zone - Zona di protezione da fulminazione
LV (BT)	Low Voltage (Bassa Tensione in c.a. (400/230V))
MDIX	Medium Dependent Interface
M&E	Mechanical and Electrical
MMI	Man Machine Interface
NIC	Network Interface Controller
PBX	Private Branche eXchange
PDS	Premises Distribution System
PE	Protective Earthing - Conduttore di protezione
PEN	Conduttore di protezione e neutro
PMS	Power Management System - Sistema di gestione del la potenza
PSTN	Public Switched Telephone Network-(rete telefonica commutata ad accesso pubblico)
RFI	The Italian Railroad authority "Rete Ferroviaria Italiana"
RTMS	Road Traffic Management System (sistema di gestione del traffico stradale)

RWiM	Railroad Weight In Motion system (sistema per il rilevamento dinamico del peso). In this document RWiM is solely referring to Weight In Motion systems for trains. See also WiM.
SCADA	Supervisory Control and Data Acquisition system-Sistemi di Supervisione Controllo ed Acquisizione Dati
SHMS	Structural Health Monitoring System
SI	System of Units
SILS	Serviceability level of the Bridge: Extreme accidental and environmental loading conditions
SLS 1 and 2	Serviceability level of the Bridge (Normal use)
SPD	Surge Protection Device
TCS	Traffic Control System (sistema di controllo del traffico)
TETRA	TErrestrial Trunked Radio-(radio multiaccesso transeuropea)
UNI	Ente Nazionale Italiano di Unificazione
UPS	Uninterruptible Power Supply - alimentazione continua
VLAN	Virtual Local Area Network
VMS	Variable Message Sign (pannello a messaggio variabile)
VoIP	Voice Over internet Protocol
WAN	Wide Area Network-(rete a grande copertura geografica)
WiM	Weight In Motion system (sistema per il rilevamento dinamico del peso). In this document WiM is solely referring to roadway WiM. See also RWiM.

1 Executive Summary

1.1 Introduction

The Design Specifications together with the design drawings describe the Mechanical and Electrical (M&E) Works to be performed under the contract.

The M&E design work covers the main bridge between eastern viaduct bridge and western viaduct bridge. The bridge has a dual carriageway road with two lanes and an emergency lane in each direction and a dual railway track in the middle section of the bridge.

The railway installations and all M&E installations outside the Main Bridge and anchor blocks are not covered by these design specifications.

These Design Specifications are based on the contractual documents issued by Stretto di Messina S.p.A.

1.2 Aim of the Design Specifications

The aim of these Design Specifications is to describe the functions of the bridge installations and highlight improvements and updates of the design, if any, since award of the Contract in 2005.

1.3 Traffic Management System (Roads)

The objective of the traffic management system is to:

- to manage the traffic flow according to changing actual traffic, road, structural- and meteorological conditions achieving efficient and safe passage for road vehicles on the bridge.
- to provide a predictions basis for continuous provision of traffic data for traffic analysis purposes - primarily traffic statistical purposes and simulation of extreme situations for training purposes.

1.4 Electric Power Supply System

The electrical power supply and distribution provides electrical power to all the installations on the bridge. To maintain electrical power on failure on the primary electrical grids emergency generators

and Uninterruptable Power Supplies (UPS), are provided. The emergency generator and UPS systems maintain power to selected safety systems.

1.5 Communication Systems

The aim of the communication systems is to support the Operation and Maintenance staff working on the bridge in their duties and to support transmission of data for the various technical alarm, control and monitoring systems.

The communication systems will provide voice and data communication on and inside the bridge by a TETRA radio communication network and a data communication network, and by wired telephones installed in the bridge deck, the towers, substations, equipment shelters, the Control Room and the Toll Station. A gateway to the Public Switched Telephone Network will be included giving the users of the telephone network the possibility to communicate with external subscribers.

Emergency telephones will be installed along both sides of the bridge roads.

It is assumed that Police, Rescue and other emergency services have their own radio communication systems and that their respective technical organisations will provide the necessary radio coverage.

The communications systems are designed using state of the art digital technology in order to ensure flexibility and maximum lifetime of the equipment.

1.6 Management, Control and Monitoring Systems

The system for operation of the bridge will be designed to support real-time management, control and monitoring systems of the road and railway traffic and provide sufficient means for management of bridge maintenance and preparation of analysis and detection of risks in case of extreme weather or/and traffic conditions. The system will monitor and provide possibility for remote control of M&E electrically operated equipment.

The bridge management and control and monitoring systems will be interconnected with installations for all approaching parts of the traffic system.

This data input is not limited to daily operation events only, but will focus also on short term and long term prediction of traffic volumes, maintenance needs and optimization of interventions in

case of traffic restrictions due to weather conditions, special transports, traffic accidents and safety threats.

1.7 Lighting Systems

The following lighting installations will be established on the bridge.

- Navigation and aircraft warning lights
- Road lighting (including service roads).
- Architectural lighting for Towers and Suspension System, including Deck

The road lighting is designed with use of LED technology to minimise power consumption and spill light, and to facilitate maintenance.

Lighting will be installed in the internal volumes (bridge deck, towers, crossing beams, anchor blocks etc.) to allow operation, inspection and maintenance activities.

1.8 Safety Systems

The Bridge will be equipped with an efficient system for fire detection and fighting related installations in the technical rooms.

The security related installations are described in a separate report and will include access control and automatic and operator based detection of threats related to the bridge operation security.

1.9 Lighting Protection and Earthing

Lightning protection system and earthing facilities will be provided for the lightning protection and earthing of the installations on the bridge, as well as bridge structures. The lightning protection system will be based on natural parts of the structures which are made of steel, including bridge towers, steel girder and reinforcement bars in the concrete foundations.

In order to reduce the probability of damage due to lightning current flowing in the LPS, the down-conductors will be arranged in such a way that from the point of strike to earth:

- several parallel current paths exist;
- the length of the current paths is kept to a minimum;

- all metallic constructions are bonded to conducting parts of the structure

All electrical systems will be earthed in accordance with the standards.

1.10 Monitoring of Structures

The Structural Health Monitoring System (SHMS) will be a sophisticated redundant set-up that will provide the owner and operator with important information concerning structural behaviour and safety as well as information that will assist with operation and maintenance planning. The SHMS will also provide a valuable tool for investigating and trouble-shooting unforeseen problematic behaviour such as wind induced vibrations.

1.11 Water Distribution and Fire Fighting

This system is designed for the pressurized water distribution for the following purposes:

- Fire fighting on bridge and towers (Fire hydrant system).
- Fire detection and fire fighting for technical installations.
- Washing system for steel structures.

The fire distribution main on bridge are placed on both sides of the railway girder.

The fire mains are connected to fire hydrants located along the main. The fire hydrants will be accessible from the roads.

In the towers will fire hydrants be located at the base and in each cross beam.

Fire hydrants for bridge will be for 1,000 l/min at 6,9 bar. Fire hydrants for towers will be for 300 l/min at 4 bar.

The utility water valves and the utility water distribution pipes for the bridge are placed on the one side of the railway girder next to one of the fire mains.

Wash valves will be placed along the utility water main for connection to mobile water reservoirs on the Inspection and maintenance gantry for suspended bridge.

Utility water to the wash valves in the tower will be supplied from the pump station located on ground site near the tower base.

The wash valves will be placed next to the gantry access doors inside the towers so they can be reached from the gantries, when the wash water tanks on the gantries are to be filled up.

The fire detection in technical rooms with electronic equipment will be based on smoke detectors connected to fire alarm control panels. In case of detection of fire the system will automatically release fire fighting by means of inert gas. The inert gas containers will be supplied for each technical room.

1.12 Drainage

The purpose of the drainage system is to collect polluted storm water from the bridge and treat it at land based facilities before discharge to the sea.

Secondly the drainage system at the bridge will be provided with overflow possibilities in order to better control surcharge of the drainage system at the bridge.

Drainage of the storm water from the bridge will be achieved by gravity.

2 Introduction

This design specification must be read together with the project design drawings.

2.1 Stretto di Messina Link

The characteristics and overall scope of the Permanent Works under this Contract are outlined as follows:

- The limits for these M&E design works cover main bridge only and are limited to the part of the bridge between the eastern viaduct bridge and western viaduct bridge, but covers anchor blocks also.
- A dual carriageway road on the bridge with two lanes in each direction and service road lanes.
- A dual railway track in the middle section of the bridge (except technical railway installations).

Furthermore, the M&E design cover preparations for these parts of the installations which will be installed outside the Main Bridge but are natural part of the bridge installations. These parts of the bridge installations are:

- Main power supply substations on shore in Calabria and Messina
- Water pumping station
- Control Room for operation and management of the Bridge
- Structural measurement sensors to be installed outside the Bridge area

The design of M&E systems outside the Main Bridge and anchorage blocks will be covered by separate design package prepared by the General Contractor at later stage.

2.2 Basis Documents

This Design Specifications and the design drawings are based on:

- The contractual documents issued by the Owner, Stretto di Messina S.p.A

- Design Basis Doc. No. CG1000-PRGDPCG-0000000000-01A

A list of contractual documents covering the “Definitivo” and “Esecutivo” design for the Stretto di Messina Bridge is included in Appendix 1.

2.3 Electrical and Mechanical (M&E) Installations and Systems on the Bridge

The M&E installations and systems will guarantee reliable operation and safety of the bridge. They consist of common systems and bridge installations and systems.

2.3.1 Common Systems

The common systems are not related to any definite geographic location at the bridge. The common systems for the Stretto di Messina Link are:

- Traffic management system (roads).
- Redundant electric power supply system.
- Telecommunication system ensuring voice communication and data transmission
- Control and Monitoring systems.

2.3.2 Bridge Installations and Systems

The bridge installations and systems will include:

- External lighting systems
- Interior lighting
- Safety systems (fire fighting and detection)
- Security systems (separate report)
- Lightning protection and earthing
- Electrical distribution system for LV power supply of mechanical and electrical systems

- Emergency telephones
- Monitoring of structures
- Dehumidification (in separate report)
- Hydraulic Buffers (in separate report)
- Fire fighting
- Water distribution
- Drainage
- Ducting for electrical cabling
- Inspection and access facilities.

3 General Design Requirements

3.1 Priority of Codes and Standards

The priority of codes and standards will be in accordance with following sequence:

1 Italian acts in force

2 Document G.C.G.F.04.01

3 UNI EN (National Italian Standards) and CEI

4 Euronorm (EN, CENELEC)

5 BS-ASTM.

The most applicable standards are shown in Appendix 2.

3.2 Environmental conditions

The Environmental and Loads Conditions to be considered during the design are those specified in the document GCG.F.04.01 “Design Specifications and Performances required for the Bridge” and

GCG.F.05.03 “10.9.4.1 Parametri progettuales di base”. However the following further parameters will also be considered:

Table 3.2 Climatic conditions for electrical and mechanical equipment, installations and systems

Max Relative Air humidity	100%
Relative Air humidity at +20°C	<90%
Relative Air humidity at +40°C	<50%
Min. Environmental Temperature at the sea level	-5 °C
Max. Environmental Temperature at the sea level	+ 43°C
Max Level of instantaneous rainfall	This to be understood as the design rain with a return period of 100 years. To identified during detailed design
Rain per month	51-160 mm
Condensation	Yes
Salt-fog	Yes
Max wind speed (as per CEI 11-17)	180 km/h
Level of wind velocity corresponding to serviceability limit SLIS	60 m/s
Level of wind velocity corresponding to serviceability limit SLS2. Occurrence: every 200 years	47 m/s
Prevailing Wind Direction	NW-S
Seismicity	as per applicable regulations and table 3.3 below
Lightnings	1,5-2,5 number/year/km2

3.3 Seismic Conditions

Table 3.3 Seismic conditions for electrical and mechanical equipment, installations and systems

Seismic factor	Magnitude	Unit	Reference document
Earthquake, max severity	M=7.1	Richter	Ref.: PP 2R B0 001/2.5.1
Earthquake, acceleration corresponding to serviceability limit SILS	6.3	m/s^2	Ref.: PP 2R B0 001/2.5.1
Earthquake, acceleration corresponding to serviceability limit SLS2 Occurrence: every 200 years	2.6	m/s^2	
Tsunami, withstand	-	-	Any instrumentation equipment (sensors) that has interface to the sea. Ref.: Doc. no. PP 2R A 22/2.5.1
Tsunami, warning	-	-	Warning system will be proposed by others. Ref.: Doc. no. G.C.G.F.05.03 page 362 of part 2.

3.4 System of Units

The International System of Units (metric system) as specified in IEC or BS 5555 will be used throughout the Contract.

3.5 Design life

The design life L_d of the bridge is 200 years.

The design life of M&E installations is shorter than 200 years due to technological development in this field and need for continuous upgrading of these systems in order to follow up on new technical developments. For electrical and mechanical installations a maintenance plan must be prepared and this plan will include periodical replacements of the components and/or whole systems.

The minimum design life for M&E components will comply with the requirements defined in Appendix 3.

3.6 Safety during operation

All the materials and the equipment will be designed and manufactured to insure safety to the personnel and machinery also in case of failure of the electrical or hydraulic network and related control and regulation systems.

The height and the size of the areas to be used by the personnel will be designed as per applicable standards to meet all the required safety conditions.

All the electrical components will be fire retardant, no toxic and zero smoke, if nothing else specified.

Dangers or any kind of risk will be outlined by using signage as per applicable regulation. All warning text will be in Italian language.

All the material and equipment will be provided with all the necessary safety devices to allow the correct use and maintenance (i.e. locks, earthing, etc…).

Furthermore he must guarantee a very high safety standard to passengers and personnel both in normal and emergency conditions.

The safe operation of electrical and mechanical systems will be ensured under normal conditions and in case of failure conditions.

The systems are dimensioned to ensure CF (Complete Functionality) of the bridge in case of failures such as failure in part of electrical power supply system or failure in the water supply system. At CF the operation of railway and road will be guaranteed.

The systems will ensure safe operation of the bridge in case of lack of adequate natural illumination.

3.7 Operation

All the components will have an identification tag carrying the main data of the project and the main identification parameter of the component itself.

All the apparatus, such as breakers, regulators, actuators, will be provided with a positioning indicator to allow immediate knowledge of its status.

The plants control devices will be easily to access.

All the measuring and indication devices will be orientated in order to facilitate the data reading.

The technological plant of the Bridge are designed in order to allow:

- Centralized remote monitoring and remote management of the plants. The Control Room will be located in the “Centro Direzionale”.
- Local control and management of the equipment and plants.
- Recording of the events and critical status’ during the functioning period, to optimise itself and facilitate the RCM activity.
- Automatic management of the routine working conditions and, in case of emergency, of the proper automatic procedure. (The local and manual management system will be allowed as well as the centralized one).

3.8 Inspection and Maintenance

All the components will be constructed in order to facilitate the inspection and mounting/dismounting operations for maintenance and repairing/replacement purposes.

Furthermore all the electromechanical installation will not interfere with the maintenance activities of the main infrastructures.

The components will be designed to reduce the risk of liquid contamination during the dismounting or in general disassembly activities. Controlled liquid discharge and collection facilities will be provided.

All the main components will be provided with lifting accessories (hooks, lifting lugs, etc) to facilitate handling and transport.

3.9 Electromagnetic Compatibility

The electrical and mechanical apparatus and equipment will comply with EMC directive 89/336/ECC with later changes.

The equipment will be CE marked.

3.10 Vibration Resistance

The equipment will function correctly under vibrations of the bridge structures induced by:

- Railways: about 200 trains a day
- Road traffic: about 140,000 cars a day
- High wind velocities.

The equipment will withstand earthquake vibrations and shock of the bridge structures.

3.11 Standardization and inter-changeability

All the components will be interchangeable for the following, as minimum:

- Homologous pieces of materials and identical apparatus.
- Similar Accessories of different systems: i.e. electrical motors, pumps, Valves, electrical devices, etc.

The main data, tolerances, etc. to define the inter-changeability of the pieces will be included in the drawings.

3.12 Operation Costs

All the systems and components, will be designed to minimize the operation costs, energy demand satisfying the LCC requirements described in the Document GCG.F.06.02 " RMC Studies and LCC Studies ".

3.13 Mechanical Stress

Particular care is taken to reduce the mechanical stresses due, for example, to vibrations, structural deformations, thermal expansions etc.

The following guideline are followed:

- The measurement, security devices, actuators, etc. will be installed and protected by vibrations by using shock absorbers, independent supports).
- The plants will be provided with expansion joints, where necessary, in order to ensure structural elasticity. All the elastic connections, expansion devices etc. will be designed in order to guarantee the integrity of all the strength, process continuity, isolation, tightness characteristics, etc.

Sleeves for pipes, cables, etc. will be foreseen to cross walls or diaphragms and to guarantee mechanical protection and /or, whenever required, liquid or gas tightness.

3.14 Aesthetical and Ergonomic Characteristics

Materials and components will be aesthetically acceptable and integrated in the environmental contest.

The selected materials have surfaces finishing and provide protections, shelters, etc., wherever necessary.

The apparatus and devices for management and viewing will be constructed accordingly to the ergonomic requirements as specified in the EN 292, EN 614, EN 894, ISO 6385, ISO 9241.

3.15 Voltage Levels

The power supply voltage from the utility (ENEL) will be 20 kV, 50 Hz.

The power distribution voltages are:

- 6 kV 3 phase, 50Hz
- 400/230 V, 3 phases + neutral + PE, 50 Hz
- 24 V, 50 Hz

3.16 Pipes and Ducts Tightness

The Pipes and Ducts for liquids will be fully tight. No water, oil, grease or air leakage will be accepted.

The fluid discharges will be collected and evacuated by using proper circuits.

3.17 Corrosion Protection

All installation parts which may be exposed to corrosion will effectively be protected against corrosion, either by suitable coating or will be made of non-corrosive material.

No hygroscopic or subject to musty and fungus growth material will be used.

The electrical material will be tropicalized and class B isolated, as minimum. Higher class will be accepted providing that the heating class will remain within the class B.

The small apparatus will be provided with inox support material and screw. If these will not be available in the market, the pieces will be passivated or cadmium plated.

Electrical equipment must be provided with anti condensation heaters as required to eliminate condensations in switchboards and equipment.

When selecting materials and components due attention must be paid to the corrosive environment, especially to following climatic conditions:

- Salt-fog
- High relative humidity
- Condensation
- Galvanic corrosion
- Elevated temperatures.

The equipment will be protected against effects of mechanical wear, grease or other liquids.

3.18 Degree of protection by enclosure

3.18.1 General

The electrical and mechanical equipment will be protected against ingress of dust and liquids.

The outdoor equipment will be as a minimum protected against dust and low pressure jets of water: Protection degree minimum IP 55.

The indoor equipment will be as a minimum protected against objects over 1 mm and direct sprays of water: Protection degree minimum IP 43.

Other requirements will be as specified in the relevant requisition documents.

3.18.2 Tropicalisation and Prevention of Condensation

The equipment will be tested for operating in extended humidity and temperature range under salt-fog conditions.

All enclosures will be designed to minimise condensation, with provision for ventilation and drainage as appropriate. Openings for ventilation and drainage must not give access to sand, dust and salt-fog.

All electrical cubicles will be equipped with suitable dimensioned electric heaters for automatic humidity control.

All materials that are exposed to direct sun radiation will be made of UV-resistant materials.

3.18.3 Protection against Insects and Vermin

All equipment will be designed to withstand attack from insects, vermin such as rats and rodents.

Preservation will be carried out by means of careful selected materials, chemical preservation and mechanical barriers.

All enclosures containing electrical or mechanical equipment will be provided with gaskets, steel mesh or similar mechanical barriers to ensure effective protection against intrusion.

3.19 Environnemental pollution

3.19.1 Noise

All the equipment and auxiliary components will be designed to reduce the noise impact through sound, vibrations etc.

The noise limits for the machinery, components….will not exceed the NR 78 curve ISO 1996, that are fixed in 85 dB (A) maximum.

3.19.2 Chemical pollution

Chemical pollution will not be allowed.

3.19.3 Lighting pollution

The Bridge lighting system is designed in order to minimise lighting spill and impact on the sea and other surrounding areas.

4 External Lighting Systems

4.1 General

The following external lighting systems are designed:

- Sea and air traffic lights
- Architectural lighting for Towers and Suspension System, including Deck
- Road lighting (including maintenance and operation lanes).

In general, the lighting system for the air traffic will not affect the safety during the takeoff and landing operations (i.e. through threshold).

Furthermore during the design, the following has been taken under particular care:

- Light intensity, to avoid aircraft threshold
- The light colour complies with the applicable standards

- Light layout is designed to avoid similitude to airport runway, routes….
- Minimising the light spill on the sea surface

Laser and high intensity floodlights installation, if allowed, will be studied to meet the relevant standard and regulations.

The lighting system will also reduce the impact against the sea traffic.

The external lighting systems include:

- Road lighting
- Illumination of the towers and the suspension cables
- Navigation warning lights
- Aircraft warning lights.

The systems will ensure safe and comfortable operation of the bridge in case of lack of adequate natural illumination. They will ensure the visibility and surveillance of the bridge.

4.2 Road Lighting

4.2.1 System design specification

Table 4.1 Required illumination and luminance values for roads

Illumination or luminance	Value
Average horizontal illumination	30 lux
Ratio min/average illumination	0.4
Ratio min/max illumination (%)	<10
Average luminance	1.5 cd/m^2
Longitudinal uniformity	0.7
Comfort index	7

The road lighting system will be based on luminaires with LED lamps, to provide high efficiency, long life time and fair colour rendering and be similar to the lighting on the other parts of the highway.

The maximum voltage variation at the luminaires will be kept within ± 5%.

The road lighting systems will be automatically switched by the SCADA system, with possibility of manual override at the transformer substations for maintenance situations. The automatic switching will have staggered time delays in order to reduce the total inrush current at switch-on.

Reduction of the lighting level during hours of low traffic intensity is provided. This function is controlled by CMS/SCADA.

The road lighting will be designed to minimise power consumption and spill light, and to facilitate maintenance.

The daytime appearance of the road lighting installations will be closely coordinated with the landscaping and architectural features of the bridges during the detailed design phase.

There will be two luminaires on each pole. Each of these two luminaires will be connected alternately to the two backbone cables in order to limit the consequences for traffic safety of a fault in one transformer substation or high voltage feeder or in one backbone cable.

4.2.2 System Design Improvement

All road light will be LED.

The use of LED provides a solution that reduces the impact of our environment. LED is very flexible regarding, lighting control, easy mounting and colour temperature.

LED has a long life time that means less maintained. The luminaires are easy to upgrade to benefit the latest technology improvements.

The use of the intelligent road light will reduce the power consumption, and dimming the light when there is low traffic intensity (RTMS) or increase the light locally on the bridge in case of road accidents or road repair to increase the safety for other user of the road.

The road light will be controlled in order to adapt the lighting level to the weather condition such as heavy rain, fog to make the road more visible and safe for the user of the bridge.

4.3 Architectural Lighting

4.3.1 General

The illumination will provide a pleasant and uniform luminance of the surfaces of the bridge structures. The luminance level will be kept low, approximately 2-10 cd/m^2.

The final design of the floodlighting systems during Projetto Esecutivo phase, will optimise the uniformity of the luminance, and will minimise light spill and consequently light pollution. The lighting patterns caused by scattered light in foggy weather conditions will be particularly addressed during the design.

The luminaires will be directed or screened to prevent glare in the directions of road and sea traffic.

The aesthetical lighting systems will be automatically switched by the CMS/SCADA system, with possibility of manual override at the transformer substations for maintenance situations. The automatic switching will trigger a separate lighting control system, which will govern the dynamic switching patterns of the illumination.

The functioning of the lighting systems will be monitored by the CMS/SCADA system by monitoring the current of each final circuit supplying the lamps, with alarm for currents below 90% of the steady-state current measured with all lamps functioning. Fault signals from the dedicated lighting control system will also be monitored.

4.3.2 Towers

4.3.2.1 System Design Specification

The towers and cross beams will be illuminated by means of long range LED floodlights with controllable colour temperature of the light, ranging from warm white at about 2700 K to cool white at about 6500 K.

The illumination will provide a pleasant and uniform luminance of the surfaces of the bridge structures. The luminance level will be kept low, approximately 2-10 cd/m^2.

The final detailed design (Projetto Esecutivo) of the floodlighting systems will optimise the uniformity of the luminance, and will minimise light spill and consequently light pollution. The lighting patterns caused by scattered light in foggy weather conditions will be particularly addressed during the design.

The luminaires will be directed or screened to prevent glare in the directions of road and sea traffic.

Alternative systems may be considered to limit the light pollution for instance the systems utilizing fibre optics.

4.3.2.2 System Design Improvements

The lighting will be based on the newest LED technology and provide possibility to control and adapt the illumination to the natural light conditions.

The design includes control of the individual luminaires, which will allow selection of different colour temperatures and different dynamic switching patterns.

The idea is to illuminate the bridge with white light in different hues of colour temperature, referencing the changing colours of the daylight. One example could be that the towers and cross beams are warm white, the cross beams cool white and the hangers neutral white.

The dynamic switching patterns will be programmable. One scenario could be that the illumination is first switched on at the towers, after that on the cross beams. Then the illumination of the hangers comes on, first near the towers and thereafter slowly progressing from each side towards the centre of the bridge.

4.3.3 Suspension System

The hangers of the suspension system will be lighted.

The illumination will be provided by very narrow spotlights mounted at the top of each hanger, grazing the light down along the hanger.

The beam spread must be very narrow, ideally max 2˚ to 4˚. Presently, LED luminaires with such narrow beam spread are not available, but with the current very rapid technological development of LED luminaires, such spotlights should be available at the time of construction.

The present design, which has been based on available technology, includes 150 W metal halogen spotlight luminaires for the illumination of the hangers.

4.3.4 Superstructure

In order to complete the visual night time impression of the bridge, and to outline the structure for the sea traffic and viewers on land on both side, the underside of the bridge deck will be illuminated. This will be realised by illuminating the sides of the cross girders located per every 30 m, thereby creating a repetitive pattern of light.

4.3.5 Luminaires

The illumination of bridge structures will be provided by floodlight luminaires with LED lamps, which produce a white light (colour temperature within 2700 K - 6500 K) with good colour rendering (R_a > 80). Luminaires with lamps in the range up to 250 W and with light distributions from narrow to wide may be applied.

The following luminaire types are envisaged:

- Type "A" for illumination of hanger cables, 150W metal halogen lamps, very narrow light distribution, 0.5 max I within ± 4º
- Type "B" for illumination of the sides of the cross girders, 250 W, narrow/wide LED, IType "C" for illumination of the tower structures, 250 W, narrow light distribution, Type "D" for supplementary illumination of main cables at positions without hanger cables, low intensity obstacle light type luminaire with omni-directional light distribution, max I = 25-40 cd. This type may be equipped with light emitting diodes for lamps.

The final selection of luminaires and their positions has been based on detailed calculations of the illumination. No luminaires will cause glare in the directions of the road traffic or the navigation channels.

All luminaires will be corrosion resistant, and have degree of protection by enclosure at min. IP 55.

All luminaires will be mounted in positions accessible for maintenance, or they will be mounted on movable and lockable supports which can bring the luminaires into maintainable positions. The

luminaires illuminating the sides of the towers will be mounted on hinged supports in order to allow passage of the maintenance gantries.

All luminaires will be equipped with bird spikes or equal to prevent birds from resting on the luminaires.

A suitable number of laser aiming devices will be delivered along with each luminaire type.

Type "B"

Description	**Specification**
Manufacture	Philips or similar
Type	eW Reach Powercore or similar
Operation voltage	100- 240 V AC / 50-60 Hz
Lamp type	LED
Optic	0.5 max I_0 within ± 5º, 0.5 max I_{90} more than ± 17º
Light	White
Control	On/off, no dimming
IP rating	IP65

Type "C"

Description	**Specification**
Manufacture	Philips or similar
Type	eW Reach Powercore or similar
Operation voltage	100- 240 V AC / 50-60 Hz

Lamp Type	LED
Optic	0.5 max I within ± 5-8º
Light	White
Control	On/off, no dimming
IP rating	IP65

Type "D" Lighting on the main cable

Description	**Specification**
Manufacture	O.C.E.M or similar
Type	LER or similar
Wattage	90 W
Lamp Type	LED
Colour/Beam	Neutral white
IP rating	IP65

Ligthing on the top tower and cross girders

Description	**Specification**
Manufacture	Philips or similar
Type	eW Graze Powercore or similar
Power	60W
Lampe type	LED

Operation voltage	100- 240 V AC / 50-60 Hz
Colour/Beam	Warm white tower top/10*60^0 Cold white cross girders/ 10*60^0
IP rating	IP65

4.4 Navigation Warning Lights

The lighting system of the Bridge and the Strait is designed according to the applicable rules, standards and requirements issued by IALA and will be coordinated with requirements provided by the Marine Authority (i.e. COMANDO ZONA FARI – " MARIFARI MESSINA").

The bridge will not restrict the navigable water for any vessels with a height below the level of the bridge deck underside. The leading lights are placed in accordance with the navigation channels defined for the Messina Strait in 2008. These navigation channels may be modified by the naval authorities in accordance with the characteristics of the bridge. The navigation lights shall then be moved accordingly.

Red and green leading lights, and white range lights will equipped with long-life, LED lamps.

The effective range of the lights will be 7.5 - 10 nm.

The operation will be monitored by current sensors, and will be signalled to the CMS/SCADA system.

Description	**Specification**
Manufacture	Tideland or similar
Type	MLED-140 or similar
Operation voltage	9 to 36 VDC

Colours	Red, green, white
Visibility	360^0 horizon
Monitor and Control	Capable
Operation temperature	- 40 ^oC to 60^oC

4.5 Aircraft Warning Lights

Obstacle lights are designed according to the ICAO, International Civil Aviation Organization, (Annex 14 – Volume 1° - chapter 4°) and “Regulation for the airport construction and operation”- ENAC, OAC, NIKAO standards.

White, flashing aviation warning lights, high intensity type A, will be located from the ground level to the top of the towers and at approximately 100 m spacing. Each light has a maximum spread of 120°. Therefore, to ensure visibility from all bearings 4 lights will be placed at each level. The lights will be mounted in openings in the tower walls, to allow maintenance from the inside and to avoid that the luminaires create shadows in the architectural illumination of the tower surfaces.

The intensity of the light emission, is automatically adjustable by photocell / CMS/SCADA in three steps, corresponding to full daylight (200,000 cd), twilight (20,000 cd), and night (2,000 cd). The high intensity obstacle lights are equipped with xenon lamps.

The feeding of the mentioned switchgears will be continuous from UPS and with diesel genset backup and the UPS will have at least 1.0 hour back-up time.

Aeronautical marking of the cable stays will be medium intensity fixed red lights as ICAO type C, equipped with LED lamps.

White, flashing aviation warning lights, high intensity type A,

Description	**Specification**
Manufacture	Orga or similar
Type	L1000 or similar

Operation voltage	100-240 vac(+/-10), 50-60 Hz
Power consumption	< 150 W
Control	Internal microprocessor based for power management, flash character, daylight on/off and failure alarm control
Alarms	Volt free dry alarm relay contact (2A) for lamp failure further alarms and status information via CIP control unit
Photocell (Sunswitch)	Two internal photocells fitted in the light fixture for automatic day/night control
Light source / life expectancy	Xenon flash tube, >2 years life, safe plug fitting
Colour	White
Effective intensity Daytime Twilight Night	 200.000 Cd white +/-25% 20.000 Cd white +/-25% 2.000 Cd white +/-25%
Flash character	40-60 fpm
Operation temperature	- 55 ^{o}C to 55^{o}C, 95 % relative humidity
Ip	IP67

Aeronautical marking of the cable stays will be medium intensity fixed red lights as ICAO type C,

Description	**Specification**
Manufacture	Orga or similar
Type	L350 or similar

Operation voltage	100-240 vac(+/-10), 50-60 Hz
Power consumption	< 35 W continuous or 20 fpm during night time
Control	Internal microprocessor based for power management, flash character, daylight on/off and failure alarm control
Alarms	Volt free dry alarm relay contact (2A) for lamp failure further alarms and status information via CIP control unit
Photocell (Sunswitch)	Internal photocells fitted in the light fixture for automatic day/night control
Light source / life expectancy	High performance LED
Lensdiameter / Colour	Ø300 mm UV resistant clear dome
Effective intensity	2.000 Cd white +/-25%, set to operate at night time
Flash character	20 fpm or steady burning
Operation temperature	- 55 ^{o}C to 55^{o}C, 95 % relative humidity
Ip	IP65

5 Internal Lighting and Power

5.1 General Requirements

Internal lighting will be installed in the internal volumes (bridge deck, towers, cross beams, anchor blocks etc.) to allow operation, inspection and maintenance activities.

This lighting system will be integrated also with battery powered lamps, to allow evacuation and increase safety in case of power supply failures.

All the maintenance and inspection routes will be provided with power sockets (at intervals of 30 m) for tools or auxiliary lamps connection.

5.2 Interior Lighting

All interior light will be LED-tubes, that reduce the power consumption and have a long life time and less maintenance, than standard incandescent or fluorescent lamps.

The installations include interior lighting and power in all parts of the bridge that are accessible for inspections, maintenance or service.

An average illumination level of minimum 200 lx will be provided at all areas where regular work, maintenance or operation takes place. The uniformity (E minimum/E average) will be ≥ 30 %.

An average illumination level of minimum 50 lx will be provided along walkways. The uniformity (E minimum/E average) will be ≥ 30 %.

Emergency lighting along access ways / escape routes, as well as at working area will be provided.

The emergency lighting will provide minimum 5 lx. The uniformity (E minimum/E average) will be ≥ 5 %.

Luminaires will be manufactured in such a way that it is easy to replace lamps by using common hand tools.

Every third of the internal luminaires will be equipped for emergency lighting and will be supplied from UPS which have a capacity at minimum one hour back up time.

The emergency lighting will switch on automatically when the power supply to general lighting circuit is off for any reason.

5.2.1 Terminal blocks

18W Luminaires will be places 2 m above each stair landing mounted with wire from the above stair landing.

5.2.2 Specification

The luminaires will have reinforced non-flammable polyester body and be able to function at an ambient temperature of 55 degrees Celsius. The IP code will be 65 and the security class will be II (double insulated).

Luminaire housing

Description	**Specification**
Manufacture	Glamox or similar
Type	I40 or similar
IP	65
Vandal class	Class II
Light source	T8 18-36-58W
Mounting	Ceiling, walls, luminaire tracks, on horizontal wire and suspension brackets

LED Tube

Description	**9W**	**18W**	**36W**
Manufacture			
LED quantity:	180 PCS	300PCS	576PCS
Beam angle	120-180 °	120-180 °	120-180 °
Input voltage	85VAC-265VAC	85VAC-265VAC	85VAC-265VAC
Luminous flux	650-700 Lm	1600-1800 Lm	2900-3500 Lm

5.3 Socket Outlets

All the maintenance and inspection routes will be provided with power sockets (at intervals of 30 meters) for tools or auxiliary lamps connection.

All socket outlets will have a screwed-on cover to the outlet, providing a degree of protection min. IP 56, and be impact proof.

Socket outlets (except where one single outlet is required) will be placed in clusters (or built together as a switchboard assembly).

A cluster will as a minimum contain:

- One 400V AC (3 phase + neutral + earth), 16 A switched socket outlet.
- One 230V AC (2 phase + neutral), 16 A switched socket outlet.
- One 24V AC (2 phase + neutral), 16 A switched socket outlet.

The 400 V and 230 V socket outlets will be protected against indirect contact by residual current circuit breakers.

The 24 V socket outlets will be supplied via a step - down safety transformer providing galvanic isolation from the network.

5.4 System design improvements

All internal lighting will be based on LED technology.

6 Road Traffic Management System (RTMS)

6.1 General

This chapter states the functional specifications of the Road Traffic Management System (RTMS) for the Messina Strait Bridge. The purpose of the RTMS is to provide information on predicted and actual road traffic conditions, as well as selected information on rail traffic, to allow the Traffic Management Centre to exercise appropriate management of the road traffic and to assess predicted and actual static loads on the bridge by road and rail traffic. The RTMS is also referred to

as "Bridge TMS". The terms RTMS and "Network TMS" are used for installations on the bridge and on the approach networks respectively.

Traffic Management Systems on the road network (network TMS) outside the bridge is covered by Component No. 2

Actual railroad traffic management for the bridge is handled by RFI and is outside the scope of this document. However train weight and axle counts for trains entering and leaving the bridge will be monitored as part of Network TMS. . The weighing and counting functions will be implemented in a subsystem called Railway WiM (RWiM).

In this chapter the term "traffic" will be taken to mean road traffic unless it is specifically stated otherwise.

The main characteristics of the RTMS are:

- the RTMS will be implemented as two segregated environments, a production environment and a training environment
- the production environment comprises a dual-server configuration with one server being active and one server providing hot standby
- the RTMS will allow operators in the control centre to maintain an overview of current road, weather and traffic situations on the bridge
- the RTMS will allow operators in the control centre to execute and control all required dynamic traffic management operations on the bridge
- the RTMS will be implemented as a distributed control system, which - through a number of local substations - collects data to the RTMS server and conveys commands from the RTMS server to the roadside equipment via the local substations
- the RTMS will be an application built on top of the SCADA system platform, utilising the SCADA system's Man-Machine-Interface for input of control instructions from operators and display of status and events. The SCADA system's storage facilities will be used for long and short term holding of acquired data and calculated results

The key objectives of the RTMS are:

- to provide a system basis for continuous provision of traffic data for:
  - prediction purposes, including prediction of traffic load and the traffic load's static load on the bridge
  - traffic analysis purposes - primarily traffic statistical purposes and simulation of extreme situations for training purposes
- to enable management of traffic flow on the bridge so as to make it safe and efficient under changing traffic, road and meteorological conditions
- to assess axle weight of vehicles entering the bridge for the purpose of logging of cases where overload is detected real-time

The RTMS will comprise the following main function groups:

- traffic management
  - traffic monitoring
  - traffic prediction
  - traffic information
  - traffic control
- incident management
  - incident monitoring
  - recovery coordination
- technical system operation and maintenance
  - monitoring of all RTMS systems and modules
  - monitoring of all communication infrastructure
- monitoring of selected road weather parameters
- monitoring of train axle weight
- interfacing to other systems according to section 6.3 below.

Data collected in the production environment will furthermore form a reference basis for an off-line traffic management simulation

- replay of recorded incidents and traffic information
- verification of traffic management scenarios

These simulation functions will be realised in the training system environment.

For Man-Machine Interface (MMI), asset management, and other system administrative functions the general functions provided by the SCADA system will be used.

6.2 Portals

Traffic management equipment on the bridge will primarily be placed on 8 portals (VMS type 1) each spanning the road. In between the portals speed limit variable signs (VMS type 2) are placed on separate masts on both sides of the road. The location of portals, speed limit VMS', RTMS Substations (RTS), Road Weather Stations (RWS) and connected sensors are shown in a table in section 6.9.

In order to avoid conflicts with light poles and bridge hangers each portal and speed limit mast is placed on special consoles half-way between neighbouring girders.

Reference is made to the following drawings:

- CG1000 P 1A D P IT M4 GT 00 00 00 01 B - Distribution of the portals and VMS along the bridge.
- CG1000 P 2A D P IT M4 GT 00 00 00 01 B. Illustration of a portal, barriers and VMS. Note that not all equipment is installed on every portal.
- CG1000 P AX D P SS R4 00 00 00 00 16 A - Consoles for fastening of the portals to the bridge deck

The distance between portals and the intermediary speed limit signs vary between 240 and 300 meters due to constraints given by the location of power substations and planned or prepared vehicle crossings and service areas.

6.3 Communication Infrastructure

In general, communication within the RTMS and between the RTMS and other systems will be realised on the basis of the redundant fibre optical data network, the Bridge Area Network (BAN), spanning the entire length of the bridge and connecting the RTMS bridge installations with the Control Centre.

Detectors and actuators (e.g. VMS, barriers etc.) attached to a local substation on the BAN will be connected through local field networks managed via the substation in order to allow local monitoring and control to be performed without reliance on communication between the Control Centre and the local substation.

Each data connection will be monitored for problems and failure by a network management system (ref. sec. 14.3.4.1).

The general data flow is illustrated in Figure 6.1

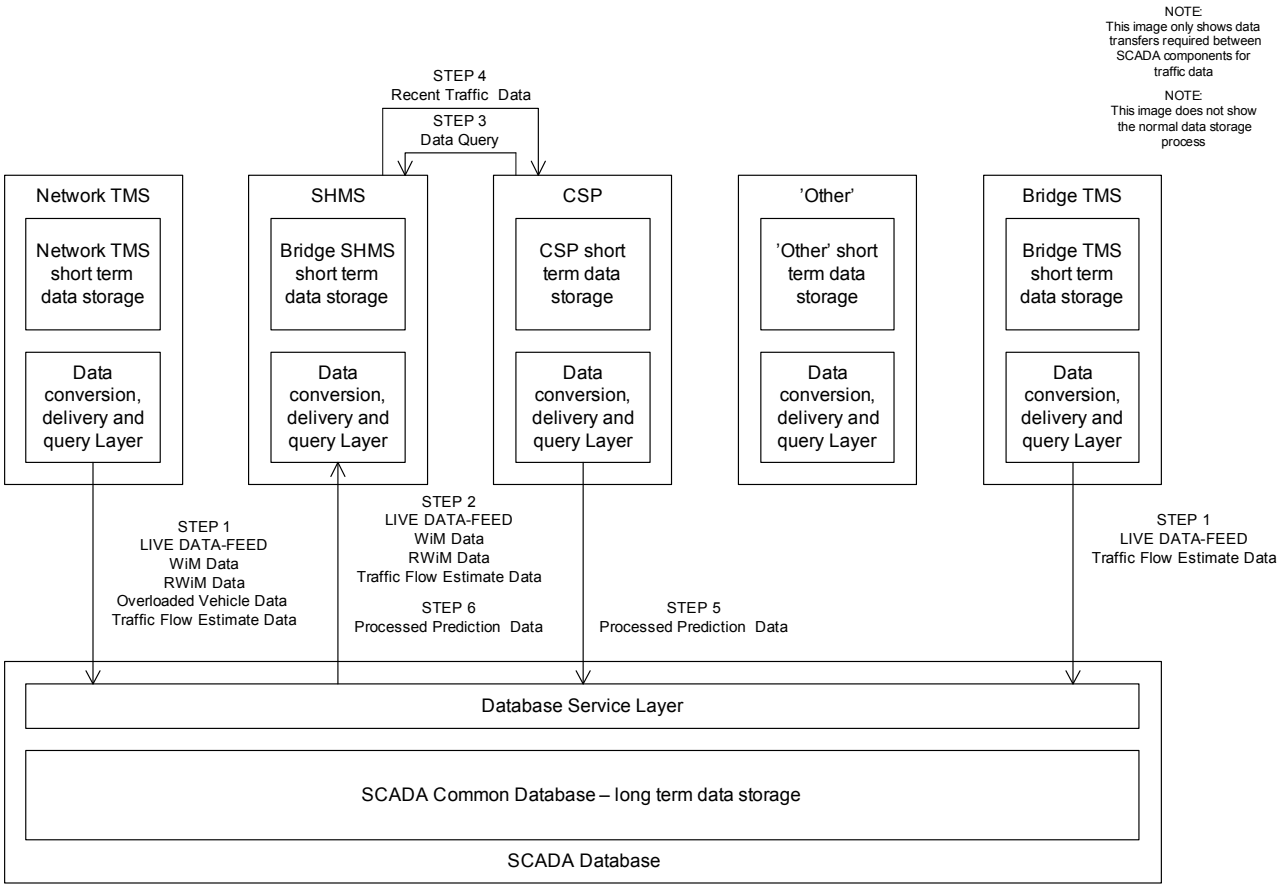


Figure 6.1: Data flow

6.4 Traffic Management

6.4.1 Traffic monitoring

Traffic monitoring is responsible for providing all real-time traffic information required to enable dynamic traffic management to be performed.

Traffic monitoring is also responsible for gathering traffic information for later use in the SHMS and in RTMS functions such as statistical analysis, traffic simulation, verification of traffic management scenarios etc.

Traffic monitoring makes use of 3 different types of video cameras. All cameras are installed on the portals above the traffic lanes. The location of the portals is listed in the table in section 6.9 and drawing CG1000 P 1A D P IT M4 GT 00 00 00 01.

Type A: Fixed cameras used for automatic monitoring (se section 6.4.1.1) and incident detection (see section 6.5.1). 3 cameras are installed on each portal.

Type B: Pan, tilt and zoom (PTZ) camera for manual monitoring (see section 6.4.1.2). 1 camera is installed on each portal.

Type C: Fixed camera for Automatic Licence Plate Detection (see section 6.4.1.1). 1-3 cameras are installed on selected portals.

6.4.1.1 Automatic monitoring of road traffic parameters

Automatic acquisition of the required traffic data will be accomplished via local substations and attached video cameras Type A In addition the licence plate of each vehicle entering the bridge will be identified using dedicated cameras type C installed in fixed positions above the traffic lanes on the first portal.

The Type A cameras will have the capability to detect speed and class of vehicles passing the portal with vehicle speeds up to 150 km/h. Sensitivity of the cameras allow for these functions to be

performed under light conditions of 0,1 lux. The cameras will be supplied with internal image processing hard- and firmware, with power supply board, remote control unit, and interface connection to fibre optic network.

The automatic monitoring system will be implemented so that the bridge is divided into a number of sections on each side of the bridge, each consisting of 2 normal traffic lanes and an emergency lane.

On the bridge, the following traffic parameters will be monitored for each lane in each section:

- traffic flow speed
- traffic volume (vehicle/hour)
- traffic density (i.e. number of vehicles pr. km)
- traffic composition[1]

To accomplish this, the system software will continuously track traffic in each lane and section by assigning to each observed vehicle:

- a vehicle speed (the traffic flow speed)
- a vehicle class (refer to section 6.4.2.1)
- a standard weight (see also section 6.4.1.3)

The identification of vehicle licence plates will be accomplished by cameras type C with automatic licence plate recognition ALPR) functionality. Type C cameras will be installed above each of the three lanes (2 traffic lanes and 1 emergency lane) at the first portal in the normal traffic direction. To support bi-directional operation lane 1 on the last portal will also be equipped.

The Type C cameras will have the capability to read licence plate information off vehicles passing the portal with speeds up to 150 km/h. The cameras will have built in infrared flash and will be supplied with internal image processing hard- and firmware, power supply board, remote control unit, and interface connection to fibre optic network.

[1] expressed in vehicle category percentages of the total number of vehicles.

All data will be time stamped when acquired or calculated as close to the point of origin as possible. This is done in order to provide a high degree of comparability across data from different sources. Traffic data will also be tagged with geographical origin or reference information making it possible to identify the exact source of the data. Traffic data will be transferred to the SCADA database as a live data-feed. Traffic data (or "Traffic Flow Estimate Data" as referred to in SHMS report CG1000-P-2S-D-P-IT-M3-SM-00-00-00-01) will be copied to the SHMS from the SCADA database as a live data-feed.

6.4.1.2 Operator based monitoring of road traffic parameters

A CCTV system will provide Control Centre operators with 24/7 real-time visual coverage of the entire roadway system on the bridge. The visual coverage will be used as basis for the operators' evaluation of road, weather and traffic conditions on the bridge in conjunction with the real-time traffic information provided by the automatic monitoring system (see section 6.4.1.1). Further, the visual coverage will act as an important support tool to Control Centre operators performing incident management.

The CCTV system cameras Type B will provide full motion (25 frames/sec) full colour images in a resolution sufficient to enable Control Centre operators to distinguish individual vehicles and persons anywhere on the bridge under any foreseeable set of circumstances

The Type B cameras will, unlike the Type A and Type C cameras, allow the operators to pan, tilt and zoom (PTZ).

All video records will be displayable via the SCADA system:

- on operator workstation display units
- on large display wall in the Control Room

All data will be accessible for data presentation as follows:

- on local monitors/operator consoles
- on large display walls in the Control Room
- in custom designed reports
- in custom designed data presentation pictures, graphs and curves

The configuration and layout of diagrams, pictures, reports, graphs, etc. will be developed as part of detailed design of the system.

Any Control Centre operator will be able to select live video feed from any camera - or any combination of cameras - in the CCTV-system, for display on his own workstation monitor and/or on the video wall system in the Control Room. All video feeds will have encoded information about time and place of recording and compass orientation of camera.

All elements of the CCTV-system (cameras, data communication, server and displays) will support:

- video streaming protocol: H.264 (MPEG-4)
- resolution: High Definition TV (HDTV) - 1920 x 1080p25

, or superseding best practise protocols and resolution at the time of installation.

6.4.1.3 Axle weight monitoring and traffic load assessment

The RTMS will acquire axle weight data for each vehicle entering and leaving the bridge using Weigh-in-Motion systems (WiM) in order to:

- record cases of vehicle overload
- create and maintain a database of average loads of vehicles in up to 5 vehicle classes
- provide accurate vehicle data to the SHMS for monitoring of total traffic load on the bridge
- provide accurate vehicle data to Computing, Simulation and Prediction (CSP) for predictions of traffic load on the bridge. Refer to section 13.6.

The monitoring of the accurate real-time total traffic load on the bridge is important for the continuous monitoring of residual load capacity of the bridge, which will influence the control of traffic (vehicle and rail) on the bridge. The monitoring of residual load capacity of the bridge shall be performed by the SHMS.

Real-time axle weight monitoring will be performed on each lane using WiM systems positioned on the bridge approaches just off the bridge itself. The WiM systems will therefore be installed as part of the Network TMS, presented in Component No 2.

The traffic load on pre-defined sections of the bridge will be monitored continuously using traffic data recorded by video detectors (see section 6.4.1.1), with fixed standard weights assigned to each vehicle category on the basis of statistically compiled average loads for different vehicle categories as recorded by the WiM systems.

The WiM sites will be equipped with cameras (Type A) so that detected overloads can be documented by digital images of the offending vehicle. The documentation will be stored by the WiM and a notification sent to the operator. At later stage it can be decided exactly how the stored documentation will be used.

WiM data will include:

- time and location information
- vehicle type
- time of passage of first axle
- vehicle classification according to 6.4.2.1
- weight of vehicle
- length of vehicle
- speed of vehicle
- for each axle:
  - axle weight
  - distance to the previous axle of the same vehicle (value will be e.g. null for the first axle)

A data record will be provided for each vehicle. For each vehicle weighed, a unique data set identifier will be assigned. WiM data will be stored based on the data set identifier only.

The WiM systems will be installed in a suitable location that is sufficiently stable and level, so that the negative influence of any dynamic behaviour of the support structure and vehicles is minimised. The WiM site will be a location that is not susceptible to flooding, and will be well-drained. The WiM systems will be designed in accordance with the design requirements for a Type

II system as presented in ASTM E 1318-94. A discussion concerning the selection of an appropriate WiM system, as well as information on a current suitable system, is given in Appendix 6.

WiM data will be transferred to the SCADA database as a live data-feed. WiM data will be copied to the SHMS from the SCADA database as a live data-feed.

6.4.2 Bridge traffic load prediction

In order to be able to continuously predict bridge traffic load from road traffic and trains, a running 10 minutes estimate shall be calculated. The road topology within 10 minutes / 20 km of driving distance includes several junctions. A significant part of the road traffic that crosses the bridge may potentially start or end journeys within 10 minutes from the bridge. The accuracy of 10 minute predictions will therefore be limited.

The 10 minutes estimate will be based on:

- statistical road traffic data on the actual weekday and time. The statistical basis will be automatically adjusted based on the actual traffic intensity measured by Type A cameras 20 km north from the bridge on the A3 motorway and immediately north of Messina. In addition, the staff can adjust the basis manually based on knowledge of special events, processions, road maintenance or accidents. Data input needed is traffic intensity divided in small and large vehicles at the measuring stations
- Input from the Railway Weigh-in-Motion systems (RWiM) discussed in section 6.8[2]

The RTMS will not include functions specifically aimed at controlling traffic influx to the bridge as a function of predicted and actual traffic flow on the road and rail network on and off the bridge, but the bridge Control Center staff will have at their disposal all the traffic management functions implemented in the RTMS and the agreed operational procedures. Depending on the agreed operational procedures, the following traffic management actions can be considered by the staff:

- delay train access to the bridge
- throttle road traffic from Sicily at the toll station

[2] note, for practical reasons this information cannot be supplied with a 10 minutes look ahead

- throttle road traffic by using lane control signals on and off the bridge
- throttle road traffic off the bridge by means available in the Network TMS, presented in Component No. 2.

6.4.2.1 Vehicle classes

RTMS will support classification of road vehicles into the following categories:

- cars
- cars with trailers
- lorries
- lorries with trailers
- buses

Classification into each category will be made with a minimum accuracy of 90%, and minimum 95% of all vehicles will be detected by the classification system.

6.4.2.2 10 minutes estimate algorithm

The 10 minutes traffic estimate will build on the following detailing of road traffic data:

- statistical road traffic data on the actual weekday / holiday / season and time
- the statistical basis will be automatically adjusted based on the traffic intensity assessed at selected points in the road network
- the operations staff can adjust the statistical basis manually based on knowledge of special events, processions, road or bridge maintenance or accidents

The traffic estimate will make use of statistics showing the traffic intensity per vehicle class in 15 minutes and 60 minutes resolution for each weekday (peak hours and off-peak hours respectively) and in 60 minutes resolution for special days separate.

Statistical data will be factored in the traffic estimate by the number of vehicles, the average weight per vehicle and the average speed.

Example on statistical basis:

	Mondays	Thursdays	…	Fridays	Saturdays	Sundays	New years day	Epiphany day (6. January)	1. May	…
00:10										
00:20										
00:30										
00:40										
00:50										
01:00										
…										
24:00										

From Sicily to Calabria:

From Sicily to Calabria:
117 cars / 1,216 t
0 cars with trailer / 1,695t
41 solo lorries / 14,129t
7 lorries with trailer / 22,693t
3 buses / 9,126t

From Calabria to Sicily
75 cars / 1,159t

Traffic intensity data will be assessed by the local substations and one hour rolling averages of traffic intensity per vehicle class will be calculated. Actual assessments will be compared with historical intensity data matching vehicle class, day of week and time of day resulting in a calibration index. For example if on Chistmas Day 1050 cars has been counted the last hour, and 1000 cars was recorded the same hour last Christmas Day, the calibration index for cars will be 1.05.

The statistical basis for the bridge traffic will then be multiplied with the actual index per vehicle class in order to form a traffic estimate.

The Bridge Control Centre staff will be able to adjust each index based on actual local information.

This will be relevant if for example a public event in Calabria south of the bridge intersection are expected to attract an unusual amount of traffic, thus causing automatically calculated indexes to be misleading.

The load estimate will be calculated as:

start
set load:=0
for each direction
for each class of vehicles

- take the 10 minutes basis (e.g. 117 for cars Tuesdays between 00:30 and 00:40) and multiply it with the current index (say 1,05) = 122,85
- multiply the result with 6 (as one hour is 6 times 10 minutes) and the bridge length in km (say 3,5 km) and divide with the average speed (118 km/h) = 21,9 cars on the bridge
- multiply the result with the average weight (1,216 t) = 26,6 tonnes
- add the result to the load

next class
next direction
print load
end

6.4.2.3 Flow monitoring

Cameras (Type A) installed on each side of the bridge at 4 equidistantly sited locations will determine vehicle class and speed of each vehicle, as discussed in section 6.4.1.1. Each vehicle will be allocated an average class specific weight derived from the statistical information provided by the WiM installations, as discussed in section 6.4.1.3.

6.4.3 Traffic information

Variable message signs (VMS) with text and pictograms, speed limits and lane signals (VMS type 1) will be placed on portals. VMS and other equipment on the portals is illustrated in drawing CG1000 P 2A D P IT M4 GT 00 00 00 01 A.

In between the portals additional speed limit VMS (VMS type 2) are located on separate poles.

The location of the portals and speed limit VMS is shown in table 2 and in drawing CG1000 P 1A D P IT M4 GT 00 00 00 01.

6.4.3.1 Variable Message Signs (VMS), text

VMS will have the following specifications:

- Fully remotely controllable from the Control Centre
- Based on light emitting technology with built-in automatic intensity control, that adjusts emitted light according to intensity of background light and direct light onto the VMS surface
- Free format text with three rows of 25 characters each
- Display colours: yellow, yellow/white, white matrix dots on black background as class C2 of EN12966
- Detailed feed back on operational status incl. information allowing TMC operators to assess the visual appearance of the sign display as perceived by road users

On bridge sections where two-way traffic will be supported, the VMS' will be dual-faced.

6.4.3.2 Variable Message Signs (VMS), speed limits

VMS for displaying dynamic speed limits will have the following specifications:

- speed limits: display of 3 digits, in any legal combination
- speed limit similar to the pictogram

- Remotely controllable from the Control Centre
- Based on light emitting technology with built-in intensity control, that adjusts emitted light according to intensity of background light and direct light onto the VMS surface

- Detailed feed back on operational status incl. information allowing TMC operators to assess the visual appearance of the sign display as perceived by road users

On bridge sections where two-way traffic will be supported, the VMS will be dual-faced.

6.4.3.3 Variable Message Signs (VMS), other

VMS for displaying dynamic messages other than speed limits are placed on top of the portals, and will have the following specifications:

- Ability to show the following pre/defined signs>
  - Queue: similar to the pictogram shown but in contrasting layout.

  - Slippery road: similar to the pictogram shown but in contrasting layout except for red triangle

  - Accident: similar to the pictogram shown but in contrasting layout except red triangle

- Two-way traffic: similar to the pictogram shown but in contrasting layout except red triangle

- Other signs (pictograms) can be added by software.

- Remotely controllable from the Control Centre
- Based on light emitting technology with built-in intensity control, that adjusts emitted light according to intensity of background light and direct light onto the VMS surface
- detailed feed back on operational status incl. information allowing TMC operators to assess the visual appearance of the sign display as perceived by road users

On bridge sections/lanes where two-way traffic will be supported, the VMS will be dual-faced.

6.4.4 Traffic control

6.4.4.1 Moveable barriers, bridge access

Moveable barriers will be installed landside immediately north and south of the bridge. The purpose of these barriers is to prevent any traffic from entering the bridge in cases where accidents or adverse weather conditions make traffic on the bridge unwanted or unsafe.

The barriers will be remotely controllable electro mechanical devices that can efficiently block each of the traffic lanes and the emergency lane. Blocking of the emergency lane will operate independently from blocking of the traffic lanes in order to allow passage of rescue vehicles onto the bridge in any situation.

Each barrier will be equipped with two or three sets of flashing red warning lights, depending on the size of the barrier. The warning lights will flash alternating.

These barriers are illustrated in drawing CG1000 P 2A D P IT M4 GT 00 00 00 01 A...

6.4.4.2 Retractable barriers, cross over access

Retractable barriers will be installed in parallel with the left crash barriers in a manner that allows cross over openings to be established when needed. When access to crossing over is not required, the barriers will act as a fully integrated extension to the left side crash barrier providing the same protection to traffic as the normal crash barrier.

The barriers will be remotely controllable electro mechanical devices capable of efficient blocking access to crossing over (closed state) respectively providing access to crossing over (open state).

6.4.4.3 Lane Control Signals (LCS)

Lane Control Signals (LCS') will be installed under the portal cross beams, centred above each traffic lane and emergency lane. For lanes where two-way traffic is supported, the LCS' will be dual-faced. Each LCS will have the following minimum specifications:

- capable of displaying any of the following symbols - one at a time: "green down arrow" (lane open), "yellow left arrow" (merge left), "yellow right arrow" (merge right), "red diagonal cross" (lane closed)
- road users will experience clearly distinguishable symbols at approximately 500 m distance under any foreseeable environmental conditions where visibility is minimum 500 m

6.5 Incident Management System (IMS)

The RTMS will be provided with an Incident Management System (IMS) with the following functions:

- Automatic Incident Detection (AID)
- operator based event verification and logging
- operator based incident management

6.5.1 Automatic Incident Detection (AID)

AID will be implemented on the basis of a CCTV cameras Type A with automatic video processing software aimed at detecting the following incident types:

- stationary vehicles in any lane (incl. emergency lanes)
- stationary vehicles in any lay-by
- foreign objects on the roadway (people, lost goods etc.)
- slow moving traffic in any lane.
- traffic in emergency lane when not allowed

Cameras type A will be fixed (i.e. not pan, tilt, zoom (PTZ) type) and will be able to provide a video quality enabling AID functionality 24/7 in all foreseeable environmental conditions with minimum visibility of 500m[3].

Figure 6.2: Example showing an AID system detecting a stopped vehicle on a bridge

6.5.2 Event verification and logging

All automatically detected incidents will require operator verification. The AID-system will be provided with an incident verification form for a formal registration and storing of events. A similar form will be devised for handling of operator based incident detection.

[3] in situations with severely reduced visibility it is assumed that appropriate speed restrictions will be imposed on traffic crossing the bridge, so that reduced AID functionality in adverse weather conditions is being compensated for at least in part.

Verification of events will be protected by authentication of the operator

Further handling of each verified incident event will be in scope of the Incident and Control Management System.

All recorded incidents will be accessible for later use in incident analysis and for use in traffic simulations on the Simulator and Training Console.

6.5.3 Incident management

The RTMS will be provided with an incident management facility with the following functions:

- preparation and visualisation of incident response plans for handling incident scenarios. The predefined plans will cover all major functions to be handled by the operator in case of an incident
- definition of semi-automated information to be conveyed to road users via VMS signs and text when wanted/required

Semi-automatic implies that information scenarios are predefined but no action is taken (i.e. no information provided) before being approved by an operator.

The system will be prepared for predefined response to typical accidents, e.g.:

- major accidents
- minor accidents
- weather conditions
- stalled vehicle
- lost goods

Information on road weather conditions will be obtained from the road weather stations (RWS) as described in section 6.7.

6.6 Technical infrastructure

6.6.1 Data Processing and Management

The system software will be based on an industry standard software package with performance and quality proven in other similar RTMSs.

All data acquired or calculated by the RTMS system will be stored in the SCADA database system.

The RTMS will be capable of providing storage for selected aggregated historical data for a period of at least 10 years on line (hard disks or SAN) and for an unlimited time on magnetic tapes or similar technology.

The local substations will be equipped with a data storage system capable of storing data from the field equipment even in case of failure of the communication between the substation and the Control Centre. The local substations' storage will be capable of retaining a minimum of 200 hours of unprocessed information, without operator attendance regardless of the sampling regime in force.

After connection to the Control Centre is re-established, the local substations will transmit buffered data to RTMS so that the database of the RTMS holds a complete series of data regardless of any communication breakdown period less than 200 hours.

All data collected by the RTMS field equipment will be tagged and time stamped where first stored, so that data always can be traced back to a specific time and location. All data recorded will be time-stamped in accordance with the system clock. The RTMS will have a clock function capable of keeping permanent synchronisation with an external clock source to within +/- 10 ms. The RTMS will be responsible for keeping all attached field equipment synchronised to the RTMS clock with similar accuracy.

All real-time data will be stored in a short term storage within the RTMS system to allow internal RTMS assessments/calculations to be made in real-time. The RTMS system will stream a live data-feed to the SCADA database thus making data available to subscribing functions like the SHMS.

Alarms acquired from field equipment data communication equipment or generated in the RTMS server will all be transmitted to SCADA in real-time.

6.6.2 RTMS Central Computer

The RTMS' Central Computer will be installed in the Traffic Management Centre (TMC) in the Control Room located in the Bridge Administration Building ("Centro Direzionale").

The central computer will consist of computers/servers which together will comply with the following minimum specifications:

- Redundant system with duplication of all hardware and software, automatic detection of failure in the active system and taking-over by the standby system in a hot-standby configuration.
- All hardware suited for mounting in 19" racks
- Newest technology at the time of procurement
- Mean time between failure (MTBF) for major active components and subsystems not less than 1 year.

6.6.3 Local Substations

The RTMS comprises two types of local substations, one for traffic monitoring and traffic control equipment and one for road weather monitoring. The first type is referred to as Road Traffic Station (RTS) and the latter type is referred to as Road Weather Stations (RWS').

All RTS substations will be installed on the bridge deck in conjunction with portal installations.

The local substations will be constructed on the basis of distributed computers which together will comply with the following requirements:

- Newest technology at the time of procurement
- Industrial standard equipment
- Mean time between failure (MTBF) for major active components and subsystems not less than 1 year.

All local substations will have electrical power supplied from uninterruptible power supply (UPS) capable of supporting their function for at least 24 hours in case of failure on the power supply network. All local substations will also be installed in cabinets with heating/cooling, interface connection to fibre optic network, connectors to sensors, operating system, and remote control software.

6.7 Road weather monitoring

In order to enable safe pass ability of the bridge in adverse weather conditions, the following road weather related data will be monitored:

- Wind speed and direction (incl. gust)
- Road and air temperature
- Precipitation, type and intensity (rain, snow, sleet, hail)
- Road surface condition (water veil, ice, snow, freezing point etc.)
- Visibility (mist, fog etc.)

Information on road weather conditions will be obtained from RWS' equipped with appropriate detectors for assessment of the listed parameters. The RTMS will make observations available in the database for any subscribing function to use immediately after completion of the observation.

Observation points will be chosen in a manner so that observations can be taken as being representative or worst case as appropriate, e.g. wind effects will be measured where representative for the length of the bridge while road condition will be assessed at "worst case" points.

RWS' will be installed in conjunction with portals or VMS installations as appropriate so that sharing of access points to the BAN can be achieved. Each RWS will have a number of sensors attached so that the following parameters can be observed:

East side of bridge:

- RWS E1: road condition, air temperature, air humidity
- RWS E2: road condition, wind speed and direction, visibility

- RWS E3:road condition
- RWS E4: road condition, precipitation

West side of bridge:

- RWS W1: road condition, air temperature, air humidity
- RWS W2: road condition, wind speed and direction, visibility
- RWS W3:road condition
- RWS W4: road condition, precipitation

Road condition sensors will be installed on both sides of the bridge at equidistant intervals roughly corresponding to 1/5'th of the length of the bridge.

6.8 Automatic monitoring of train weight

The total traffic (vehicle and rail) load on the bridge needs to be accurately monitored by the SHMS. WiM will provide accurate data on vehicle weights, as discussed in section 6.4. The weight of trains will also be monitored. The weight of trains entering the bridge will be measured on the approaches, using Railway Weigh-in-Motion systems (RWiM) installed at a distance from the bridge that is greater than the maximum train length. Train detection facilities will be provided at each end of the bridge on the track for trains leaving the bridge. The RWiM systems and train detection facilities will be installed as part of the Network TMS, presented in Component No. 2.

The RWiM will provide the following information:

- RWiM identifier (implicitly giving location and direction of train)
- Date and time of passage of first axle
- Total weight of train
- Total length of train
- Speed of train
- For each axle:

- Weight of axle
- Distance to the previous axle on the same train (value will be e.g. null for the first axle)

A data record will be provided for each axle. For each train weighed, a unique identifier will be assigned to the data set. RWiM data will be stored based on the data set identifier only.

The RWiM systems will be installed in a suitable location that is sufficiently stable and level, such that the negative influence of dynamic behaviour of support structure and trains on the weighing is minimised. The RWiM site will be a location that is not susceptible to flooding, and will be well-drained. The RWiM systems will measure axle weight with an accuracy of +/-10% or better, for all train speeds up to 120km/hr. A discussion concerning the selection of an appropriate RWiM system, as well as information on a current suitable system, is given in Appendix 6.

The RTMS will continuously compare information recorded for trains entering the bridge and trains leaving the bridge. An operator alarm will be raised if any discrepancies are detected.
RWiM data will be transferred to the SCADA database as a live data-feed. RWiM data will be copied to the SHMS from the SCADA database as a live data-feed.

6.9 Overview of RTMS parameters

The table below gives an overview of how the RTMS is distributed across the bridge.

Lato ovest del ponte *West side of bridge*				Lato orientale del ponte *East side of bridge*		
Parametri *Parameters*	Installazione *Installation*	Infrastrutture *Infrastructure*	Posizione (km) *Location (km)*	Infrastrutture *Infrastructure*	Installazione *Installation*	Parametri *Parameters*
ALPR	RTS	Portal / VMS type 1	151	Portal / VMS type 1	RTS	alpr
Sicilia torre / *Sicily Tower*			256	Sicilia torre / Sicily Tower		
		VMS type 2	391	VMS type 2		
rc	RWS, RTS	Portal / VMS type 1	631	Portal / VMS type 1	RWS, RTS	pc, rc, at, ah

		VMS type 2	871	VMS type 2		
	RTS	Portal / VMS type 1	1141	Portal / VMS type 1	RTS	
rc, ws, wd, vb	RWS	VMS type 2	1381	VMS type 2	RWS	rc
	REB	Cambio di carreggiata	1471	*Veh. X-ing*	REB	
	RTS	Portal / VMS type 1	1621	Portal / VMS type 1	RTS	
Mezzo ponte			1906	*Bridge middle*		
Rc		VMS type 2	1921	VMS type 2		rc
	RWS, RTS	Portal / VMS type 1	2191	Portal / VMS type 1	RWS, RTS	
	REB	Cambio di carreggiata	2341	*Veh. X-ing*	REB	
rc		VMS type 2	2431	VMS type 2		rc, vb, wd, ws
	RTS	Portal / VMS type 1	2671	Portal / VMS type 1	RTS	
		VMS type 2	2941	VMS type 2		
pc, rc, at, ah	RWS, RTS	Portal / VMS type 1	3181	Portal / VMS type 1	RWS, RTS	rc
		VMS type 2	3421	VMS type 2		
Calabria torre / *Calabria Tower*			3556	Calabria torre / *Calabria Tower*		

alpr	RTS	Portal / VMS type 1	3661	Portal / VMS type 1	RTS	ALPR

LEGEND

RWS	Road Weather Station
RTS	Local SubStation
VMS	Variable Message Signs
REB	Retractable barrier
ah	air humidity
at	air temperature
pc	precipitation
rc	road condition
vb	visibility
wd	wind direction
ws	wind speed
ALPR	Automatic Licence Plate Recognition in 3 lanes
alpr	Automatic Licence Plate Recognition in 1 lane

7 Power Supply and Distribution

7.1 General

The power supply and distribution networks will be established distributing electrical power to the installations on the bridge. The main components of the power distribution system are:

- Main power supply substation at Calabria side of the Bridge QMT-SS-Calabria 20 kV switchgear and 20/6 kV transformer.
- Main power supply substation at Sicily side of the Bridge QMT-SS-Sicily 20 kV switchgear and 20/6 kV transformer.
- Emergency diesel power supply station at Calabria side of the Bridge.
- Emergency diesel power supply station at Sicily side of the Bridge.

- Distribution substations on land in Calabria QMT-G-Calabria.
- Distribution substations on land in Sicily QMT-G-Sicily.
- 8 Distribution substations on the Bridge QMT-A1 to QMT-A8.
- 2 Distribution substations in the north tower QMT-A11 and QMT-A12
- 2 Distribution substations in the south tower QMT-A21and QMT-A22
- 2 Distribution substations at the water systems north QMT-A13 and QMT-A14
- 2 Distribution substations at the water system south QMT-A23 and QMT-A24
- Uninterruptible power supplies (UPS) in the power substations.
- Distributions boards downstream the distribution substations
- Medium voltage cable system.
- Low voltage cable system.
- The traction system for the railway is excluded from this design specification.
- This design specification provides the starting point for the detailed design of the Power Supply and Distribution systems.

7.2 Electrical loads analysis

For details please see the Electrical Calculation Report CG1000 P 4R D P IT E2 SI 00 00 00 01.

7.2.1 Load Types

On the bridge the main electrical loads are split into the below types for the analysis performed: Road lighting, service lane lighting, internal lighting, architectural lighting, navigation and aeronautical lighting, mechanical installations,Trafic management systems, communication systems, control and monitoring. The loads are grouped by the criticality of having the systems electrical powered at all times.

7.2.2 Loads Classification

The electrical loads are classified by criticality to ensure that systems safety and technical integrity is maintained during power failures:

a) Critical essential loads with a centralized UPS system

- Control Room equipment[4]
- Monitoring and supervision instruments
- Sea and air traffic lights
- TMS panels (Variable Signal Panels)
- Telephone and data transmission
- Safety lighting
- Elevators alarm systems

b) Essential loads with back-up supply from emergency generators:

- Elevators

-Fire pumps

- UPS

- Road Lighting (depending on the anti-sabotage and risk analysis. UPS feeding will be available for a certain number of road lamps).

- Internal lighting and maintenance routes lighting.

c) Normal loads disconnected on ENEL failure

- Power sockets
- Dehumidification system
- Architectural lighting and catenaries

[4] The UPS for the bridge control room is excluded from this design specification.

7.2.3 Power Demand

Power demand is calculated based on power consumption during operation of M&E equipment. The power demand is calculated for night and daylight periods with the operation conditions:

- Normal operation
- Operation without power supply from ENEL.

7.3 System Configuration and Operation

7.3.1 System Configuration

The Electrical power supply for the bridge installations is provided from two redundant substations, QMT-SS-Sicily and QMT-SS-Calabria power supplied from the national grid, ENEL. The QMT-SS substations feed the bridge ring network distributing the power to the bridge loads. Emergency generators are installed as back-up to the national grid supply.

Each of the QMT-SS substations will be designed to provide power for all installations on the bridge (2x100%)

Each of the Emergency Generators will be designed to provide power for half of the bridge essential loads (2x50%)

During power transfer between systems the consumers will be switched off. Where this is unacceptable UPS will be provided. (Critical loads).

Please refer to drawing Power Distribution – General Single Line Diagram – 6kV CG1000 P 4A D P IT E2 DE 00 00 00 01.

The LV power distribution system will be a radial system distributing the power from the 400/230V substations to the electrical loads. Nominal voltage of the system is 400/230V with earthed neutral.

The systems of an area will operate on two independent circuits reducing the risks of loosing a completed system of an area.

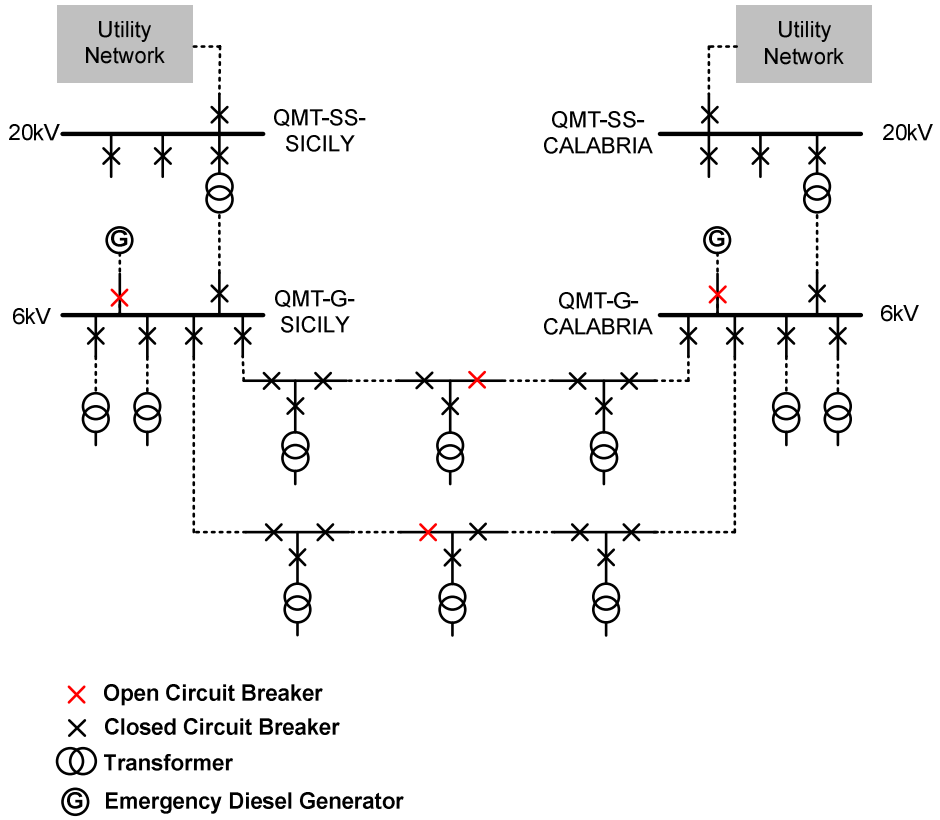
Table 7.1 Location and number of main components

Location	Description	Number
QMT-SS-Sicily QMT-SS-Calabria	20 kV substation	2
QMT-SS-Sicily QMT-SS-Calabria	20/6 kV transformers	2
QMT-G- Sicilia QMT-G-Calabria	6.0 kV substations	2
QMT-G- Sicilia QMT-G-Calabria	Emergency generators: 6 kV	2
Towers	6/0.4 kV substations	4
Anchor blocks	6/0.4 kV substations	2
QMT-A1, A3, A5 and A7 Bridge West Side	6 kV /0.4kV substations	4
QMT-A2, A4, A6 and A8 Bridge East Side	6 kV /0.4kV substations	4

7.3.2 Operation Modes

7.3.2.1 Normal operation

During normal conditions the ring network on the bridge will be open and each of the 20 kV switchgears feed approximately half of the total electrical bridge load from the ENEL grid. Consequently half of the bridge is fed from the Calabria and the other half from Sicilia.



7.3.2.2 Emergency operation

If one of the 20 kV mains (ENEL power grid) fails the system must change to emergency operation. The faulty mains power supply will be disconnected and the ring will be closed, and all loads will be fed from the other healthy national grid supply.

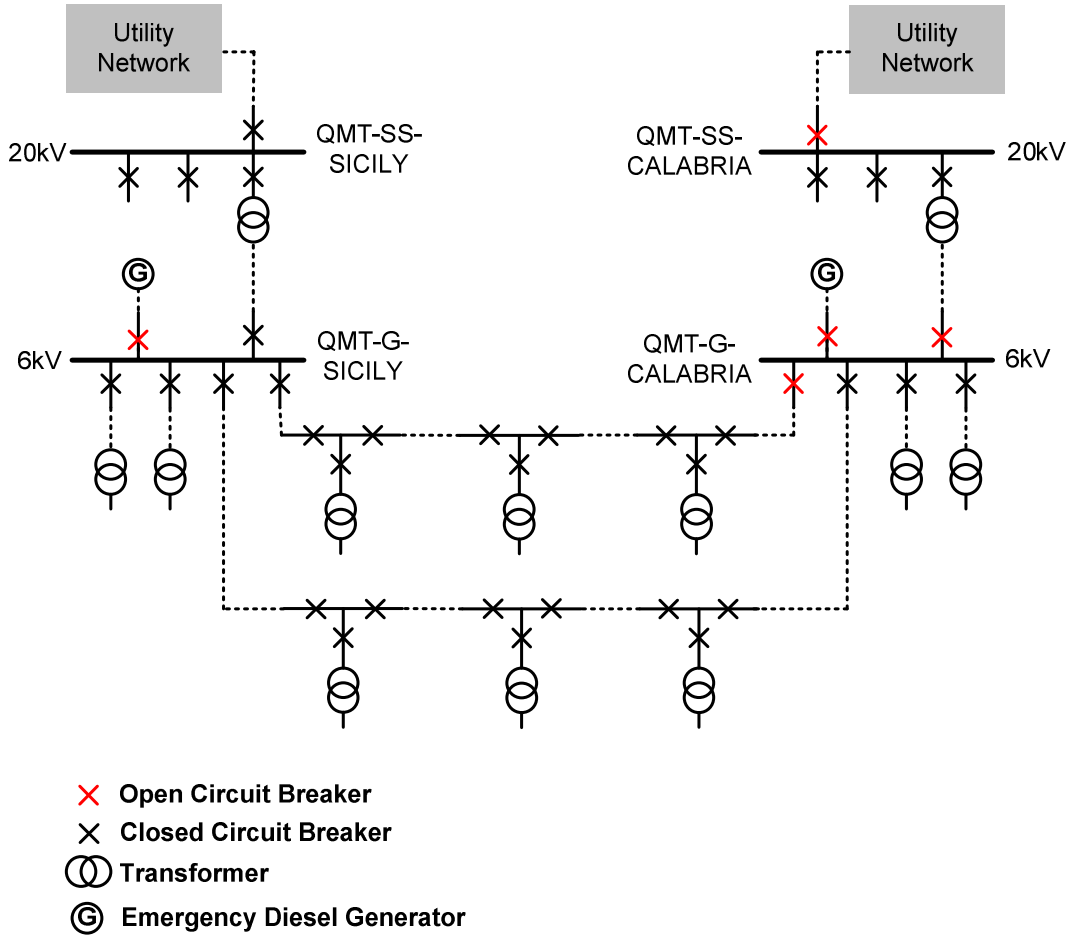


Fig. 7.3.2.2-1 Fault operation scenario with utility supply from one side only - Scenario 2

If the situation escalates and both national grids fail, the bridge network will be isolated from the ENEL grids, the ring reopened and the 2 emergency generators fed the essential loads, half of the bridge each. The “normal loads” will be disconnected.

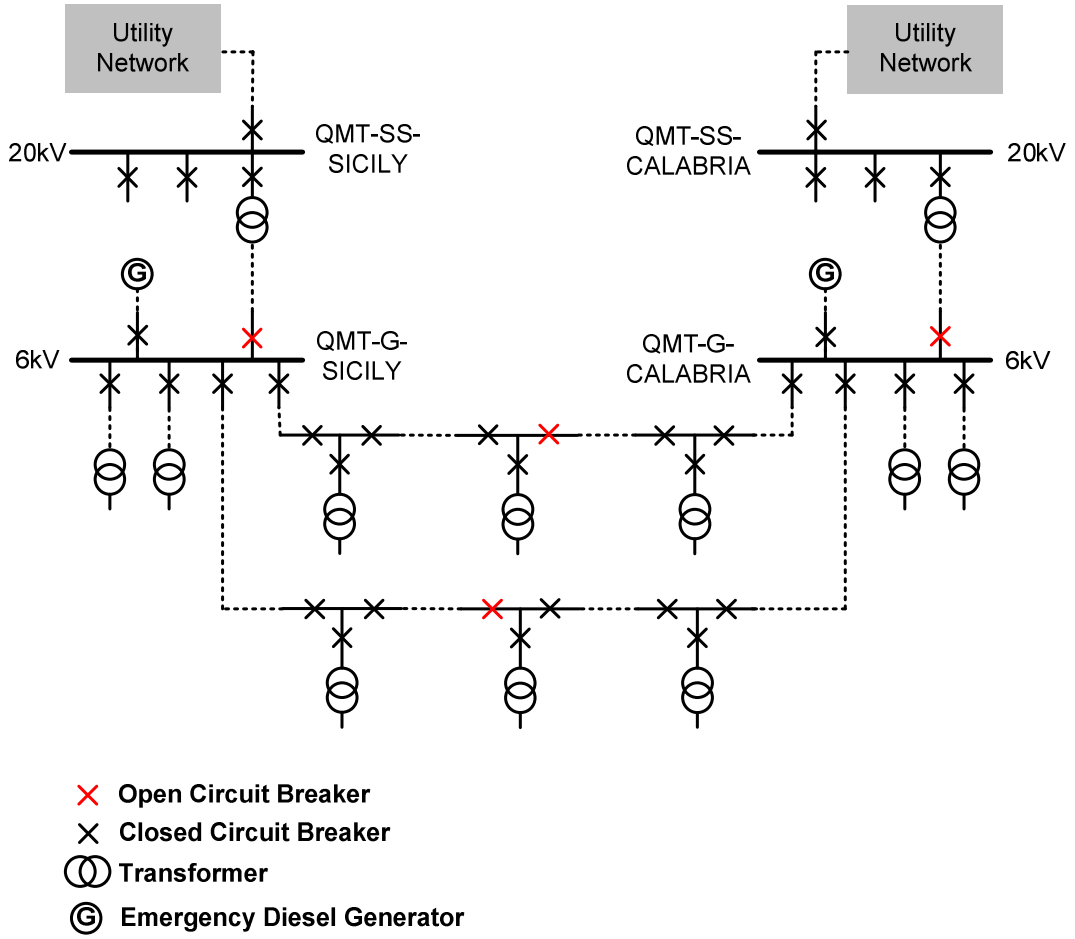


Fig. 7.3.2.2-2 Fault operation scenario with emergency power supply from diesel generator sets - Scenario 3

None of the electrical power supplies will run in parallel at any time and no synchronisation between the systems will be provided. On switching between the operation modes, affected systems will have a power cut during the transmission period. Systems not accepting a power-cut will be UPS powered.

The power system will be prepared for future installation of synchronisation facilities enabling the load transfer from the grid to the Emergency Generator and back without the need for a shut down of the electrical loads on the bridge.

The power distribution system is prepared for reconfiguring of the supply in case of failure in a transformer substation. In this case the faulty substation will be isolated by circuit breakers in neighbouring substations and supplied by the remaining healthy feeder.

Further specifications for the Emergency Power Supply appears from Section 8.

7.3.3 Distribution Voltages and Topology

The loads on the bridge will be supplied through 6/0.4kV transformers located along the bridge which gives:

- Reduction of weight and cross section of electrical cables
- Easier installation and maintenance
- Easier installation of compact transformers.

Selection of 6 kV voltage level facilitates the generation of energy directly on 6 kV level by means of 6 kV emergency alternators.

Two 20/6.0 kV switchboards will be located in proximity of the towers, where also the ENEL MV feeders will be located.

The QMT-G-Sicilia and Calabria substations will feed all electrical loads in the towers and on the bridge.

Table 7.2 Distribution Voltages

Location	**Nominal Voltage kV**
QMT-SS switchgear Sicilia	20/6
QMT-SS switchgear Calabria	20/6
QMT-G-Sicilia	6/0.4/0.23
QMT-G-Calabria	6/0.4/0.23

Anchor block	6/0.4/0.23
Tower high altitude	6/0.4/0.23
Tower low altitude	6/0.4/0.23
Bridge	6/0.4/0.23
Water reservoir	6/0.4/0.23

The voltages will be kept within the guidelines of EN 50160. The design will aim to have a voltage variations from nominal limited to ±4% on the MV, ±5% for lighting circuits and ±6% on other systems.

7.3.4 Monitoring of the Power Supply System

All transformers, generators, UPS and switchboards will be monitored and controlled from the computer-based Power Management System (PMS) and Control and Monitoring System (CMS). The electrical systems will provide the I/Os required by the PMS and CMS.

For further details please refer to section 13.

7.4 M V Switchboards

7.4.1 General specifications for all MV switchgear

The MV switchgear will comply with the following general main requirements:

Description	**Specification**
Design standards	IEC
Nominal voltage (Tensione nominale)	24kV 3 phases

Operation voltage	20kV depending on location
BIL (livello nominale di isolamento (tensione di tenuta ad impulse 1.2/50μs a secco verso terra e tra le fasi (valore di cresta)	125 kV
Rated short time power frequency voltage (Livello nominale di isolamento (tensione di tenuta a frequenza industriale per un minuto a secco verso terra e tra le fasi)	50 kV
Power frequency (frequenza nominale)	50 Hz
Nominal current (corrente nominale)	630 A
Rated short circuit breaking current (1s)	31.5 kA (or 20 kA) decided in Projetto esecutivo
Seismic zone	UBC zone 4
Circuit breakers (interrutore)	SF6 or vacuum (decided in Projetto esecutivo)
Circuit breaker close and latch	≥80 kA
Circuit breaker interrupting time	≤3 cycle
Lightning protection	Zone 2
Protection relays	Electronic relays, as shown on the drawings

Current and voltage transformers	Cast resin (class and ratio to be decided in the Projetto esecutivo phase)
Degree of protection by enclosure , IEC 60529	IP3X
Interlocks	Effective interlocks between disconnector, circuit-breaker and earthing switch. Operation of all switching devices with the door closed.

Table 7.3a General requirements to 20 kV switchgear

Description	**Specification**
Design standards	IEC
Nominal voltage	7.2kV 3 phases
Operation voltage	6kV depending on location
BIL (livello nominale di isolamento (tensione di tenuta ad impulse 1.2/50μs a secco verso terra e tra le fasi (valore di cresta)	60kV
Rated short time power frequency voltage (Livello nominale di isolamento (tensione di tenuta a frequenza industriale per un minuto a secco verso terra e tra le fasi)	20 kV
Power frequency	50 Hz

Seismic zone	UBC zone 4
Circuit breakers (interrutore)	SF6 or vacuum (decided in Projetto esecutivo)
Circuit breaker close and latch	≥80 kA
Circuit breaker interrupting time	≤3 cycle
Lightning protection	Zone 2
Protection relays	Electronic relays, as shown on the drawings
Current and voltage transformers	Cast resin (class and ratio to be decided in the Projetto esecutivo phase)
Degree of protection by enclosure , IEC 60529	IP3X
Interlocks	Effective interlocks between disconnector, circuit-breaker and earthing switch. Operation of all switching devices with the door closed.

Table 7.4b General requirements to 6 kV switchgear

For the electrical design of the outgoings from the switchboard please see the project single line drawings and protection schemes.

The switchgear assembly will have dead-front steel structures containing equipment compartments with switching apparatus, primary bus system, ground bus system, auxiliary compartments and transformers, protection and control devices, control bus (as required) and connection provisions for primary, ground, and control circuits.

The switchboard will be designed for front access only. The switchboards will be provided with single line diagram on the front and operation equipment for easy and safe operation. The

switchboard will be provided with facilities for local operation with indications of the switchboard status, voltages, relay protection, trips and currents as well as switch position.

The basic structure will be of modular construction and fabricated of galvanised steel complete with a corrosion protection sufficient for use in saliferous environment on the bridge.

Bus bars will be copper and will be completely isolated and coated with an insulation that is flame retardant, non-hygroscopic and high-dielectric. Bus supports will be flame retardant. Earth bus bars will match the max earth fault current at the location but minimum 125mm^2 . Internal wiring will be manufactures standard.

The design will be for bottom cable entry. Switchboard maximum dimensions will be limited by the location of installation. Minimum space around the switchboards will be: Front 1200mm, side 30mm and top 35mm.

Control switches, instruments, meters, position indicating lights, protective relays, etc. will be in a separate compartment from the circuit breaker.

All other monitoring devices such as CT's and limit switches may be located within other compartments.

Low voltage compartment door mounted devices will be mounted on the front of the switchgear panels and arranged in logical and symmetrical manner.

The breaker cubicles and circuit breaker units will be constructed so that units of the same rating are interchangeable. The circuit breaker enclosure will have interference blocking to prevent the insertion of improperly rated breakers.

The power circuit breakers will be electrically operated, 3-pole type, with motor charged spring type stored energy operating mechanism, with manual back-up function.

Voltage and Current transformers, VT's and CT's will be designed to withstand the Basic Impulse Level (BIL) of the switchgear. Transformers will be cast resin type.

Voltage transformers will be protected against short circuit currents.

All protective relays, auxiliary relays, indicating instruments, recording instruments, indicating lights, transducers, etc. will be housed in the low voltage compartment. The low voltage compartment will be isolated from the above equipment.

The protection relays will from the front be IP51 where practically achievable.

A multi-function, 3-phase microprocessor based protection and control relay system will be provided and installed in the low voltage compartments. This system will be interfaced with a Power Management System (PMS). For operation and interface requirements to the PMS please see the specification of the PMS system.

Protection relays will be provided with the functions indicated on the protection scheme drawings but with a minimum of:

- 3-phase overcurrent protection time and instantaneous, and directional in the ring units.
- Ground overcurrent (time and instantaneous)
- High set instantaneous
- Ammeter, demand and peak demand ammeters
- Event recording
- Accumulation of breaker interrupting duty
- Continuous self-checking
- Communications ports for remote terminal connection.

The protection relays will protect the units and connected equipment. The switchboard protections design will ensure that protection, safety trips and interlocks are maintained even on loss of PMS and CMS systems.

The protection equipment of the ring-main switchboards will include directional relays with an accuracy enabling reasonable discrimination in the system independent of power flow direction. These relays will also have provision for remote operation and reset function to ensure quick recovery of healthy systems from the Control Room.

Breakers can close only on a deenergized bus, if not covered by synchronisation facilities. This will be monitored and controlled by a separate dead bus protection relay.

The control voltage will be from 230V AC UPS unit.

The switchgear will provide control and monitoring signals for remote operation and monitoring as required by the computerised power management system and monitoring and control system (PMS and CMS).

Manufactures standard test in accordance with IEC will be performed.

7.4.2 Withdrawable type switchgear

The switchboards of the main substations, QMT-SS and QMT-G will be provided with withdrawable type switchgear.

The switchboards will be equipped with solidly grounded poly carbonate shutters, which shall automatically open when the breaker is racked into the connected position and close (covering the primary contacts and current transformers) when racked to the test or disconnected positions or withdrawn from the cell. Shutter earthing will be by dedicated ground wires. The actuation of the shutters shall be by the movement of the circuit breaker and be padlockable in closed position.

The power circuit breakers will be electrically operated, 3-pole, draw-out type, with vacuum interrupters and motorised charging of a spring type stored energy operating mechanism. The power circuit breaker will be provided with self-aligning line-side and load-side disconnecting devices. The breaker racking system will allow smooth, consistent breaker movement with the door closed and will have three positions in addition to the fully withdrawn position; disconnect, test and connected.

The circuit breaker will stop and lock in all three positions, requiring operator action to move from one position to another. The circuit breaker will be provided with an integral racking mechanism.

The draw-out mechanism will hold the breakers rigidly in the CONNECTED (primaries and secondaries engaged), TEST (primary contacts disconnected and shutter closed, but control contacts engaged) and DISCONNECTED (both primary and secondary contacts disengaged) positions, with the door closed.

The secondary contact plug will automatically disconnect when the breaker is moved from the TEST to the DISCONNECTED position. The disconnecting device will be positioned and constructed as to not expose the operator to live parts.

Interlocks will be provided in order to prevent connecting the breaker to, or disconnecting it from the bus stabs unless the breaker is OPEN (tripped), assuring proper sequencing and safe operation. The close springs of the circuit breaker will automatically discharge when the breaker is released from the cell by pulling in on the truck latch assembly.

The switchgear shall be constructed in accordance with the following main requirements:

Description	**Specification**
Switchgear type	Withdrawable
Rated current	See drawings
Interrupting capacity	≥1000 MVA
Circuit breaker interrupting capacity	≥31.5kA (or 20 kA - to be decided during the Projetto esecutivo phase)
Busbar	Single
Breaker close and latch	≥80 kA
Degree of protection by enclosure , IEC 60529	IP3X

Table 7.4a Technical data for 20kV

Description	**Specification**
Switchgear type	Withdrawable

Rated current	See drawings
Interrupting capacity	≥1000 MVA
Circuit breaker interrupting capacity	≥10.0kA
Busbar	Single
Breaker close and latch	≥80 kA
Degree of protection by enclosure , IEC 60529	IP3X

Table 7.4b Technical data for 6 kV switchgear

7.4.3 Fixed circuit breaker type switchgear

The switchboards on the bridge and in the towers will be fixed circuit breaker type switchboards. This to keep the installations physically small to enable the substations to be installed on the bridge obtaining easy access to the facilities and a good working environment for maintenance and repair. The dimensions of the switchgear compartments will not exceed the following dimensions:

- Depth≤ 1000mm
- Height≤ 1800mm

These, compact type switchgear will comply with the following main requirements:

Description	**Specification**
Circuit breaker type	SF6 or vacuum
Circuit breaker mounting	Fixed-mounted

Busbar	Single

Table 7.5 Technical data for MV fixed mounted switchgear

The switchgear will be factory assembled type and sealed - for - life design according to IEC 62 271-200 (sealed pressure system).

The switchgear will be constructed to withstand:

- Salt water
- Air humidity up to 95%

The feeder earthing switch will be make-proof.

The switchgear will be wall-standing design.

Cable connection access will be from front or rear, bottom entry.

The switchgear shall be constructed in accordance with the following main requirements:

Description	**Specification**
Switchgear type	Fixed
Rated current	See drawings
Busbar	Single
Degree of protection by enclosure, IEC 60529	IP 4X
Environmental class	Tropical with thermostat controlled ventilation of compartments

Table 7.6 Technical requirements to MV switchgear substation in the bridge

7.4.4 Surge arresters

The medium voltage switchboards will be equipped with lightning arresters in the cable feeder compartments.

The surge arresters will be screened gapless surge arresters (Metal oxide **arrester**) designed for direct connection onto outer cone bushings in accordance to EN50180 or EN50181. The insulation of the screened surge arrester is made of a highly modified silicone rubber characterized by high tracking resistance, elongation at break and non-flammability. The active part is a metal oxide arrester which meets the requirements of IEC-60099-4 for separable and dead-front arresters. The combination of screened connector and surge arrester exceeds CENELEC HD 629.1 S1 requirements.

The main characteristics of the arrester will be as follows:

<u>For 6 kV switchgear</u>

- Rated current: 10kA
- Operating duty impulse withstand current (4/10μs): 100 kA
- Continuous operating voltage U_c: 6kV
- Rated voltage: 7.5kV
- Residual voltage at 20 kA (8/20 μs): 20kV
- Residual voltage at 40 kA (8/20 μs): 22.5kV
- Energy high current impulse: 5,3 kJ/kV Uc

<u>For 20 kV switchgear</u>

- Rated current: 10kA
- Operating duty impulse withstand current (4/10μs): 100 kA
- Continuous operating voltage U_c: 20kV
- Rated voltage: 22kV
- Residual voltage at 20 kA (8/20 μs): 68kV
- Residual voltage at 40 kA (8/20 μs): 79kV
- Energy high current impulse: 5,3 kJ/kV Uc

7.5 LV Switchboards

7.5.1 LV switchgear

The low voltage switchboards will comply with the following main requirements:

Description	**Specification**
Type	Fixed
Rated nominal voltage	≥ 690 V
Operating voltage	400/230V, 3phase,
Rated frequency	50 Hz
Short circuit strength (1sec)	20 kA
Nominal current of bus bars	Sized in accordance with IEC 60439
Degree of protection, EN 60529	IP 43
Separation of busbars from the functional units	Form 4b

Table 7.7 Relevant standard specification

For the electrical design of the outgoings from the switchboard please see the project single line drawings and protection schemes.

The LV switchboards will consist of incoming section and power distribution circuits. All switchboards shall be accessible only from the front and no rear access will be necessary for operation and maintenance.

The design, material, construction and performance of the low voltage switchboards will comply with the latest international standards.

The switchboards will be cubicle type with a logical arrangement of cubicles, terminal compartments and cable channels for easy operation and maintenance.

Access to the inside of cubicles containing protective devices will be by means of a hinged door fixed shut by means of a moulded lever type latch which shall be able to be locked with the means of a proprietary locking system.

All fixing accessories will have anti-corrosion finish.

Each individual switchboard will have min. 20% spare space for future installation.

Electrical construction, general requirements

The earthing system will be TN-S, i.e. the protective (earth) conductor and the neutral conductor will be electrically separate throughout the installation and only be connected at one place in the main switchboard receiving the transformer feeder. The switchboard will be provided with 4 bus bars. 3 phases and neutral sized for the switchboard $I_{n.}$ but minimum 200mm^2, and the earth busbar will be minimum 250mm^2. Internal wiring will have a minimum cable size of 1.5mm^2.

Overcurrent protection will generally be fuseless.

Switchboards will be provided with equipment to detect failing voltage in the main supply.

All handles of control circuit switches will be accessible without opening of doors.

Anti condensation heaters will be installed inside switchboards. These heaters will be thermostatically controlled.

The main structure of the switchboard will be bonded directly to the earth bar. Installed devices, module steel cases and framework shall be bonded to earth. All hinged covers will be bonded to module cases via a separate flexible copper conductor min. 2.5mm^2.

A selector switch "local/remote control" will be installed at the front of the switchboard switching from local operation to remote operation from the control room.

Ground fault protection will be provided as required by the electrical standards.

Manufactures standard test in accordance with IEC will be performed.

7.5.2 Surge protection

The SPDs shall be installed in all main switchboards. These SPDs will be located in a transition zone between zone LPZ 0_B and zone 2 and shall be rated for possible induced lightning current as in zone 0_B. The SPDs shall comply with the following minimum specifications:

SPD according to EN 61643-11	Type 1
Nominal ac voltage U_N	230 / 400 V
Max. continuous ac voltage U_C	255 V
Lightning impulse current (10/350) [L,N-PE] I_{imp}	25 kA
Nominal discharge current (8/20) I_n	25 / 100 kA
Voltage protection level [L-PE] U_P	≤ 1.5 kV

All other SPDs in switchboards would be rated for zone 2. The SPDs shall comply with the following minimum specifications:

SPD according to EN 61643-11	Type 2
Nominal voltage ac U_N	230/400 V
Max. continuous ac voltage U_C	275 V
Nominal discharge current (8/20) I_n	20 kA
Short circuit withstand capability at max. mains-side overcurrent protection	50 kArms
TOV voltage U_T	335 V / 5 sec.

All local control switchboards for connection of traffic signs, CCTV etc. will be equipped with SPDs for IT systems in accordance with EN 61643-21:2001. The final protection of this equipment will be decided depending of the equipment manufacturers specifications during the Projetto Esecutivo phase.

7.6 Transformers

Power and distribution transformers shall comply with all relevant IEC/CEI standards, ref. section 3.1, and in particular CEI 14-8, CEI 14-32, CEI EN 60076 (dry type transformers applicable sections), CENELEC HD 46451, CENELEC HD 538.1 S1 & S1/A1, CEI 14-4 (dry type

transformers applicable sections), CEI 14-28 and CEI 14-12. Saranno inoltre fabbricati seguendo un sistema di Garanzia di Qualità conforme alla norma UNI. EN 29001 - ISO 9001.

The power substation transformers (designation BBT10 and BBT20) will comply with the following technical specifications:

Description	**Specification**
Insulation type	Dry, cast resin or similar
Design standard	As specified above
Nominal voltage for HV side	20 kV
Nominal voltage for LV side	6 V
Rated frequency	50 Hz ± 0.2 %
Rated power	3.200 kVA
Primary BIL	≥ 125 kV
Secondary BIL	≥60 kV
Impedance	6%
No load losses at T=75 °C	≤1%
Tapings on HV side	2x±2.5%, off-load
Vector group	DYn 11

Insulation class	F
Cooling	Natural (ONAN)
Windings temperature monitoring and alarm	4 sets of PT 100 in all 3 phase windings and neutral and one temperature monitoring of each winding at the transformer connected as follows: I trasformatori dovranno essere equipaggiati di un sistema di protezione termica comprendente: • n° 3 termoresistenze Pt 100 nell'avvolgimento BT; • n° 1 termoresistenza Pt 100 nel nucleo magnetico; • n° 1 cassetta di centralizzazione contenente i morsetti delle suddette termoresistenze, posta sulla parte superiore del nucleo; • n° 1 centralina termometrica digitale a 4 sonde prevista con visualizzazione della temperatura delle tre fasi e del neutro determinazione del 'set point' di allarme e sgancio predisposizione per il controllo automatico dei ventilatori di raffreddamento tensione di alimentazione universale AC/DC ed uscita seriale.
Environmental protection	Installed in transformer room
Climatic and Environmental classification	C2 and E2 (Più precisamente la classe E2 garantirà l'idoneità della macchina a funzionare in ambiente con presenza di inquinamento industriale ed elevata presenza di condensa, mentre la classe C2 garantirà l'idoneità del trasformatore ad essere stoccato e a funzionare con temperature fino a -25 °C.)
Fire safety	Self extinguishing, fire class F1

Table 7.6.1 Relevant standard specification for MV/MV power substation transformers

All MV/LV transformers comply with the following main requirements:

Description	**Specification**
Insulation type	Dry, cast resin or similar
Design standard	As specified above
Nominal voltage for HV side	6 kV
Nominal voltage for LV side	400/230 V
Rated frequency	50 Hz ± 0.2 %
Rated power	As shown on single line diagrams
Primary BIL	≥ 125 kV
Secondary BIL	-
Impedance	4% (<250kVA) 6% (>630kVA)
No load losses at T=75 °C	≤1%
Tapings on HV side	2x±2.5%
Vector group	DYn 11
Winding temperature monitoring and alarm	4 sets of PT 100 in all 3 phase windings and neutral and one temperature monitoring of each winding at the transformer connected as follows:

	I trasformatori dovranno essere equipaggiati di un sistema di protezione termica comprendente: • n° 3 termoresistenze Pt 100 nell'avvolgimento BT; • n° 1 termoresistenza Pt 100 nel nucleo magnetico; • n° 1 cassetta di centralizzazione contenente i morsetti delle suddette termoresistenze, posta sulla parte superiore del nucleo; n° 1 centralina termometrica digitale a 4 sonde prevista con visualizzazione della temperatura delle tre fasi e del neutro determinazione del 'set point' di allarme e sgancio predisposizione per il controllo automatico dei ventilatori di raffreddamento tensione di alimentazione universale AC/DC ed uscita seriale.
Environmental protection	Steel enclosure, IP 23, with forced internal ventilation controlled by thermostat, except transformers in portal buildings.
Climatic and Environmental classification	C2 and E2 (Più precisamente la classe E2 garantirà l'idoneità della macchina a funzionare in ambiente con presenza di inquinamento industriale ed elevata presenza di condensa, mentre la classe C2 garantirà l'idoneità del trasformatore ad essere stoccato e a funzionare con temperature fino a -25 °C.)
Fire safety	Self extinguishing, fire class F1

Table 7.6.2 Relevant standard specification for MV/LV transformers

The transformer enclosure will be provided with automatic controlled cooling fan.

The winding temperature will be monitored and two level alarms transmitted to the Power Management System (PMS).

Neutral point of the transformers will be earthed.

Status of the transformer's ventilation systems shall be transmitted to PMS.

Manufactures standard test in accordance with IEC will be performed.

7.7 Power factor correction

All lighting installations will be power factor corrected within the equipment. No central power factor correction equipment (plant) is foreseen.

7.8 Packaged substations

The substations on the bridge will be packaged substation of a compact outdoor type.

For the bridge installations there are 8 packaged substations on the bridge and 2 packaged substation at the anchorblocks. Total 10 packaged substations.

The electrical equipment of the Packaged Substations is shown on the design drawings and the technical specifications of the equipment are given in section 7.4, 7.5, 7.6 and 8.3.

It will be a metal enclosed type constructed of anodised aluminium sheets with a minimum thickness of 2.0 mm.

It will be designed, manufactured and tested in accordance with applicable IEC standards.

The substation will be designed to withstand local geological and meteorological conditions. The substations will be located close to the crass barrier of the bridge road and special precautions made to ensure that the substation will move together with the crass barrier on an accident on the road.

The packaged substations will be equipped with separate rooms for MV switchboards, transformer, LV switchboards and communication equipment including control and monitoring.

All rooms of the substation will be equipped with AC units, fire detection and fighting.

The substation will be padlocable to avoid intrusion.

The substation will be equipped with earthing facilities.

7.9 Cables

The cables will comply with the technical specifications given in the Document GCG.G.03.05 section 2.10 and dated 15 luglio 2004.

7.9.1 Cables for connection of 20kV substations to ENEL grid

The cables will comply with the following technical specifications:

Standard Norma di riferimento	CEI 20-11; CEI 20-13
Voltage	18/30 kV
Type Sigla CEI UNEL 35011	RG7H1OZR
Manufacturer	Prysmian, or similar
Operation temperature Temperatura di funzionamento	90° C
Temperature short circuit Temperatura di cortocircuito	250° C
Cable characteristics Caratteristiche del cavo	fire retardant and with low emission of corrosive subtances non propagazione dell'incendio e ridotta emissione di sostanze corrosive
	low emission of opaque smoke and toxic gases and without corrosive gases (AFUMEX)
	Flexible, compact stranded bare copper

Conductors Conduttore	conductor Rigido, Conduttore a corda rotonda compatta di rame rosso
Insulation Isolante	High module rubber compound, G7 type Mescola di gomma ad alto modulo G7
Armour Armatura	Galvanised steel straps A piattine di acciaio zincato
Sheath Guaina	PVC, Rz type; colour red PVC, di qualita Rz, colore rosso

7.9.2 Cables 20 kV for connection of transformers

The cables will comply with the following technical specifications:

Standard Norma di riferimento	CEI 20-11; CEI 20-13
Voltage	18/30 kV
Type Sigla CEI UNEL 35011	RG7H1R
Manufacturer	Prysmian, or similar
Operation temperature Temperatura di funzionamento	90° C
Temperature short circuit Temperatura di cortocircuito	250° C
	fire retardant and with low emission of

Cable characteristics Caratteristiche del cavo	corrosive subtances non propagazione dell'incendio e ridotta emissione di sostanze corrosive low emission of opaque smoke and toxic gases and without corrosive gases (AFUMEX)
Conductors Conduttore	Flexible, compact stranded bare copper conductor Rigido, Conduttore a corda rotonda compatta di rame rosso
Insulation Isolante	High module rubber compound, G7 type Mescola di gomma ad alto modulo G7
Screen Schermatura	Bare copper wire A filo di rame rosso
Sheath Guaina	PVC, Rz type; colour red PVC, di qualita Rz, colore rosso

7.9.3 Cables 6kV for connection to transformers

The cables will comply with the following technical specifications:

Standard Norma di riferimento	CEI 20-11; CEI 20-13
Voltage Tensione	6/10 kV

Type Sigla CEI UNEL 35011	RG7H1R
Manufacturer	Prysmian, or similar
Operation temperature Temperatura di funzionamento	90° C
Temperature short circuit Temperatura di cortocircuito	250° C
Cable characteristics	fire retardant and with low emission of corrosive subtances non propagazione dell'incendio e ridotta emissione di sostanze corrosive
Caratteristiche del cavo	low emission of opaque smoke and toxic gases and without corrosive gases (AFUMEX)
Conductors Conduttore	Flexible, compact stranded bare copper conductor Rigido, Conduttore a corda rotonda compatta di rame rosso
Insulation Isolante	High module rubber compound, G7 type Mescola di gomma ad alto modulo G7
Screen Schermatura	Bare copper wire A filo di rame rosso
Sheath Guaina	PVC, Rz type; colour red PVC, di qualita Rz, colore rosso

7.9.4 Cables for 6kV power distribution

The cables will comply with the following technical specifications:

Standard Norma di riferimento	CEI 20-11; CEI 20-13
Voltage	6/10 kV
Type Sigla CEI UNEL 35011	RG7H1OZR
Manufacturer	Prysmian, or similar
Operation temperature Temperatura di funzionamento	90° C
Temperature short circuit Temperatura di cortocircuito	250° C
Cable characteristics	fire retardant and with low emission of corrosive subtances non propagazione dell'incendio e ridotta emissione di sostanze corrosive
Caratteristiche del cavo	low emission of opaque smoke and toxic gases and without corrosive gases (AFUMEX)
Conductors Conduttore	Copper, flexible rigido
Insulation Isolante	High module rubber compound, G7 type Mescola di gomma ad alto modulo G7
Armour Armatura	Galvanised steel straps A piattine di acciaio zincato

Sheath Guaina	PVC, Rz type; colour red PVC, di qualita Rz, colore rosso

7.9.5 Low voltage cables for power distribution

The cables for the power distribution (cavi di bassa tensione per la distribuzione) will comply with the following technical specifications:

Standard Norma di riferimento	CEI 20-11; CEI 20-13, CEI 20-34, CEI 20-35; CEI 20-22 II; CEI 20-37;
Voltage	0.6/1 kV
Type Sigla CEI UNEL 35011	FG7(O)M1
Manufacturer	Prysmian, or similar
Operation temperature Temperatura di funzionamento	90° C
Temperature short circuit Temperatura di cortocircuito	250° C
Cable characteristics Caratteristiche del cavo	Fire retardant and with low emission of corrosive subtances Non propagazione dell'incendio e ridotta emissione di sostanze corrosive Very low emission of opaque smoke and toxic gases and without corrosive gases (AFUMEX)
Conductors Conduttore	flexible annealed bare copper conductor, with yellow green

	flessibile di rame rosso ricotto, con giallo/verde
Insulation Isolante	High module HEPR rubber, with higher electrical, mechanical and thermal performances (CEI 20-11 - CEI 20-34 standards) Gomma HEPR ad alto modulo, che conferisce al cavo elevate caratteristiche elettriche, meccaniche e termiche (norme CEI 20-11 - CEI 20-34)
Sheath Guaina	Special PVC grey outer sheath, Rz type with coloured line In PVC speciale di qualita Rz, colore grigio con banda colorata

Standard Norma di riferimento	CEI 20-11; CEI 20-13, CEI 20-34, CEI 20-35; CEI 20-22 II; CEI 20-37/2;
Voltage	0.6/1 kV
Type Sigla CEI UNEL 35011	FG7OR
Manufacturer	Prysmian, or similar
Operation temperature Temperatura di funzionamento	90° C
Temperature short circuit Temperatura di cortocircuito	250° C
Application	Suitable for fixed installation both indoor and outdoor, on cable trays, in pipe, conduits or

Caratteristiche del cavo	similar systems. Can be directly buried Adatti per posa fissa sia all'interno, che all'esterno su passerelle, in tubazioni, canalette o sistemi similari. Possono essere direttamente interrati
Caratteristiche del cavo	Very low emission of opaque smoke and toxic gases and without corrosive gases (AFUMEX)
Conductors Conduttore	Stranded flexible annealed bare copper conductor Conduttore a corda rotonda flessibile di rame rosso ricotto
Insulation Isolante	High module HEPR rubber, with higher electrical, mechanical and thermal performances (CEI 20-11 - CEI 20-34 standards) Gomma HEPR ad alto modulo, che conferisce al cavo elevate caratteristiche elettriche, meccaniche e termiche (norme CEI 20-11 - CEI 20-34)
Sheath Guaina	Special PVC grey outer sheath, Rz type with coloured line In PVC speciale di qualita Rz, colore grigio con banda colorata

7.9.6 Cables for installation in surface-mounted or embedded conduits

The cables with cross sections up to 6 mm² will comply with the following technical specifications:

Standard Norma di riferimento	CEI 20-11; CEI 20-14, CEI 20-22 II; CEI 20-37/2; CEI 20-34, CEI 20-35
Voltage Tensione	0.6/1 kV
Type Sigla CEI UNEL 35011	N1VV-K
Manufacturer	Prysmian, or similar
Operation temperature Temperatura di funzionamento	70° C
Temperature short circuit Temperatura di cortocircuito	160° C
Conductors Conduttore	Flexible stranded annealed bare copper conductor corda rotonda flessibile di rame rosso ricotto
Insulation Isolante	PVC, R2 type In PVC di qualità R2

The cables with cross sections above 6 mm² will comply with the following technical specifications:

Standard Norma di riferimento	CEI 20-11; CEI 20-22 II; CEI 20-37/2; CEI 20-34, CEI 20-20, CEI 20-35
Voltage Tensione	1 kV
Type	N07V-K

Sigla CEI UNEL 35011	
Manufacturer	Prysmian, or similar
Operation temperature Temperatura di funzionamento	70° C
Temperature short circuit Temperatura di cortocircuito	160° C
Conductors Conduttore	Flexible stranded annealed bare copper conductor corda rotonda flessibile di rame rosso ricotto
Insulation Isolante	PVC, R2 type In PVC di qualità R2

Cables in conduits and protected trunking in switchboards and areas with increased requirements to safety for persons working in the area will in general comply with the following requirements:

Standard Norma di riferimento	CEI 20-11; CEI 20-22 II; CEI 20-34, CEI 20-35; CEI 20-37; CEI 20-38,
Voltage Tensione	0.45/0.75 kV
Type Sigla CEI UNEL 35011	N07G9-K
Manufacturer	Prysmian, or similar
Operation temperature Temperatura di funzionamento	70° C
Temperature short circuit Temperatura di cortocircuito	160° C

Conductors Conduttore	Stranded flexible bare copper conductor Conduttore a corda flessibile di rame rosso
Insulation Isolante	Cross-linked elastomeric compound, G9 type Elastomerico reticolato di qualita G9
Cable characteristics Caratteristiche del cavo	Very low emission of smoke and toxic gases Bassissima emissione di fumi e gas tossici

7.9.7 Cables for security systems

The cables will comply with the following technical specifications:

Standard Norma di riferimento	CEI 20-11; CEI 20-38, CEI 20-22 III; CEI 20-34; CEI 20-36; CEI 20-45, CEI 20-35, CEI 20-37
Voltage Tensione	0.6/1 kV
Type Sigla CEI UNEL 35011	FG10OM & FG10(O)M1
Manufacturer	Prysmian, or similar
Operation temperature Temperatura di funzionamento	90° C
Temperature short circuit Temperatura di cortocircuito	250° C
Cable applications	Suitable for the strictest safety requirements in the case of fire, such as: emergency lightings,

Caratteristiche del cavo	alarm and automatic fire detection systems, fire extinguishing systems, automatic emergency exits, lift systems, activation of smoke outlets or shutters, fans, air conditioning, and telephone and video-surveillance systems. Fixed installation. Sono destinati per impianti che richiedono i massimi requisiti di sicurezza nei confronti degli incendi quali: impianti per luci di emergenza, di allarme e di rilevazione automatica dell'incendio, dispositivi di spegnimento incendio e apertura porte automatiche, sistemi di elevazione, di aerazione e di condizionamento, sistemi telefonici di emergenza. Posa fissa.
Conductors Conduttore	Flexible stranded bare copper conductor Conduttore a corda flessibile di rame rosso
Insulation Isolante	Cross-linked elastomeric compound, G10 type Elastomerico reticolato di qualita G10
Fire resistant barrier Barriera ignifuga	Mica/glass tape Nastro mica/vetro

7.10 Cable terminals

7.10.1 Cable termination for medium voltage cables

The indoor cable terminals will comply with the following specifications:

Standard Norme di riferimento	CEE 20-24
Temperature Temperatura di funzionamento	90° C
Temperature short-circuit Temperatura di cortocircuito	250° C
Manufacturer	Prismian, or similar
Type	STI Slip on indoor modular termination suitable for indoor applications in highly polluted environments or in small stations up to 30 kV. Elastico modulare per interno che lo rendono atto ad usi interni in ambienti fortemente inquinati o in cabine di ridotte dimensioni fino a 30 kV.

For connection of switchgear in the bridge substations the following compact connectors will be used, where applicable:

Standard Norme di riferimento	ENEL DJ 4135, IEC 71
Temperature Temperatura di funzionamento	90° C
Temperature short-circuit	250° C

Temperatura di cortocircuito	
Manufaturer	Prismian, or similar
Type	FMCE Separable connectors for rated voltage up to 20 kV Sconnettibile fino a 20 kV
Application Caratteristiche del terminale	Separable connectors designed for connections to transformers, switch-gears, motors and equipments. Suitable for single-core medium voltage solid insulated cables, both indoor and outdoor, at 20 kV 250 A Terminale sconnettibile per collegamento a trasformatori, cabine e motori. Adatto per cavi unipolari estrusi di media tensione, sia per interno che per esterno a 20 kV 250 A

Cable joints will be resin joints in accordance with CEE 20-24.

7.10.2 Cable termination for LV-cables

Low voltage joints for power distribution cables will comply with the following specifications:

Standard Norme di riferimento	CEI 20-33
Temperature Temperatura di funzionamento	90° C
Temperature short-circuit	250° C

Temperatura di cortocircuito	
Manufaturer	Prismian, or similar
Type	SGB Separable connectors for rated voltage up to 20 kV Sconnettibile fino a 20 kV
Application Caratteristiche del terminale	Cast resin straight joints for cables with solid insulation for rated voltage up to 1 kV. Giunto di linea in resina colata per cavi ad isolante estruso fin a 1 kV.

8 Emergency power supply

8.1 General

As described in section 7.3.2 'Operation Modes' a number of M&E facilities on the bridge are essential for its safe operation. The essential facilities as described in 7.2.2 Loads Classification will be secured against failure in mains availability and will be connected to a back-up power supply in form of emergency diesel generator and UPS.

8.1.1 General design criteria

8.1.1.1 System of units

The International System of Units (metric system) as specified in ISO is used throughout the design.

8.1.1.2 Voltage

Generator unit supply voltage 6 kV 3 phases, 50 Hz.

8.1.1.3 Climatic conditions

All installations are designed and constructed in such way that they will operate and withstand the local conditions.

The local climatic conditions at the site are specified in a separate document.

8.1.1.4 Design life time

The equipment and its major components have their designed life time not less than defined in Appendix 3 - Design Life.

8.2 Diesel generator sets

8.2.1 Scope of works

The back up power supply will be based on diesel generator set(s).

8.2.2 Design criteria

8.2.2.1 Standards

The design, materials and equipment associated with this section comply with the latest issue, including all amendments, of the following standards:

Number	Title
ISO 8528, Part 1 - 10 incl.	Reciprocating internal combustion engine driven alternating current generator sets.
ISO 3046-1	Reciprocating internal combustion engines - performance. Part 1: Declarations of power, fuel and lubricating oil consumptions, and test methods - Additional requirements for engines for general use.
ABGSM	General specifications and performance
IEC 60034	Rotating electrical machines
IEC 60439-1	Specification for low-voltage switchgear and control gear assemblies

8.2.3 Functional requirements

The emergency generator will be designed to provide power supply to all essential facilities plus 20% of spare capacity.

The diesel generator sets will be stand-by type of the machines.

The emergency power supply will comply with the following minimum functional requirements:

- Automatic start in case of disconnection of the primary power supply

- Take over of 100% of load within 30 seconds from start command
- Disclosure of parallel operation with the public power grid

The dieselgenerator set will be designed to a voltage stability of 1% with a voltage drop of 3% when fully loaded.

The generator plant will be on cold standby, since UPS systems will supply the essential system loads, if required, until the emergency generator(s) are in operation.

The plant will be equipped with a control panel providing the following functions:

- Automatic, or manual start in case of mains failure
- Automatic operation and control
- Protection equipment
- Remote monitoring by PMS

An automatic power management system (PMS) will disconnect the primary power system from the grid in case of power cut and connect the system to the relevant diesel generator set. Automatic procedures for reconfiguration of the power supply system will be provided by the PMS. The PMS systems will synchronize with the grid when the power is re-established on the public grid.

The PMS function are defined in section 13.12.

The procedures for disconnection and reconnection of the bridge power supply system to the electrical grids in Calabria side and Sicily side of the Bridge will be agreed with the power authorities.

8.2.4 Technical specifications

The generator plant will be a standard diesel generator set fulfilling the below requirements:

- Complete emergency diesel-generator unit with all electrical and mechanical facilities (fuel system, cooling system, exhaust etc.)

8.2.4.1 Prime mover

The prime mover will be designed/calculated by the dieselgenerator manufacture and will comply with the following minimum requirements:

- a water-cooled, 4-cycle, naturally aspirated, turbo charged, after cooled, multi-cylinder, direct injection industrial / marine diesel engine
- The engine will run on diesel fuel.
- A sturdy elastic coupling will connect the engine and the generator, and both will be mounted on a common base plate forming part of the supply,
- Proven and highly effective anti-vibrating mountings will be provided between base plate and concrete foundation.
- The engine will be provided with an electrical starter motor, engaging with the fly wheel ring gear and disengaging automatically when the engine starts.
- The equipment will include an adequately rated lead/acid battery together with an automatic mains energized battery charger. The battery will allow not less than 5 start attempts without need for recharging.

The emissions of the power plant will comply with current standards fulfilling the requirements for gas emission.

Lubrication of the engine will be by means of an engine driven integral pump. The pump will have on the suction side a coarse strainer and on the delivery side a duplex `full flow' fine filter complete with changeover cock incorporating pressure by-passes to facilitate oil flow to the engine should the filter become blocked.

The lubricating oil system capacity will be sufficient to enable the engine to run continuously for 48 hours at any load without replenishment. The governor of the engine will be electronic type and be capable of fine governing of speed to ISO 3046/IV.

EXHAUST

Exhaust pipe will be lagged with a removable aluminium cladding.

Residential engine exhaust gas silencer will be provided for each engine, size and type as recommended by the generator set manufacturer to meet the sound attenuation level of a residential environment.

GENERATOR

The generator will comply with the following requirements:

Rated power	>1600 kVA/1280kW
Rated voltage	6300 V ± 4%, 3 phase + N
Inrush Current	10 kA
Max. Voltage drop during Inrush 0 to full load	<10%
Frequency	50 Hz +-5%
Rated speed	<1500 r.p.m
Insulation class	H, for tropical environment
Deviation factor of voltage wave form	5 %
Type	Synchronous brushless and self-exciting
Cooling	Radial fan
Max. Noise level	80 dB(A)
Protection / Form	IP 23 / B2/B20

Winding temperature monitoring	2 thermistors in hottest place of windings. Stage 1: Alarm; Stage 2: shut down of the generator

EARTHING

The Generators neutral will be solidly earthed to the buildings earth.

CONTROL SYSTEM

The generator set will be provided with a microprocessor based control system that is designed to provide automatic starting, monitoring, and control functions for the generator set and its auxiliary equipment.

The generator control system and electrical equipment will be **prepared** for automatic synchronization to the grid.

The synchronization will support:

- Automatic synchronization across the generator main breaker when connecting the generator to the electrical grid
- Automatic synchronization across incoming ENEL breaker when connecting the ENEL grid to the electrical network of the bridge. (By controlling the generator)

The control system will be designed for either local monitoring and control of the generator set, or remote monitoring and control from a Power Management System (PMS) with control from the control room.

Voltage regulation will maintained the voltage within ± 2½% from no load to full load including cold to hot variation at any power factor from 0.8 to unity.

Automatic shutdown of the set and lockout of the starting system will result from any of the following:

- Low lubricating oil pressure

- High cooling water temperature
- Failed to start
- Engine over speed (if speed exceed 20% above normal)
- High stator temperature

The control system will include the following protective functions:

- Automatic change over switch interlocked electrically with mains circuit breaker
- Overload protection
- Differential protection
- Reverse power flow
- Visual & Audible Fault indication and alarm accept/reset
- All necessary controls needed to prevent starting of machines on momentary fluctuations of main voltage
- A selector switch for operation of the equipment in automatic and manual mode and off position
- A selector switch for operation of the equipment in local and remote position
- Automatic start sequence control.

The following equipment will be included in the control panel:

- Voltmeter and selector switch to indicate individual phase and line voltage
- Ammeter and selector switch to indicate the line current
- Frequency meter
- Hour run counter
- Engine 'start' & 'stop' push button and lock switch
- 'Remote' & 'Local' selector switch with provision for start & stop at main panel board

- 'Auto', 'Manual' & 'Off' selector switch
- 'Emergency Stop' push button
- Mains operated battery charger of the constant potential type with MCCB, ammeter, incorporating mains failure relay
- Run indicator lamp
- Fault indicator lamp
- Audible Alarm
- Lamp test push buttons, Alarm accept and reset buttons
- Tachometer and Speed indicator
- 3 Pole MCCB with neutral link

The following engine related items will be mounted separate from the control cubicle.

- Battery charge indicator
- Lubrication oil pressure indicator
- Cooling water temperature indicator
- Engine speed adjustment (speed droop between 0 and 6 %)
- Fuel level in integral fuel tank low
- Fuel level in integral fuel tank high
- Fuel level in main storage fuel tank low

FUEL SYSTEM

- The system will be equipped with a double skin sub base fuel storage tank with capacity for 24 hours operation at 100% load.
- The tank will be provided with all necessary fittings including fill, vent, drain and overflow line, level indication and access for inspection and maintenance. Level switches will be provided for the following services:

- Low level alarm
- High level alarm
- Low level start of transfer pump
- High level stop of transfer pump

One electric motor-driven fuel transfer pump and one standby manual pump will be provided to enable the fuel day tank to be filled from the main storage tank. The capacity of the pump will be such that the service tank can be completely filled in not more than one hour. All necessary check valves, by-pass valves, float valves and maintenance valves on piping system are to be provided.

The pump motor starter control panel will be provided with following features:

- AUTO/MANUAL selector switch
- Thermal overload protection
- Ground fault protection relay
- Indicator lamps for - Common alarm- Run - Stop - Fuel low level at main storage tank

The pump will start automatically if AUTO operation selected and on receipt of signal from the level switches in the base tank. The pump will stop when low level at main storage tank is detected.

The following signals will be transferred to the PMS:

- Pump in operation
- Pump common alarm
- Fuel low level at main storage tank

A main storage fuel tank will be installed. The tank will consist of one underground tank of capacity 9000 litres, including piping and valves. The tank will be cylindrical, fabricated from 6mm thick high quality black steel plate welded on internal and external seams, hydro-statically tested at factory to a pressure of one atmosphere for 24 hours with welds proven sound and supplied complete with inspection manhole (600mm diameter) with hermetical sealing cover, lifting lugs and reinforcements for supporting the concrete access hatch. The cover will be provided with

necessary connection for tank filling, fuel transfer, fuel return, tank emptying and de-sliming, venting and dipstick level control. The fill pipe couplings will suit to the local standard inlet sizes.

The main tank will be provided with low-level alarm and an overfilling safety device.

8.2.5 Diesel Generator Test

The Diesel Generator manufactures standard tests will be performed meeting the IEC standards.

8.2.6 Execution of the works

The diesel generators will be installed in dedicated rooms in portal buildings.

The plant will be installed in accordance with manufacturer's instruction.

The diesel generator set will be installed on vibration dampers.

All cabling will be installed in cable channels in the floor.

8.3 Uninterruptible Power Supply (UPS)

8.3.1 Scope of works

The UPS will maintain the power supply to the equipment which do not accept a power cut or where a power cut is unacceptable for safety reasons. Emergency lighting installation will also be power supplied from the centralised UPS units.

8.3.2 Standards

The UPS will meet the requirements of:

EN 50171	Central Power Supply Systems
IEC 60445	Basic and safety principles for man-machine interface, marking and identification - Identification of equipment terminals and conductor terminations
IEC 1000 ((801) level 4	Transient immunity requirements
NFPA 111	Standard on Stored Electrical Energy Emergency and Standby Power Systems, 2010 Edition
IEC 61000 series	Electromagnetic compatibility. Part 1-9

IEC 60439	Low-voltage switchgear and control gear assemblies
IEC 62040-1-1	Uninterruptible power systems (UPS) - Part 1-1: General and safety requirements for UPS used in operator access areas
IEC 60623	Secondary Cells and Batteries Containing Alkaline or Other Non-Acid Electrolytes

Table 8.1 Relevant standard specification

8.3.3 Functional requirements

The UPS units will have a back-up time sufficient to maintain the emergency power supply for the time defined in Appendix 4.

8.3.4 Technical specifications

The UPS systems will be of the on-line or double conversion type as Siemens CP200 series or similar. Each UPS system will comprise a rectifier, battery charger, inverter modules, internal static bypass switch and batteries.

The UPS will be 230V 50Hz system also supplying the control circuits of the MV and LV switchboards controlcircuits.

The continuous output power rating of the UPS units will be as specified in Appendix 4 at a 0.8 lagging power factor.

The UPS system will be designed with 20% spare capacity at commissioning. It will supply clean, uninterrupted power to the essential loads.

The UPS will operate at 230 V, 50Hz (+/-0.1 Hz).

The battery charging circuit will be rated to recharge a fully discharged battery to 90% in 10 hours. Batteries will be “maintenance free” lead batteries.. The battery will comply IEC.

The battery design life is defined in Appendix 3.

- The rectifier/charger converting from AC to DC will be of the solid-state type with fully controlled 6 or 12 pulse Thyristor Bridge and anti-harmonic chokes. The rectifier will be equipped with soft start function to reduce inrush currents.

The battery charging voltage will be with an accuracy of ±1%. The battery charging will match the chosen battery type to obtain maximum reliability and life time of the batteries. Battery temperature will be monitored and necessary action taken on high temperature. The battery charging circuit will be rated to recharge a fully discharged battery to 90% in 10 hours. The system will be provided with a normally open contact rated for remote monitoring by PMS.

The inverter will be based on the PWM (pulse width modulation) technology. IGBT (Insulated gate bipolar transistors) should be applied for the power stacks.

The UPS will be installed in a steel compartment equipped with hinged front access doors. The enclosure will be provided with forced ventilation and prepared for connection to external cooling unit, except UPS in portal buildings.

The UPS will automatically shot down when battery voltage reaches critical low level. An alarm is sent to the PMS and CMS 10 and 5 minutes before the UPS is actually shut down.

9 Lightning protection

The lightning protection of following structural elements is designed:

1 Lightning protection of towers.

2 Lightning protection of anchor blocks.

3 Lightning protection and earthing of the bridge deck.

4 Equipotential bonding of all steel constructions and elements of the bridge.

5 Provisions for earthing of M&E installations on the deck and in the towers and anchor blocks.

The following systems are not a part of the present design:

- Lighting protection and grounding of the railway systems (Railway system design)
- Lighting protection of the primary substation buildings (part of the Land works design)
- Lighting protection of the Management building (part of the Land works)

Furthermore, all electrical switchboards will be equipped with lightning arresters, chosen in accordance with classification of lightning protection levels ref. EN 62305-1 Protection against lightning. General principles.

9.1 Standards

The lightning protection system and installations will comply with the CEI, EN end IEC standards specified in the table below.

Table 9.1 Specific Codes and Standards for Lightning protection systems and grounding.

Description	Norm or Standard	
	CEI or UNI	**EN or IEC**
Protezione delle strutture contro i fulmini	CEI 81-10/1 to 4	EN62305
Lightning protection components		EN501164

9.2 Analysis of Risks during Lighting Discharges

A Failure Modes and Effects Analysis (F.M.E.A) and Fault Tree Analysis (F.T.A) will be carried out during Projetto Esecutivo phase in order to detect possible risks to both Bridge structures and its electrical and mechanical installations during lightning discharges, as well as to prove the robustness. Results of these analyses will be a part of the design necessary for the manufacturing of equipment and for the installation works.

9.3 Other Design Criteria

The frequency of lightings in the region is in average 1.5-2.5 year/km^2, however higher frequency must be expected around the bridge.

9.4 Towers

The steel construction of the tower forms a natural air termination and down conductor. The construction consists of a number of steel sections and cross beams. The joints of exterior plates

are welded by complete penetration welds and the joints of interior plates and stiffening bars are bolted. It is foreseen that the electrical resistance of the joints is sufficiently high to ensure equipotential bonding of the sections and the crossbeams.

The tower cross beams are constructed of steel and will be used as the earthing down conductor for electrical and mechanical installations located in the cross beams.

9.5 Tower Foundations

The reinforcement of tower foundations will be equipotentially bonded with the steel construction of the tower and grounded. The reinforcement bars are in a direct contact with the concrete, i.e. are not insulated from the concrete by an external insulation sheet such as epoxy resin.

As a minimum requirement rings will be constructed of horizontal steel reinforcement bars and wires interconnected by means of connection clamps. A ring will be constructed for approximately each 10 m of the foundations depth, starting from the bottom of a foundation. Each of the rings will be connected to the vertical reinforcement bars (down conductors). Each down conductor consists of at least two (2) reinforcement bars. The down conductors will be interconnected. The minimal number of down conductors is four (4).

The uppermost rings will be equipotentially bonded to the basis steel construction of the tower.

From the uppermost ring outlet connections will be provided to outlets casted in the concrete of foundation above the ground level. All outlets will be prepared for connection to equipotential bonding bars. The outlets will be earthing plates (punto fisso di terra) as Dehn type M. The bonding connection between the bridge deck and the earthing plates in the tower foundation will be constructed as flexible cable or earthing braid (treccia di ponticellamento) of stainless steel or copper, not less than 95mm².

The earth termination will be constructed as a mesh network by means of reinforcement bars jointed together in the bottom of foundations by binding, the mesh size max. 2x2 m. A number of reinforcement bars will be jointed together by clamping.

The down conductors will be connected the earth termination network. The earth termination network will be constructed as at least two rings of reinforcement bars clamped together in order to secure electrical connection of these reinforcement bars. The clamps will be factory manufactured clamps (morcetti) approved for use in connection with construction of foundation electrodes. The

construction will comply with recommendations in EN 62305-3 section 5.4.4, which recommends natural earth electrodes made of interconnected reinforcing steel in the foundation.

9.6 Anchor Blocks

The steel reinforcement in concrete substructure of the anchor blocks is used as the grounding system in the similar way as the structural reinforcement of towers.

9.7 Main Cables

The cables will be protected by air termination to avoid damage, by the lighting stroke, of the polyethylene polymer insulation sheet covering the steel core of the cables.

The hand ropes on the cable inspection walkway will be utilized as an air termination. The hand ropes will be equipotentially bonded with steel core of both cables every 30 m by means of a clamp (collar).

The main cables will be equipotentially bonded by means of the cable saddle with the steel construction of the top of the towers.

The anchorage of suspension cables will be equipotentially bonded to the steel reinforcement of the anchor blocks. The following anchorage elements will be connected to the steel reinforcement:

1 Splay saddle

2 Anchorage shoes

3 Anchorages for post-tensioning.

There will be two independent bonding connections between each of those anchorage elements and bonding rings in the reinforcement of anchor blocks.

9.8 Hangers

Equipotent bonding between the hangers and the main cables and between hangers and deck cross girders will be established where the mechanical junction do not have sufficient lightning current carrying capacity.

9.9 The Deck

The Bridge deck is constructed of steel and will be used as continuous earthing conductor for electrical and mechanical equipment located on the deck. To ensure continuity the expansion joints and bearings must be equipotentially bonded by means of flexible connections.

The buffers between the deck and the towers will be bonded by flexible connection to prevent electrical lightning currents through the buffers.

The deck will be equipotentially bonded with the outlets in the tower foundation.

The deck will be earthed at the connection with Sicilia side and at the connection with Calabria side. The earthing connections will be made to foundation earthing electrodes constructed as described in section 9.5. The resistance of these electrodes will be below 2 ohms. The calculated resistance is approximately 0.1 ohm, ref. Calculation report doc. No. CG1000-P1RDPIT-M4C3000000-01.

10 Earthing and Bonding Installations

10.1 General Requirements

Earthing and bonding will be established in order to reduce the touch voltages and conduct all insulation fault currents to earth.

The earthing and bonding will comply with the Low Voltage Directive 2006/95/EEC, IEC 60364, IEC 61892.

All the electrical installations will be TNS type earthing system in accordance with IEC 60364.

The earthing system will comprise main earth electrodes, main earth bus, earthing conductors and connectors.

10.2 Earth Electrodes

Foundations of towers and terminal piers will be made of reinforced concrete and can be assumed to establish a solid and effective earth electrode which applies to earthing and protection against lightning of the bridge installation.

The connection point to the foundation earth will be fixed earthing terminals of stainless steel located in the top of the foundation structure. These earthing terminals will be provided with Ø10mm screwed connection points for connection of the bridge girder earthing system to the earth electrode.

The connection between the bridge girder earthing system and the earthing terminals at the top of the foundations will be made by means of flexible conductors not less than 95mm² stainless steel or copper.

10.3 Earthing System at the Bridge Deck

The steel construction of the bridge deck will be used as earth reference.

The following main earthing bars will be installed at each electrical substation:

- Earthing bar for 6 kV system (PE - bar - 6 kV)
- Earthing bar for 0,4 kV system (PE - bar - 0.4 kV)
- Earthing bar for instrumentation and communication systems (IE - bar)

Each of these earting bars will be located close to the relevant equipment and used as main reference point for these installations.

The main earth bars on the bridge deck will be solidly earthed via connections to a minimum of two earth bolts for each earth bar, and screwed into base plates welded to the bridge deck structure.

The main earthing bars in towers will be established in similar way, but skrewed into base plates welded to the tower structure at the substation location area.

The main earthing bars in separate substation buildings at anchor blocks will be installed in respective electrical rooms and connected to the earthing system of anchor block structure. the connection conductor will be not less than 95 mm² copper. The anchor blocks will be equipped with earthing plates for connection of the earthing bars in the anchor block substation.

The earthing system at land based substations will be established in connection with construction of substation buildings in accordance to IEC 60364.

10.4 Earthing of technical installations

The earthing system will be TNS system in accordance to IEC 60364.

All transformers will be solidly earthed at neutral point of the 400 V windings.

All other electrical equipment and electrical consumers will be earthed via earth core in the supply cables.

10.5 Bonding

All metallic constructions will be bonded to earth connection points.

Bonding will be made locally in close proximity to the items which require bonding. Normally bonding connections will be made by secure connections to steel pads (earth bosses) which will be welded to the steel deck or structure.

10.6 Design Improvements

The lightning protection is designed based on solid steel structures of the towers and bridge girder, which will be a natural part of the lightning protection system (LPS) and will provide large cross section for discharging of the lightning current to earth. Interconnected reinforcing steel in concrete foundations in accordance with EN 62305 is preferably to be used as an earth electrode.

Steel constructions of Bridge when used as a conductive shielding layer will reduce the electromagnetic fields generated by lightning in the structure as the lightning currents are distributed through large metallic section of the tower, or deck structure. This LPS design makes protection easier, in particular for special structures containing extensive electrical and electronic installations.

Furthermore, the steel reinforcement of the structure will serve as an electromagnetic shield, which assists in protecting electrical and electronic equipment from interference caused by lightning electromagnetic fields according to IEC 62305-4.

11 Cable Ways

11.1 General Requirements

In general all electrical and communications cables will be installed on cable trays or ladders.

11.2 Design Requirements

All cable trays or ladders will comply as minimum with the requirements in the table below.

Table 11.1 Cable trays

Requirement to:	**Description**
Material	Stainless steel AISI 304L indoors and outdoors
	Glass reinforced plastic can be used where suitable
	Galvanized steel CEI 7,6 , minimum thickness of 18 micrometer Approval of the Committee is required.
Reserve in space	50 %
Minimum distance at passing data and control cables, telephone cables and other service cables	300 mm
Separation from other cables	Metallic separation between power cables and service cables
Expansion joints	Yes

11.3 Improvements

On suspended deck the 6kV cableway has been moved from outside face of each road girder, to a dedicated 6kV cableway inside each road girder. This will reduce the vortex shedding on the bridge deck, which would emerge from the protruding cableway on the underside surface of the road girder. Further it will improve the mechanical and environmental protection of the 6kV cable.

In order to reduce equipment weight on suspended bridge, all cableways are of fibre glass. Supports for cableways are also reduced in order to save weight. A special custom made cable ladder with exact measures to fit inside the girder sections will be provided.

12 Railway Traffic Management System

The railway traffic management system is not part of these Design Specifications.

However information will be exchanged between the bridge control centre and the rail authorities in order to ensure the "safe" operation of the bridge.

As a minimum the following information will be exchanged:

To the rail authorities - RFI:

- minimum time for next train to enter the bridge
- maximum weight of the next train to enter the bridge
- emergency information.

To the bridge control centre:

- Weight of the next train to enter the bridge
- Estimated time for arrival of the next train
- information about carried goods.

Information will be exchanged on a serial protocol, specified by RFI.

The following interfaces to this system will be clarified:

- Information to RFI in case of emergency situation on the bridge.

- Coordination of information exchange from RFI to the bridge control room.

12.1.1 Monitoring of Railway Traffic

The total real time weight will be added the weight of the railway trains informed by RFI and the system will inform the SCADA Operator on:

- The total weight from vehicles
- Total weight of the train
- Total weight of the train and vehicles versus allowed weight during the specific weather conditions.

In case the total weight is higher than the permitted the Operator will be alarmed and will analyse the situation and:

- Request RFI to stop the train
- Stop the traffic and allow the train to pass the Bridge.

12.1.2 Monitoring of Trains

The system will be provided with monitoring of trains approaching and exiting the Bridge, which is in addition to the accurate measurement of train weights by the RWiM system discussed in section 6.8.

The recognition of trains will be provided by means of video detection sensor. The video sensor will detect the train and read the train's recognition number. There will be two video detectors installed close to the railway:

- One detector at the approach to the Bridge
- One detector at the exit from the Bridge.

The detection of the train will be result in the following actions:

- Information on the train's approach will be transmitted to the SCADA
- Data recorded by the RWiM for the detected train will be identified

- Video picture of the train will be displayed in the Control Room on the Traffic Display Screen, as long as the train is within the video image.
- Information on the train's exit from the Bridge will be transmitted to the SCADA.

The sensor will be based on a CCD video camera with integrated control and communication hardware prepared for data transmission to the Central TSM computer via fibre optical data network.

The sensor will be equipped with failure detection.

The sensors will be duplicated and arranged in a totally redundant system.

13 Management and Control System

13.1 General

The system for operation of the bridge will be designed to support real-time monitoring and management of the road and railway traffic and provide sufficient means for management of bridge maintenance and preparation of analysis and detection of risks in case of extreme weather or/and traffic conditions.

The bridge management and control system will be interconnected with installations for all approaching parts of the traffic system.

This data input is not limited to daily operation events only, but will focus also on short term and long term prediction of traffic volumes, maintenance needs and optimization of interventions in case of traffic restrictions due to weather conditions, special transports, traffic accidents and safety threats.

The system will ensure the functions:

- Monitoring functions: Physical environment, the works, the traffic, the events, the maintenance, and the apparatus and subsystems.
- Supervision functions: security.
- Management functions: Traffic, including simulations and forecasts; sensors, equipment and subsystems; events; emergencies

- Coordination function
- Safety function: Risk management, infrastructure, users, systems
- Function of information of the state to Concessionaire, police, customers and others.

Language for planning of the system is UML (www.UML.org).

13.2 Scope of Works

The total Management, Control and Monitoring system will cover functions specified briefly in section 13.1 and consist of the following individual systems interconnected together:

- Management and Control System (MACS), ref section 13.5
- Supervisory Control and Data Acquisition (SCADA) system, ref. section 13.4
- Management system for maintenance planning, ref. section 13.7
- Simulation system for structure loads and weather simulation, ref section 13.6
- Road Traffic Management system (RTMS) for monitoring and management of road traffic, monitoring of railway traffic and traffic simulations, ref. section 6 and section 12
- Structural Health Monitoring System (SHMS), ref. section 13.10
- Control and Monitoring System (CMS) for control and monitoring of technical systems (M&E), ref section 13.11.
- Power Management System (PMS) (13.13)
- Safety System (SSS) for fire detection
- Security system (separate report)

The monitoring and management work stations and large screens for display of pictures and visualisation of alarms and operation data will be located in common Control Room (Centro Direzionale) in Bridge Management building on Calabria side of the bridge. Location of the Bridge Management building will be defined during the “Projetto Executivo” phase.

The SCADA system will be provided with communication access to the Railway Management Centre (RFI) and external authorities (police, local road authority, etc.).

13.3 System Configuration

The Management and Control system will be designed as an integrated system of all expert systems listed in section 13.2, which assure safe operation of the Bridge in any operational situation and provide tools for management of maintenance of the Bridge, risk management, training and simulations, as well as reliable information exchange with administrators of interconnected highways and railways and external authorities.

All management, control and monitoring functions will be transmitted to control room located nearby the bridge.

The system will be configured as shown on drawing CG1000-P-DX-D-P-CG-00-GC-00-00-00-06.

13.4 Supervisory Control and Data Acquisition (SCADA) System

The leading principles for the SCADA will be:

- The SCADA will be a distributed control system, which through a number of expert systems collect data to the SCADA system and transmit commands from the SCADA system to the field systems' local control units (Intelligent Distributed Units-IDUs) via the above expert systems. The expert systems are listed in section 13.2.
- The SCADA system will provide Man-Machine-Interface for display of events reported by all expert systems and is de facto the main system for generation of commands, as well as is operating as the main interface between the Bridge Operator in the Bridge Control Room and the expert system sensors and remote control and monitoring equipment on the Bridge;
- The SCADA will be very reliable system working with redundant hardware, redundant communication ways as well as fail tolerant software.
- The SCADA will be provided with facilities for self-test and automatic detection of any operation failures.
- The SCADA will be equipped with operation and historical data storage facilities.

- The SCADA will be equipped with intelligent alarm log divided in prioritised alarm levels, alarm filtering, alarm acknowledgement facilities with access passwords.

The key functions for the SCADA system will be:

- to provide total overview of the overall operation situation on the Bridge to the operation staff in the Bridge Control Room.
- to alarm the operation staff in the Bridge Control Room in case of any failure in the technical equipment of the Bridge.
- to alarm the operation staff in the Bridge Control Room in case of any safety related situation in the neighbourhood of the Bridge or on the Bridge.
- to provide facilities for remote operation of all electrically controlled equipment of the Bridge.
- to handle event communication to the Management and Administration System.
- to provide reporting facilities.
- to communicate with external computer systems for RFI, road operators and external authorities.

13.4.1 General Functions and Connected Expert Systems

All technological systems operations will be monitored. The interfaces to these systems field equipment will be included in these technical expert systems and the SCADA will carry out its functions through the central computers of these systems.

The system functions are:

1. Monitoring of:
    - Physical environment and its actions (SHMS)
    - The Works during construction (SHMS)
    - The Works during operation (CMS, SHMS)
    - Traffic (RTMS)

- Events (SCADA)
- Systems and sub-systems (SCADA)
- Safety system (fire detection)

2. Surveillance:
   - Traffic on the Bridge (RTMS)
   - Security system (separate report)
3. Management of:
   - Traffic on the Bridge (RTMS)
   - Safety (separate report)
   - Data and telecommunications
4. Information to external parties:
   - RFI (SCADA & telecommunication system)
   - Operators of interconnected motorways (telecommunication system)
   - Police (telecommunication system)
   - Intervention/maintenance teams (telecommunication system)
   - Traffic.

13.4.2 Specific Monitoring Functions

In general the following functions will be provided by the technical expert systems in connection with monitoring of the systems:

- Operation status;
- Technical alarms and warnings;
- Operation time for each sub-system;
- Data communication failure;

- Safety related alarms;
- Measured values for technical measurements.

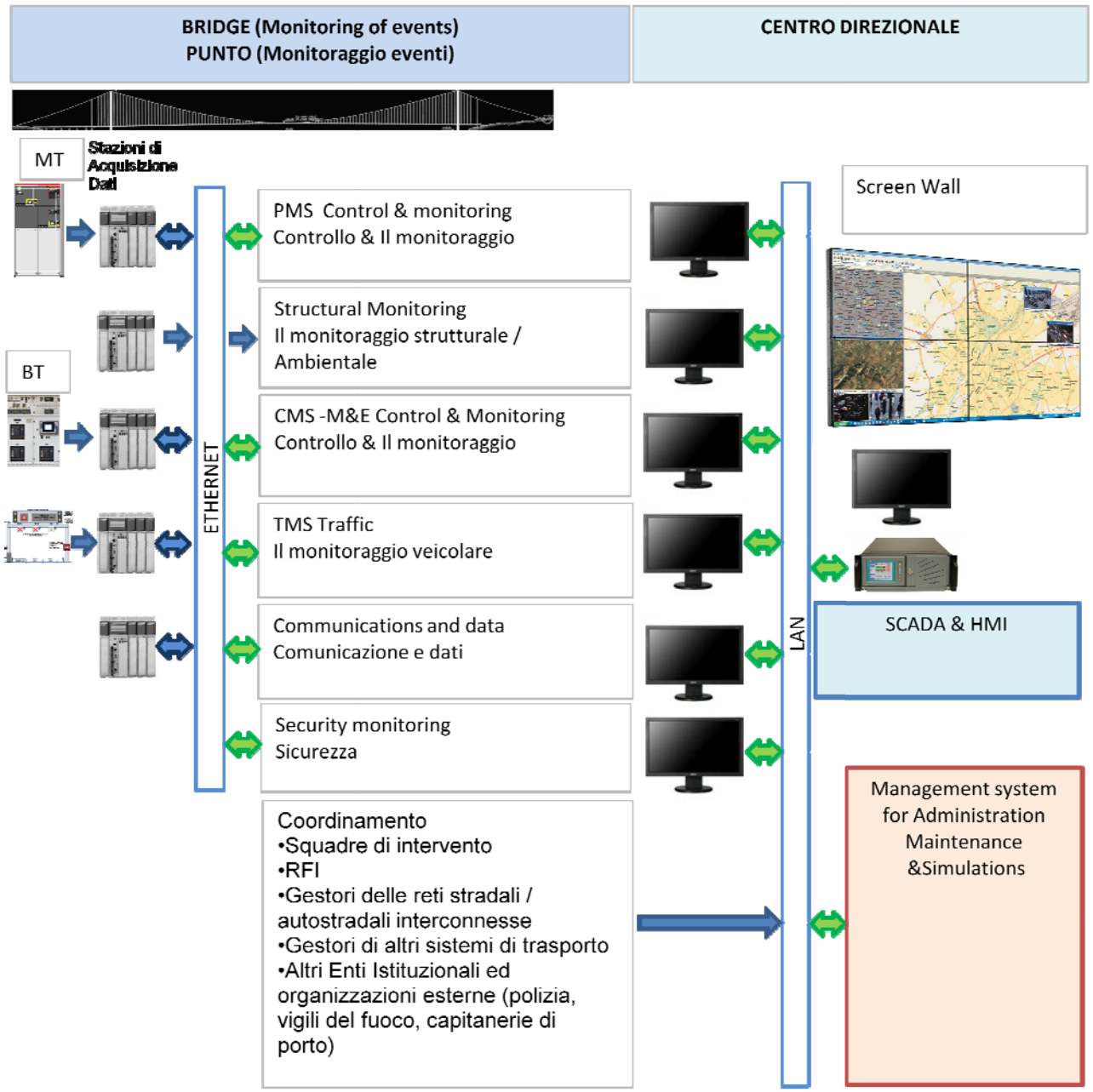


Fig. 12.4 Configuration of the Control and Monitoring System

13.4.3 SCADA Man-Machine Interface (MMI)

The SCADA Man-Machine Interface (MMI) will be designed to view both the total Bridge and its details at the same time on a large display screen arranged by means of a multi-screen system or similar technology.

Furthermore, two Operator Consoles will be used for detailed monitoring of SCADA functions by the SCADA system operators.

The display screen will be freely addressable from each SCADA Operator Consoles. Furthermore, the display screen will be addressable from operator consoles for the technical expert systems.

The display screen will be divided into three sections:

- 1st section dedicated to the Traffic Management System for display of traffic situation and traffic management events;
- 2nd section dedicated to the SCADA and the technical expert systems including layout of systems, status indications for each system (operation status, alarms, failures etc.)
- 3rd section dedicated to the surveillance in connection with intrusion, anti sabotage and anti terrorism functions

A GIS interface will be provided, through which the operators will be able to visualize on a geo-referenced map the real-time position of the technical equipment, when displayed on the display screens.

13.4.4 Data Handling

All real time data will be stored in operation database within the SCADA Central Computer. The operation database will store all data for one year period. The data which are necessary for reports and statistics will be transmitted to a historic database. The historic database will be designed for 10 years data storage period. After 10 years the data will be compressed by a logarithmic algorithm.

Collected data will constitute a historical archive, according to modalities to be defined during the design phase and approved by the Client.

13.5 Management and Control System (MACS)

Please see document Management and Control System (MACS) doc no. CG-1000-P-2S-D-P-IT-M4-C3-00-00-00-01.

13.6 Computing, Simulation & Prediction (CSP)

Please see document Management, Administration & Computer Simulation doc no. CG-1000-P-1W-D-P-IT-M4-C3-00-00-00-01.

13.7 Worksite Management System (WSMS)

Please see document Work Site Management System doc no. CG-1000-P-2S-D-P-IT-M4-C3-00-00-00-03.

13.8 Bridge Management System (BMS)

Please see document Bridge Management System doc no. CG-1000-P-2S-D-P-IT-M4-C3-00-00-00-04.

13.9 Information & Coordination Management System (ICMS)

Please see document 13.8 Information & Coordination Management System doc no. CG-1000-P-2S-D-P-IT-M4-C3-00-00-00-05.

13.10 Electronic Document Management System (EDMS)

Please see document 13.9 Electronic Document Management System doc no. CG-1000-P-WV-D-P-IT-M4-C3-00 -00-00-01.

13.11 Structural Health Monitoring System (SHMS)

Please see document Structural Health Monitoring System doc no. CG-1000-P-2S-D-P-IT-M3-SM-00-00-00-01.

13.12 Control and Monitoring System (CMS)

The CMS will be designed for a lifetime at least 15 years.

For information's about system layout please refer to drawing CG1000 P1LDPITM3 GC00000001, Control and Monitoring System for M&E - System layout - Principle Diagram and CG1000 P2LDPITM3 GC00000001, Control and Monitoring System for M&E - Control panel.

The system will be able to create, filter and sort different kinds of list as alarm lists, failure lists etc.

13.12.1 General requirements

The Control and Monitoring system will monitor and control technical systems on the bridge. The systems are:

- Weather station
- Roadway Lighting System
- Technical Areas Lighting
- Aircraft warning Light System
- Navigation warning light
- Drainage System
- Dehumidification
- Lifts
- Fire detection
- Fire fighting
- Utility water

Data collection will be made from remote I/O located in the various panels. Local logical controllers will be placed in the IDU - Intelligent Distributed Unit located in the technical room in each transformer station, to which the remote I/Os are connected.

The IDU's will be connected in a ring net configuration. Communication will be on the Bridge Area Network. Connection to the remote I/O used to collect and distribute data from the connected systems will be based on modbus communication network based on optical connections. This network will be made as a part of the CMS system.

CMS will manage coordinated operation between the connected systems as light control and alternating between the active pump station.

Based on inputs either directly or by calculation alarms and failures will be generates and flashed on the screen.

13.12.2 Human Machine Interface

The general layout and design of screens will follow the requirement for the SCADA system.

On the screens reference to drawing will be integrated.

On failure and alarms proposal for "what to do" will pop up on the screen.

13.12.3 Control requirement

13.12.3.1 General

Based on the operational feed back operation hours will be calculated for the connected systems.

Alternating operation where more than one of the same kind is installed will be performed by the CMS.

In order to reduce maintenance hours feed back from the connected system will be collected and calculated based on the actual inputs.

The actual signals for each of the systems can be seen in the I/O list drawing CG1000-P-2L-D-P-IT-M4-CG-00-00-00-01, I/O list - CMS and PMS.

13.12.3.2 Weather station

Information's as:

- Temperature

- Humidity
- Rainfall
- Wind speed
- Wind direction
- Back ground light intensity
- Fog / Visibility

will be monitored and made available for those systems requiring any or some of the information, ref. section 6.

13.12.3.3 Roadway Lighting System

Road light will be controlled on and of based on background light intensity. The actual light intensity will be dimmable controlled. The current consumption will be measured in all light circuits. The light fixture will be controlled individually by pole and giving actual status feedback.

13.12.3.4 Towers and suspension cables (and Superstructure) Lighting System

The lighting system are controlled by an integrated controller. CMS will monitor the controller and make it possible remote to override commands to switch on and off the light.

13.12.3.5 Technical Areas Lighting (Internal lighting)

Override for on and off control will be possible. The current consumption will be measured in all light circuits.

13.12.3.6 Aircraft warning Light System

Operational status for all aircraft warning light will be collected.

13.12.3.7 Navigation warning light

Operational status for all navigation warning light will be collected.

13.12.3.8 Dehumidification

De humidification units will be self-controlled units. CMS will monitor operational status. It will be possible to remote switch on and off each plant.

13.12.3.9 Lifts

Lifts will be monitored with reference to actual status, failure and alarm.

13.12.3.10 Fire detection

Monitoring of status for the fire detection will be made.

13.12.3.11 Fire fighting

Control and Monitoring of fire pump station Sicily and fire pump station Calabria:

Filling of municipality Water in the water tanks, by level controls and valve in the water supply pipe.

For information the pressure are monitored on specific locations in the firewater system. Automatic alternating operation, between Sicily and Calabria pump station are controlled by CMS.

Flow meters are installed in the water pipes these meters are used to detect leakage and CMS will in case leakage close sections valves and put both pump stations in duty operation.

Opening and closing of frost protection drain valves will be possible from CMS.

From CMS remote operation of the fire pumps will be possible.

13.12.3.12 Utility water

Control and Monitoring of utility water pumps at pump station Sicily and fire pump station Calabria: From CMS remote operation of the fire pumps will be possible.

13.12.3.13 Frost protection

The fire fighting and utility water systems will be equipped with frost protection. The main lines will be protected by opening a drain valve in the far end of the standpipe seen from the pump. Each fire hydrant and each wash valve will be equipped with self controlling electrical heat tracing.

13.13 Power Management System (PMS)

13.13.1 General requirements

The Power Management System will monitor and control technical power distribution systems for the bridge M&E installations. The systems are:

- MV switchboards
- Transformers
- LV main distribution switchboards
- UPS
- Emergency power plants

Data collection will be made from remote I/O located in the various panels. Local logical controllers will be placed in the IDU - Intelligent Distributed Unit located in the technical room in the transformer station.

The IDU's will be connected in a ring net configuration. Communication will be on the Bridge Area Network. Connection to the remote I/O used to collect and distribute data from the connected systems will be based on modbus communication network based on optical connections. This network will be made as a part of the PMS system.

PMS will manage coordinated operation between the connected systems as coupling of different switches, opening and closing of bus couplers.

13.13.2 Human Machine Interface

The general layout and design of screens will follow the requirement for the SCADA system.

On the screens reference to drawing will be integrated.

On failure and alarms proposal for "what to do" will pop up on the screen.

13.13.3 Control requirement

13.13.3.1 General

Alternating operation where more then one of the same kind is installed will be performed by the PMS.

In order to reduce maintenance hours feed back from the connected system will be collected and calculated based on the actual inputs.

The actual signals for each of the systems can be seen in the I/O list drawing CG1000 P2LDP ITM4 CG00000001, I/O list - CMS and PMS.

In case of a electrical failure causing a disconnection of an electrical system not requiring redundant power supply this system will remain disconnected until it is connected by an operator invent either locally or remote from PMS.

13.13.3.2 MV switchboards

MV distribution switchboards will be monitored and controlled from PMS. Any coupling (closing or opening) by breakers will be manually controllable either locally or remote from PMS. Monitoring and control include 20 kV and 6 kV switchboards.

Switching by any bus couplers or incoming breakers will be blocked in cases where PMS detects voltage on the bus bar. This voltage detection will be coordinated between transformer stations making it possible to close the various switches but only in case if the next bus bar is voltage free.

13.13.3.3 Transformers

PMS will monitor the operation conditions for each transformer.

13.13.3.4 LV main distribution switchboards

Opening and closing of incoming breakers will be possible. Monitoring of operational status for remaining breakers (MCB and MCCB) will be possible as well. Operation of the bus coupler for non essential power supply will be possible as a manual remote interaction.

13.13.3.5 UPS

Monitoring of operational details for each of the installed UPS will be possible.

13.13.3.6 Emergency power plants

Monitoring of operational status as:

- Voltage
- Current
- Frequency
- Energy
- Temperature
- Fuel level

No remote operation of the engine/generator is foreseen.

14 Communication Systems

The purpose of the Communication Systems Works is to establish radio, data and telephone communication for the management, operation, maintenance and emergency services of the Bridge, The Communication System Works will be established based on a standardized Infrastructure and will use the standardized Ethernet TCP/IP protocol for communication. The BAN will have interfaces to the WAN and the Control Centre. Communication to Toll stations and other relevant buildings within the area bounded by the Toll Station and the Control Centre will be established through the WAN.

The Communications System Works covers establishing of reliable communications on and inside the Bridge, towers and the anchor blocks and will support the following systems:

- Data Communication Network
- Radio Communication Network
- Telephone System

- Emergency telephones
- CCTV surveillance systems
- VMS traffic control systems
- Anti intrusion protection systems
- Anti sabotage/terrorism protection systems
- Bridge control and monitoring systems / SCADA

Other systems and network might also benefit from the Communication System Works as the design is based on a standardized infrastructure environment and a standardized Ethernet TCP/IP environment.

14.1 Outside the scope of this design components.

The following systems are not part of these works and has not been evaluated during the design:

- Communications facilities during construction of the Bridge
- Public mobile telephone communication systems
- Any other radio communication system
- Non standardizes Ethernet based systems
- WAN infrastructure on and inside the bridge

14.2 General

The Communications Systems Works are designed using state of the art digital technology in order to ensure flexibility and maximum lifetime of the equipment. Equipment and products used will have a design that ensures they are feasible for the environments that they are installed in.

Other key criteria for the design of the systems are:

- Redundancy and minimal convergence time
- Limited congestion

- Appropriate modularity
- Sufficient and scalable bandwidth
- High availability
- High manageability
- Future development potential
- Industrial Ethernet level
- Low operating and maintenance costs
- The use of international standards where applicable
- Products with high durability and feasible for the environment

Robustness, stability, scalability and ease of management and maintenance are key considerations. As the operational hours are 24 x 365 days a year, the hardware, tools and backup management will be correctly planned and provided (for later operation and maintenance).

14.3 Communications and Transmission Systems

The communication and transmission system will provide data communication facilities and functionality for data transactions related to the bridge environment and surrounding areas and will support the following system on and inside the bridge, towers and anchor blocks.

- Radio communication (RCOM)
- Telephones (TEL)
- Emergency telephones (ETEL) (S.O.S. Colonnine stations)
- Control and Monitoring system for technical plants related to the bridge
- Control Room facilities for the Bridge Area Network (BAN)
- Monitoring systems for road traffic and anti-sabotage protection
- Measurement of the structural health of the bridge

- Control and management systems for telecoms and IT-network

14.3.1 Network Concepts

The network infrastructure is grouped into the following categories:

- Bridge Area Network (BAN) LAN
- Bridge Area Network (BAN) Backbone
- Data Centre
- Wide Area Network (WAN) - running along the highway on each side of the Bridge.
- All communication between the BAN and the WAN is done via the Control Centre LAN (Local Area Network).

The figures below shows the principle of the complete BAN structure and the principle build-up of the Control Centre:

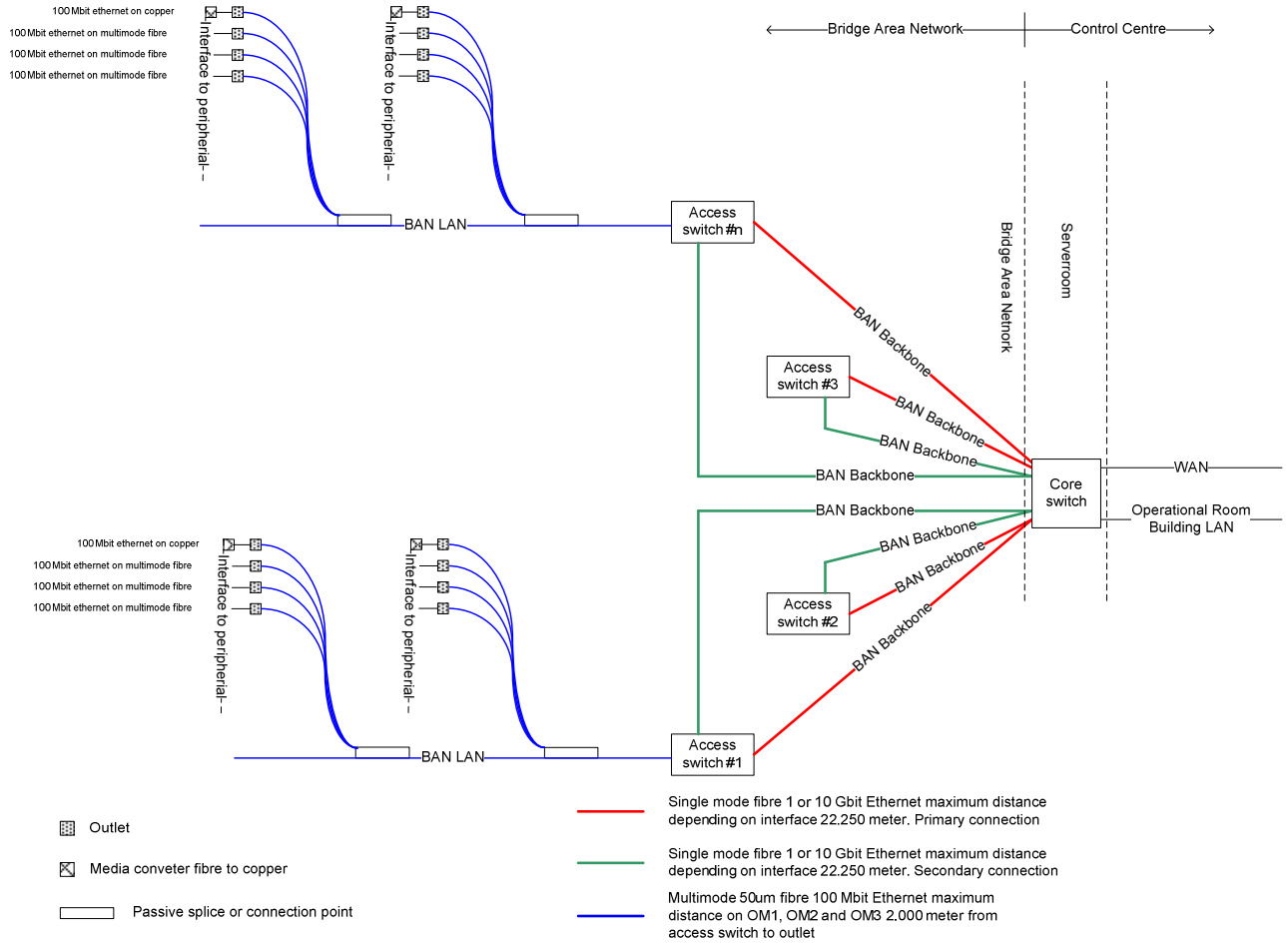


Figure 14.1 Principle layout of the Bridge Area Network (BAN)

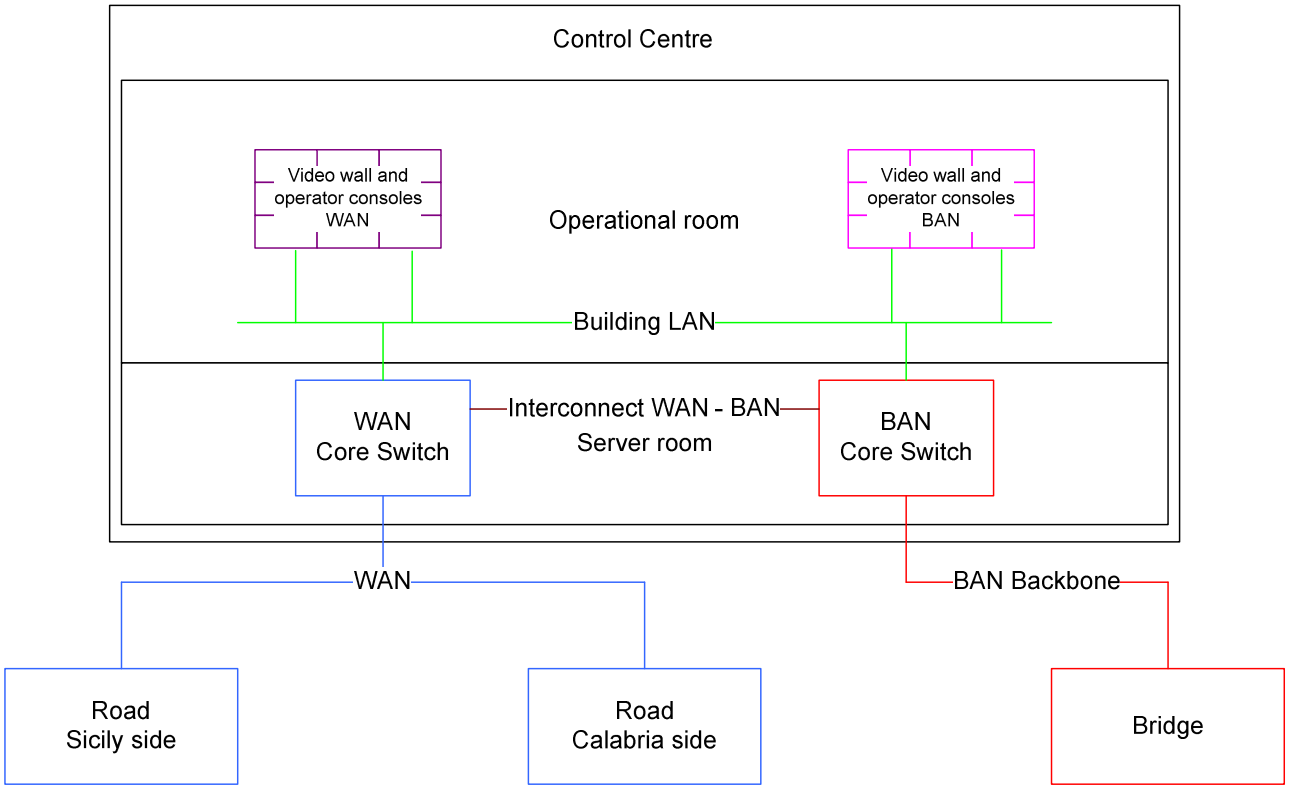


Figure 14.2 Principle build-up of the Control Centre

The complete BAN network is build up of the following parts:

IT Infrastructure - Passive:

- Backbone Fibre Optical Cabling System
- LAN Fibre Optical Cabling System
- Data Centre Cabling System

IT Infrastructure - Active:

- Transmission Systems
- Network Management System

- Interfacing to the existing communication systems

IT INFRASTRUCTURE - PASSIVE

BAN BACKBONE:

The Bridge Area Network backbone will be installed as a redundant Single Mode (OS2) fibre optical cabling system and will support a transferrate of minimum of 1 Gbit/s with the option of 10 Gbit/s.

The backbone will connect the access equipment in the nodes along the bridge and in the Utility Stations to the Core equipment in the Data Centre.

The redundant backbone cables will be installed in cable trays running inside structure and through the crossways underneath the roads and railway, one on each side of the bridge. All nodes are connected to both backbone cables.

Each of the redundant backbone cables will be installed with possible splice points for every 500 m. to allow for connection of future nodes.

Please refer to CG1001-P1RDPIT-S9SC00000002A Principle Drawing - Passive Backbone Infrastructure.

BAN LAN DISTRIBUTION:

The LAN part of the BAN will be installed as a Multi Mode (OM3) OF-2000 fibre optical cabling system following EN50173-3:2007. This allows for a total LAN cable length of 2000 m.

The LAN will allow the various systems running on the bridge to connect to their respective servers in the Data Centre or other relevant systems, via the nodes and the BAN backbone.

The LAN cables will be installed in cable trays or ducts running inside the structure and through the crossways underneath the roads and railway.

LAN splice points will be installed each 250 m. to allow for connections of peripherals along the bridge and towers. Each LAN splice point will be limited to a specific no. of connections.

At the connection points LANs (peripherals) the interface is a switched 10/100 Mbit/s SC fibre connector placed in a weather secured outlet box. If the connecting system require a different media than fibre to connect to the LAN then this will be done via media convertors located in the same outlet box.

Please refer to CG1002-P1RDPIT-S9SC00000003A Principle Drawing - Passive Horizontal Infrastructure.

TOWER AND BRIDGE AREA NETWORK

The Tower and girder (bridge) deck backbone will be designed to support and transfer a minimum of 1 (one) Gbit/s with the option of 10 Gbit/s. An alternative is to create "trunked" channels by using more fibre optic cables via switch technologies.

Network equipment located on the bridge will be housed in enclosures on both sides of the highway. The enclosures will be environmentally controlled and the choice of equipment will reflect this. Network equipment will also be placed in the transformer buildings at the foot of each tower.

Network equipment located in the data centre in the Bridge Control Room building will be subject to an interior controlled environment and the choice of equipment will reflect this.

The figure below shows an example of the backbone communication and transmission equipment design:

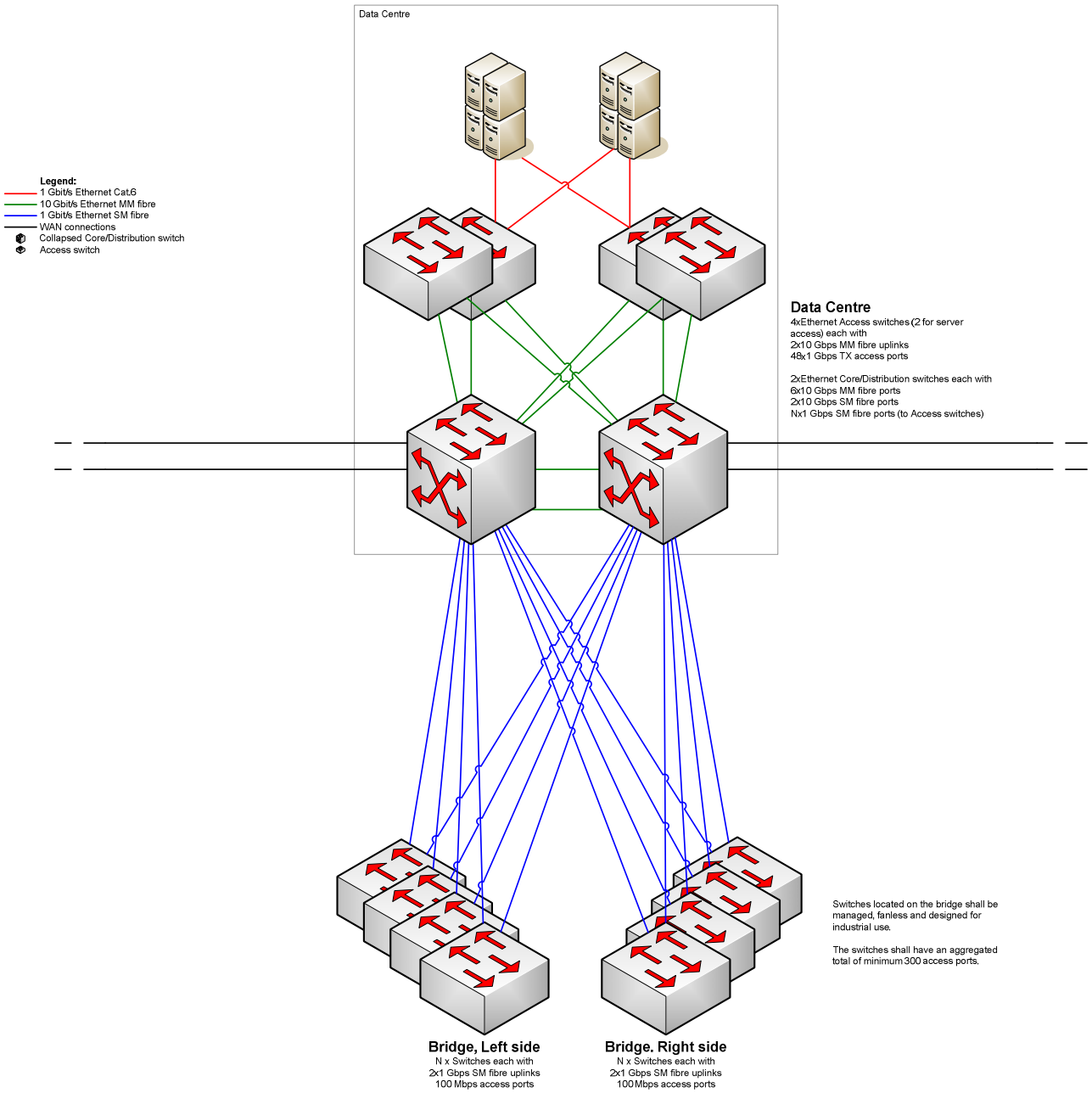


Figure 14.3 Example of the backbone communication and transmission equipment design

WIDE AREA NETWORK (WAN)

The Wide Area Network will be installed in two separate cableways. The backbone should be designed to support a minimum of 1 (one) Gbit/s with the option of 10 Gbit/s. The WAN will

connect to the BAN Core switches in the Data Centre. The WAN is not part of the scope for this document.

BRIDGE CONTROL ROOM/DATA CENTRE

The design and the corresponding infrastructure of the data centre / control room will be carried out in according to the below specifications:

- Minimum Tier II according to TIA/EIA – 942 please refer to design component no. 19 for a full description of the requirements and design specifications
- Cabling will be both copper and fibre
- Equipment and cabling will be designed with redundancy
- EN50173 and EN50174, latest version with all amendments, addenda and corrigenda

14.3.2 Technical Specifications

14.3.2.1 IT Infrastructure Passive

CABLING REQUIREMENTS, FIBRE

The fibre optic network cabling will comply with the following standards:

- The BAN backbone fibre will comply with single mode OS2 OF-10000 in according to EN50173-1:2007 Information technology – Generic cabling system - Part 1: General requirements, latest version with all amendments, addenda and corrigenda.
- The BAN/LAN fibre will comply with multimode OM3 OF-2000 in according to EN50173-1:2007, Information technology – Generic cabling system - Part 1: General requirements, latest version with all amendments, addenda and corrigenda.
- All design in and outside the bridge will follow the design specification of EN50173-3:2007, Information technology – Generic cabling system - Part 3: Industrial premises, latest version with all amendments, addenda and corrigenda.

- The design will conform to the design rule outlined in EN50173-3:2007 clause 1.2 as outlined:
  - The structure and configuration will conform to the requirements of clause 4 in according to EN50173-3:2007
  - The interface to the cabling at the telecommunications outlet will conform to the requirements of clause 8 in according to EN50173-3:2007 with respect to mating interfaces and performance
  - Connecting hardware at other places in the cabling will conform to the requirements of clause 8 in according to EN50173-3:2007.
  - The performance of channel will conform to applicable transmission performance requirements of clause 5 in according to EN50173-3:2007. This will be achieved by using the reference implementations of clause 6 and compatible cabling components conforming to the requirements of clause 7, 8 and 9, based upon a statistical approach of performance modelling in according to EN50173-3:2007.

- All installation in and outside the bridge will follow the EN50174-3:2003, Information technology – Cabling installation - Part 3: Installation planning and practices outside buildings, latest version with all amendments, addenda and corrigenda.
- All installation in the server room and the utility stations will follow the EN50174-2:2009, Information technology – Cabling installation - Part 2: Installation planning and practices inside buildings, latest version with all amendments, addenda and corrigenda.

Fibre optic cables will be routed to the following locations:

- Bridge deck (girder)
- In the Towers
- In the Bridge Control Centre
- In the anchor blocks.
- In the utility stations positioned at each side next to the bridge towers.

CABLING REQUIREMENTS, RACK OR CABINETS FOR THE SERVER ROOM

All rack or cabinets used in the server room will comply with the following standards and requirements

- All rack or cabinets used in the server room will be standardized 19" cabinets or racks with the following dimension 800 x 1000 x 2000mm (W x D x H).
- All rack or cabinets used in the server room will have 2 sets of 19" mounting frames one set in the front and one set in the rear of the rack or cabinet, so that equipment can be mounted at four positions. The 19" mounting frames can be adjusted freely inside the rack frame. All mounting frames will be fastened at three position to the rack frame.
- All rack or cabinets used in the server room will have perforated doors in the front and rear of the cabinet or rack to enable airflow through the rack or cabinet for cooling purposes.
- The fibre cabinets for active equipment will be design with a minimum of 20% additional capacity in addition to the initial design basis.
- The fibre cabinets for active equipment will be equipped with cable management so that bend radii of patch cords can be maintained in according to the specification of the manufacture.
- The server room will have a cooling and climate control to ensure that the temperature and humidity are kept within the following limits:
  - Temperature will be within 18 – 24 degree Celsius.
  - Humidity will be within 30 – 55% relative humidity

The mechanical and power distribution of the server room will have a Tier II design according to the recommendations and specifications of TIA/EIA - 942.

CABLING REQUIREMENTS, FIBRE CABLE

All fibre cables will comply with the following standards and requirements

- All fibre cables will have a suitable construction for direct burial or installation in underground ducts

- All fibre cable will have a multi loose tube construction with multiple fibre stands in each tube
- All fibre cables will have a robust construction suitable for the environment where they are installed. The construction will also support repeatedly contraction which will occur at the expansion joints.
- All fibre cables will have a rodent resistance construction
- All fibre cables will be totally non metallic construction
- All products will have a fire retardant design in according to the requirements of IEC60332-1 and 3

CABLING REQUIREMENTS, FIBRE CABINETS FOR ACTIVE EQUIPMENT ON THE BRIDGE AND IN THE UTILITY STATIONS

All fibre cabinets for equipment on the bridge and in the utility stations will comply with the following standards and requirements

- The fibre cabinet for active equipment will have an internal dimension of 700 x 800 x 2000 mm (W x D x H)
- The fibre cabinets for active equipment will have 2 sets of 19” mounting frames one set in the front and one set in the rear of the cabinet for mounting of fibre patch panels and active equipment. All equipment will be mounted at four positions in the cabinet for better stability.
- The fibre cabinets for active equipment will be design with a minimum of 20% additional capacity in addition to the initial design basis.
- The fibre cabinets for active equipment will be equipped with climate control so that the environmental condition in the cabinet can be maintained in according to the specification of the active equipment and the matting interfaces of the fibre connectors. The climate control will control the environment both in connection to temperature and humidity.
- The fibre cabinets for active equipment will be equipped with cable management so that bend radii of patch cords can be maintained in according to the specification of the manufacture.

CABLING REQUIREMENTS, FIBRE SPLICE ENCLOSURE AND BOXES

All splice enclosures and boxes will comply with the following standards and requirements

- Splice enclosure and boxes will have a ruggedized design which is able to withstand the environment they are installed in which is set to be similar to an industrial environment.
- Splice enclosure will have a design that has been tested in according to IEC 61300 and IEC 60068 and evaluate for the purpose that they are used for both in connection to temperature humidity, spill of fuel, oil, salt and similar substances that might be common for this type of environment. Either the design itself might secure the product or a substructure will protect the product against the environment.
- Splice enclosure and boxes will have a design to accommodate handling of the amount of fibre that is installed in the enclosure or box and the fibres that are routed unbroken through the enclosure.
- Two type of product will be used at different level of the design.
  - At backbone level an ordinary splice enclosure will be used
  - At horizontal LAN level an ordinary splice boxes will be used
- All products will have a fire retardant design in according to the requirements of IEC60332-1 and 3

CABLING REQUIREMENTS, FIBRE OUTLET, CONNECTORS AND PATCH PANELS

All fibre patch panels will comply with the following standards and requirements

- All fibre patch panels will mountable at 19” mounting frames.
- All fibre patch panels will have integrated cable management that will support the minimum cable bend radii of the patch cords in according to the manufactures specifications.
- All fibre patch panels will have integrated splice enclosure that will support the fusion splicing of pigtails to the supplying cable .

All fibre outlets will comply with the following standards and requirements

- All outlets that will be used will be of a robust design suitable for usage within industrial grade and exposed environments.
- All outlet will be mounted in a box which will have a high mechanical strength to withstand the environment that they are installed in. The boxes will have different design and sizes as more outlet might be positioned in the same box and fibre to copper converters also might be positioned at this location along with power supply for the peripheral equipment or the power converter.
- All outlet will have an IP protection class of 67.
- All outlet will have the possibility of mounting of a protection cover. The cover will be attached to the outlet with a wire so that it cannot be removed without tools from the site.
- All outlet will be equipped with a duplex SC connector that will have an additional structure so that the matting of connectors are maintaining the IP protection class of 67.

All outlet will have integrated splice capabilities so the mounting of connectors can be carried out by fusion splicing of pigtails prefabricated mounted connectors onto the supplying cable.

14.3.2.2 Communication and transmission equipment

The network will be designed as a multi-layer, fault tolerant TCP/IP network

The network will be deigned as a redundant, partially meshed modular network consisting of three layers:

1. Core layer
2. Distribution/Aggregation layers
3. Access/Server Access layers

The Core and Distribution layers may be collapsed into the same equipment.

Access switches will be redundantly connected to two different Distribution switches.

Access switches will not be redundant.

The network will be based on Ethernet.

Quality of Service, congestion management and multicast control will be implemented to prioritize network data traffic and to manage real-time voice and video data traffic.

Each Access switch will support multiple VLANs and will be connected simultaneously to two different Distribution/Aggregation switches.

All switches will be connected to the bridges uninterruptible power supply (UPS) system.

Time to recover and to use an alternative route will be less than two seconds from any port (from blocking/disabled to forwarding mode) in the network to any other port regardless of link recovery protocol (spanning-tree/rapid-spanning tree/mesh protocol).

The switches will:

- Be categorised as "newest technology" (must not be on end-of-life).
- Be designed and manufactured to withstand the local conditions in the Bridge without to be installed in air-conditioned rooms or shielded EMC environment.
- Support the LSS dial NIC redundant equipment, thus the fail-over links have a very limited convergence time (eventually supporting functionality as "port fast" or similar technology).
- Support dynamic VLAN distribution over the individual switches
- Support link aggregation
- Be configured with a VLAN based switched environment with Quality of Service functionality (in the case of data communication between VLANs, the routing will be based on the routing functionality in the Core/Distribution switches).
- Have a maximum response time from any port to any other port in the network (LAN and WAN) of 0.2 sec. The response time criteria will be met under maximum load conditions.
- Support an automatic configuration roll-out system for switches.
- Core/Distribution switches will be modular.

The switches will comply with:

- IEEE 802.3-2008 - Ethernet

- IEEE 802.2 - Logical Link Control
- IEEE 802.1D-2004 - MAC Bridges
- IEEE 802.1p - Class of Service Prioritization
- IEEE 802.1Q-2003 - VLAN Tagging/Multiple Spanning Tree Protocol (MSTP, formerly IEEE 802.1s)
- IEEE 802.1x - Port-based Network Access Control
- IEEE 802.3x - Full Duplex and Flow Control
- IEEE 802.3af (where necessary) - Power over Ethernet
- IEEE 802.3AX-2008 - Link Aggregation (formerly IEEE 802.3ad)
- SNMP version 2c and/or version 3
- Remote Network Monitoring (RMON I/II, RFC 2819, 2021)
- Switched Network Monitoring (SMON, RFC 2613)
- Secure HTML management (TLS/SSL)
- Secure Telnet management (SSH-2)
- RADIUS (RFC 2865, 2866) or DIAMETER (RFC 3588)
- DiffServ (RFC 2474, 2475, 2597, 3140, 3246, 3260, 4594)
- Protocol Independent Multicast - Sparse Mode (PIM-SM, RFC 4601)
- Internet Group Management Protocol (IGMP, RFC 3376)

Additionally the switches will have:

- Auto-sensing 10/100/1000 Mbps (IEEE 802.3i Type 10Base-T, 802.3u Type 100Base-TX and 802.3ab Type 1000Base-T) RJ45/8, Auto-MDIX and both full and half duplex transmission.
- Minimum of 1000 Mbit/s (1 Gbit/s, IEEE 802.3z) fibre optic connectors of type Small Form-factor Pluggable (SFP).

- Core and Server Access switches will include 10 Gbit/s (IEEE 802.3ae) fibre optic connectors of type Small Form-factor Pluggable+ (SFP+)
- The Core/Distribution/Aggregation switches will also support:
- Open Shortest Path First (OSPF RFC 2328, 5340)

As a rule of thumb, the maximum oversubscription rate for uplinks between layers will be:

1. Access to Distribution layer: 48:1
2. Server Access to Aggregation: 24:1
3. Aggregation/Distribution to Core layer: 4:1
4. Core to Core layer: 1:1

The BAN will have a minimum availability of 99.75% measured over one year.

14.3.2.3 Switch hardware requirements

All switches will have a minimum slot and interface port spare capacity of 20% for future expansion.

All hardware will be powered by 240V 50 Hz AC or Power over Ethernet (IEEE 802.3af).

CPU load on any network equipment will not exceed 75% for more than 5 minutes at any time and no more than 50% during normal operation.

All switches will be mountable in a 19-inch rack.

All switch chassis' will provide adequate ventilation to operate in the installation environment.

All switches will have a non-blocking backplane. For modular switches with full load of all switching modules - also between modules and in case of inter-module trucking.

The Core/Distribution switches will be equipped with redundant hot-swappable power supplies (international 50Hz 240V AC) to be connected to two different power distribution circuits.

The Core/Distribution switches will have redundancy/failover support that includes VRRP (RFC 5798) (or similar) on routing modules, hot-swappable supervisor engines, routing modules and line cards as well as replaceable fan-trays.

The Core switches will automatically shutdown in case of overheating.

For management purposes, all switches will have a console port with serial protocol interface for local management and diagnostics.

The hardware will be the “contemporary technical equivalent” of the specified hardware. “Contemporary technical equivalent” will be based on a comparison of technology at the time of publication of the specifications to the technology at the time of ordering the equipment.

All LAN equipment will be maintainable under warranty locally by the Employer.

All equipment will be rated for continuous operation under the ambient environmental temperature, humidity, and vibration conditions encountered at the installed location. If proposed devices are not rated for the ambient environment conditions or proposed to be located in harsh environments such as interior uncontrolled or exterior environments, all necessary housings or enclosures to ensure proper equipment operation and performance will be provided.

14.3.2.4 Switch software requirements

The network background traffic (network service traffic between switches, routing updates, and management traffic) must never exceed 10 % of the total bandwidth on any link.

All switches will have VLAN support (IEEE 802.1Q). A minimum of 4,096 VLANs will be supported.

It will be ensured, that management traffic is always flowing no matter how high the utilization of a network device or link is.

All switches will support IEEE 802.3AX Link Aggregation Control Protocol for bundling of physical interfaces into one logical channel.

All switches will support IP version 4 and 6.

All switches will support IGMP version 3.

Fragmentation of packets will be avoided wherever possible.

Switches located in the data centre will support 9 kbyte jumbo frames.

The time required to restart the network switches after a complete system failure will not exceed 10 minutes (e.g. after an extended power outage).

All active network devices will support SNMP version 2c or preferably version 3 and be able to send traps to at least two different trap receivers.

All network devices will support relevant standardized MIBs, i.e. MIBs specified in IETF RFC's.

All active network devices manageable through a Command Line Interface (CLI) will, as a minimum, support Secure Shell (SSHv2).

Active network devices that can be managed through a web interface will support SSL.

All active network devices will be able to dispatch log messages to a central syslog server in (near) real time.

All active network devices will be able to automatically retrieve time and date information from an NTP server.

All switches will support RMON or optionally SMON. Minimum RMON support for management purposes are alarms, events, history and statistics but full RMON1 and 2 support is preferred.

All switches will be able to mirror the traffic on one port onto another for monitoring and troubleshooting purposes.

All switches will have support for minimum two versions of the switch software image in flash or on disk.

All switches will support RADIUS or preferably DIAMETER.

Network devices of the same type will run the same software version.

All layer 3 switches will support the Open Shortest Path First (OSPF) routing protocol.

Switches operating on layer two will have intelligent IP multicast handling to reduce the number of different VLANs transporting the same multicast stream inside the same switch.

The Core switches will be able to withstand a Denial of Service (DoS) attack without significant performance degradation.

The Core and Distribution switches will include support for IPFIX (RFC 3917) or Netflow.

The Core switches will support full routing functionality for both IPv4 and IPv6.

On layer 3 switches Access Lists will be configurable for VLANs, Ports, Routers and MAC-addresses.

On layer 2 switches Access Lists will be configurable for VLANs, Ports and MAC-addresses.

The BAN will be segmented into multiple VLANs. Individual VLANs and subnets will be configured for different applications and users.

All VLAN routing will be completed in the Distribution/Aggregation switches.

The IEEE 802.1Q standard will be utilized for trunking encapsulation. VLAN ingress policing may be implemented to limit the rate of individual VLANs on trunk ports.

All VLAN aware network devices will use GVRP or a similar protocol for dynamic configuration and Distribution of VLAN membership information.

The BAN will be designed to minimize loops and as such VLANs will have spanning tree enabled using the Rapid Spanning Tree Protocol (RSTP) together with Multiple Spanning Tree Protocol (MSTP) or similar for layer 2 load balancing over redundant links.

MSTP will be used for VLAN load balancing and failover of VLANs between Access and Distribution switches.

Spanning tree will be enabled on all layer 2 interfaces to avoid loops in the network.

It is important, that VLANs in the Server Access layer is extendable across Server Access switches to enable free placement of servers belonging to the same VLAN.

Dynamic VLAN assignment for a specific user regardless of where the user is connected, as defined in IEEE 802.1x, will be provided through the use of AAA.

The Access switches will support IEEE 802.1x for port based security on end user ports. All end user ports will be assigned to VLANs dynamically based on the 802.1x authentication unless the port is manually configured for a specific VLAN.

Protocol Independent Multicast will be supported including PIM Sparse Mode.

14.3.2.5 Quality of Service (QoS)

DiffServ is the intended way of providing QoS to the end users and will be supported by all switches.

Access switches will be able to classify and remark the data traffic to the DSCP values determined in the QoS schedule for the BAN. DSCP markings will not be accepted at the ingress ports to the Access switches, with the only exception being where the IP Phone has a built-in switch where DSCP marking can be done.

All Access switch end user ports will support IEEE 802.1p. 802.1p will be used to ensure that IP telephones are put into the proper VLAN and gets the proper QoS treatment.

The network will be capable of supporting QoS queuing and transmission to ensure immediate delivery of higher priority and time sensitive voice, video and data packets in the event of link congestion.

Minimum QoS requirements end-to-end in the BAN will be as follows:

Table 14.1: Minimum QoS requirements end-to-end

Delay	Will not exceed a maximum of 50 ms measured one-way.[5]
Jitter	Will not exceed 10 ms
Packet Loss	Will not exceed 0.5%
BER	Bit error rate will be below 10^{-9}

QoS will be performed in hardware whenever possible.

Packets will be classified as close to the source as administratively possible, but applications or devices where the classification can be set by the end-user will not be trusted. Policing will be enforced as close to the source as well. DSCP markings will follow standards-based DSCP Per-Hop Behaviour (PHB) markings to ensure interoperability and future expansion. More information on recommended DSCP markings for a given traffic flow can be found in RFC 4594.

Queuing will be enabled on all switch/router network interfaces to ensure service guarantees.

[5] Packet size up to 1500 bytes

At least 25% of the available bandwidth on a link will be reserved for the Best Effort class.

Real-time traffic (strict priority queue) will not exceed 1/3 of the available link bandwidth.

To mitigate DoS/worm attacks, policing will be performed as close to the source as possible. Whenever supported, markdown will be done according to standards-based rules (refer to RFC 2597).

A Scavenger class will exist on all QoS enabled interfaces in the network, and abnormal traffic flows will be marked down to the Scavenger queue to ensure overall network performance in case of a worm attack.

If the network supports DSCP throughout, the Scavenger queue must not exceed 1% of the link bandwidth. If layer 2 Class of Service (CoS) values are used somewhere in the network, then the Scavenger and the Bulk queues will share the same CoS marking and the combined queue will then be set no higher than 5% of the link bandwidth.

It is important, that if a platform supports more queues than another in the network, then the queues will get mapped correctly into each other. An example of this is shown in the figure below:

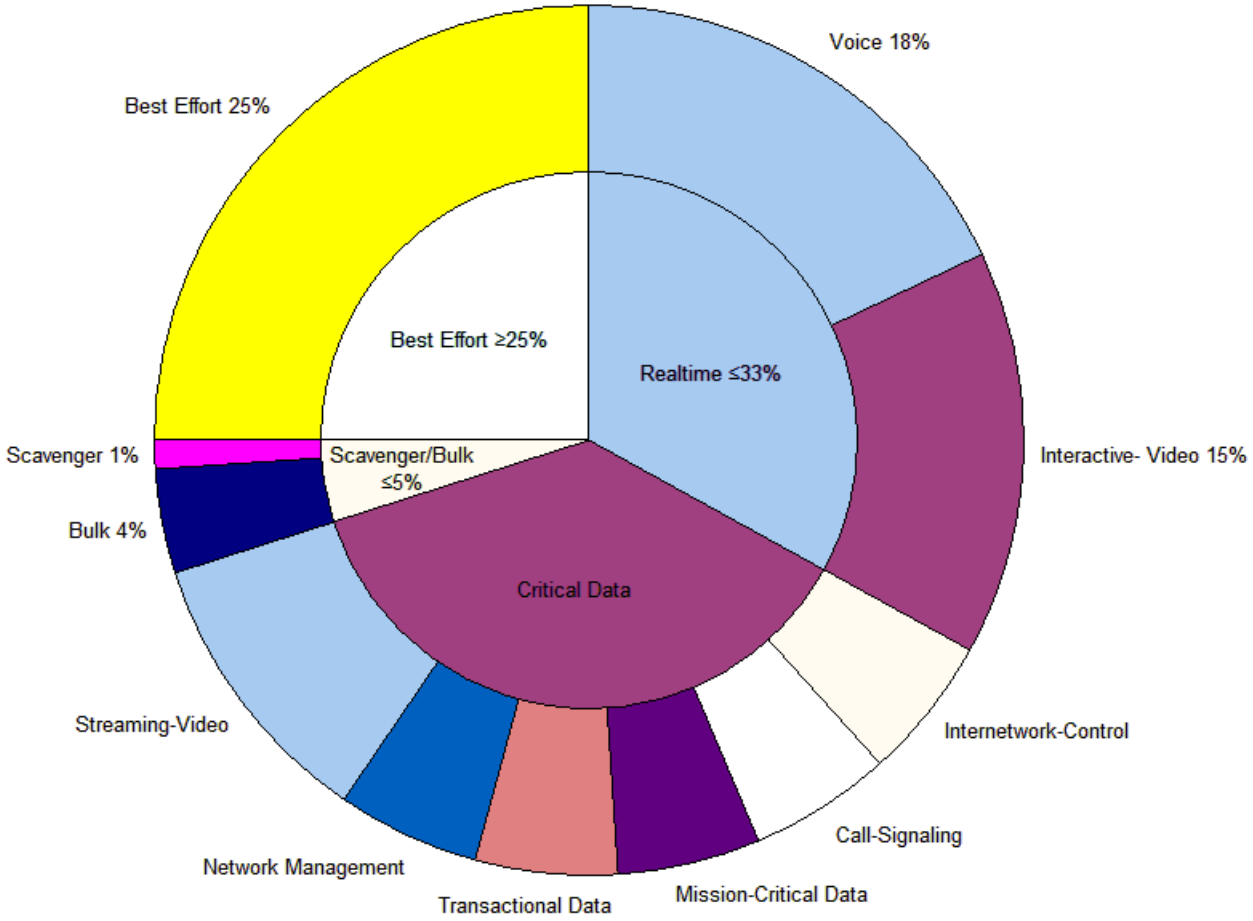


Figure 14.4: Mapping of different sized queues

The minimum number of queues on any switch/router platform will be four;

- Real-time (≤33%)
- Critical
- Best Effort (≥25%)
- Scavenger (≤5%)

Whenever supported, WRED or preferably DSCP-based WRED will be enabled on all TCP flows.

Trust, Classification, Marking, Policing and Queuing Policies will be configured on the Access switches' end user ports.

DSCP-Trust and Queuing Policies will be configured on all inters witch links.

14.3.2.6 Data Flow

Data will primarily be unicast flows between end users/equipment and the data centre.

Voice traffic will be unicast flows from end user to end user or the PSTN, except for Music on Hold that may utilize IP multicast from the data centre to the end users

CCTV (video) will use IP multicast from the cameras to the end users including the data centre. The playback of stored content in the data centres to a client on an end user device will usually be unicast.

Any end user initiated IP multicast groups for conferencing and similar will be contained in the end users VLAN and the traffic flow can be any to any.

14.3.3 Network Services

The BAN will include network services such as Domain Name Service (DNS), Dynamic Host Configuration Protocol (DHCP) and Authentication, Authorization, Accounting (AAA). The services will be hosted in the data centre in a redundant setup to ensure high availability.

14.3.3.1 DNS

DNS services will be made available for the equipment connected to the BAN.

The DNS services will be implemented as a redundant solution and will be included in the total network availability calculations.

The DNS services must be constructed in such a way, that internal hostnames will be resolved by DNS servers inside the BAN. Resolving external hostnames for internal users will be done through DNS forwarders.

The DNS servers will support Microsoft Active Directory. If Microsoft 2003 (or later) is chosen as DNS servers, name resolution across zones will be configured to use delegation for simplicity in management and configuration - otherwise standard forwarding is to be used.

To reduce the exposure of the private namespace to the Internet and to reduce the load on the internal DNS servers and the Internet connections, redundant forwarders placed in the BAN will be

responsible for all publicly accessed services from the BAN. The forwarders will make DNS queries directly to the Internet and not to the External DNS servers placed in the DMZ.

The DNS servers must be able to monitor its own functions and be able to automatically restart any DNS related services in case they stop responding or alternatively send an SNMP trap to the Network Management System indicating the fault.

14.3.3.2 DHCP

The BAN will include DHCP services for users of the network.

The DHCP services will be implemented as a redundant solution and will be included in the total network availability calculations.

The DHCP servers will be placed in the data centre.

All end users/equipment connecting to the BAN will obtain their IP address through DHCP. Always-on equipment can have a static IP address configured if needed.

The DHCP service will be able to assign addresses to clients outside the network (VLAN) the DHCP servers reside in.

DHCP clients will be able to obtain IP multicast Class D-type addresses from the DHCP servers for serving their own IP multicast groups. An example of a client initiated multicast group could be a conference call. The allocation of IP multicast addresses to clients may be done through the Multicast Address Dynamic Client Allocation Protocol (MADCAP, IETF RFC 2730). The address pool used for multicast clients will be clearly defined in the IP address plan.

The DHCP system will be able to monitor its own functions and be able to automatically restart any DHCP related services in case they stop responding or alternatively send an SNMP trap to the Network Management System indicating the fault.

14.3.3.3 AAA

The BAN will include AAA services for users of the network.

The AAA services will be implemented as a redundant solution and will be included in the total network availability calculations.

Similarly, the system will authenticate and authorize end users connecting to the BAN through IEEE 802.1x and will support wired as well as wireless users. The system will as a minimum support the 802.1x clients built into Microsoft Windows Vista and later.

The AAA system itself will be placed in the data centres.

The AAA system will be based on RADIUS or preferably the DIAMETER protocol.

All access to any network device for management purposes will be authorized through the AAA system.

Login/Logout and any changes made to a configuration on a network device must be logged to a central server including username and date-/timestamp.

The AAA system will support DHCP relay to allocate IP addresses from pools managed by a DHCP server.

The AAA system will support authentication of users contained in Windows Domains including Active Directory, Token-based authentication systems, UNIX Users, LDAP directories and SQL databases including Oracle and MySQL.

The AAA system will support CHAP and Microsoft CHAP (MS-CHAP) for authentication.

The AAA system will be able to authenticate users based on different criteria including:

- Date and time of day
- Access switch port number
- IP address
- User
- Group
- Role

The AAA system will be able to enforce network related parameters to different users like QoS, VLAN assignment and bandwidth limitations.

14.3.4 Management of Communication Systems

Software systems for maintenance and operations will be included. The following management systems including the necessary hardware and software will be provided:

- System for monitoring and control of the IT infrastructure for cabling and communication and transmission equipment.
- Telecommunications Management System for radio and telephone systems.

14.3.4.1 Network Management System (NMS)

An NMS for monitoring the network will be provided. Besides monitoring all the active network devices, the NMS will also be used as a tool for fault-resolution, device configuration and as a central (backup) repository for active network device configurations and -software.

The typical functions and tasks to consider for the NM include the following:

- Network planning, e.g. to determine network topology, dimension nodes and links, and plan for proper network rollout
- Network deployment, to install and commission equipment into the network
- Network operations, to monitor the network for any problems, failures, network security issues and issues with network performance
- Network maintenance, to perform equipment and software upgrades, provision services and tune network parameters

The NMS will be redundant and fault tolerant to the extent that if a breakdown occurs in either soft- or hardware, normal operations can be resumed within a short time frame.

All operational systems relating to the NMS will be placed in the data centre.

The NMS applications will be based on Commercial off-the-shelf (COTS) software configured to work in the specific environment.

The will be a high degree of emphasis on open systems capable of communicating with other systems through standardized protocols/languages like Extensible Mark-up Language, XML, or similar.

The NMS will be able to communicate with the active network equipment using standard protocols defined by the IETF and similar organizations and it will support the ITIL v3 and FCAPS frameworks for Service and System Management.

The NMS will support the following features:

- Real-time and historical performance analysis
- Secure web-based reporting
- Network health and availability index
- Automatic base lining and threshold
- Network diagnostic tools
- API for 3rd party integration including the Telephony system
- Several user-right access levels
- Support for industry standards

The NMS will include the ISO FCAPS functional model consisting of the following:

Table 14.2: ISO FCAPS functional model

Fault	Network problems and faults are found (monitored) and fixed.
Configuration	The network is monitored and controlled via system profiles, which include keeping track of hardware and software on the network devices and any modifications to them.
Accounting	Network resources are distributed and used equitably. Users are charged for their network and functionality usage.
Performance	Topology checks are performed and the network congestion and bottlenecks are located and minimized.
Security	Only users who are authorized to gain access to network are allowed to use the network resources. This implies equally to all users.

The NMS will be built in a hierarchy where different tasks are distributed across applications best suited for the particular task. The applications may be integrated into one system or across several systems, and then integrated by a middleware application before presented to the end-user. This

modular and hierarchical approach is to ensure the scalability of the design, where adding new device types can have a significant impact on the NMS if it was built as a single monolith system.

Similarly, it will be ensured, that management tasks are performed as close to the device being monitored as possible, i.e. if a network device type has embedded management functionality that would otherwise be handled by a NMS application, then the device's functionality will be utilized to lessen the management traffic load on the network and the load on the management system itself. An example of this could be RMON or SMON functionality embedded in the network device.

Event-based management is required over polling-based management wherever possible because it is more scalable, it lessens the load on the network and the NMS, and it occurs in real time as opposed to polling where an event will not be registered until the next polling cycle.

Similarly, exception- and policy-based management is required in the sense that, as long as the network is running smoothly, the NMS will not require the operator's attention. If a threshold is exceeded somewhere in the network, or if a policy is violated, the NMS will take appropriate action automatically, and at the same time alerting the operator to the issue, with a description of what has happened and what the NMS has done to normalize the situation (if anything). Being able to set and use policies will be an integral part of the NMS.

The NMS applications will support the use of a web-browser as a client for configuring, monitoring, and managing SNMP capable devices.

The NMS applications will support the ability to view status of devices, ports, and interfaces represented in a graphic front end.

If device viewing functionality exists for a network device used in the network, the device viewing functionality will be implemented in the NMS. Device viewing functionality (a graphical representation of a particular device's physical appearance) may include the ability of the NMS to show colour-coded ports for easy monitoring as well as being able to make standard changes to the viewed device directly through the graphic representation of the device like the opening and closing of ports, assignment of VLANs to a port, setting the port speed and duplex etc.

The NMS will be able to automatically generate a full topology map of the monitored networks and to automatically discover new devices and place them accurately on the map.

Manually adding and deleting devices to the map will also be possible.

It will be possible for the network administrator to define customized views for displaying the network topology including a user selectable background like floor plans.

It will be possible for the user to view the following information and statistics through the NMS:

- The status of a networking device, including
- CPU utilization
- Memory utilization
- Buffer utilization
- Backplane utilization
- Throughput
- Event log
- Port status, including
- Up/Down
- Speed and duplex
- Name
- Counters
- VLAN allocation
- Interfaces, including
- VLAN

The NMS will be able to show a graphical representation of large data sets - for example, through diagrams and curves to visualize trends.

The NMS will include powerful search, sorting and filtering tools.

The NMS will be able to support concurrent communication with multiple devices instead of having to serialize requests.

Any alterations to device configurations will be reflected in the NMS within 15 minutes.

The NMS will be able to utilize RMON and SMON functionalities in monitored equipment to show network resource consumption at device and port level.

The NMS will include a logging facility that can handle SNMP, Netflow/IPFIX and Syslog data from the network devices.

The NMS will be able to visually show information that seems out of the ordinary.

The NMS will have support for alerts and notifications for thresholds, device state, failures etc. triggered by SNMP traps.

The network management system will support methods of notification beyond console view, such as SNMP trap events and e-mail.

Faults will be viewable at the operators' workstation. A fault in a network device will initiate an alarm and add a record to the fault database table. Additionally, the operator will receive a warning message on the operators' workstation, notifying him about the fault. Network faults will include any hardware or software based faults in the managed systems.

Faults will be filtered, grouped and presented in different categories depending on the severity of the individual fault and the equipment the fault is originating from.

It will be possible for the network administrator to define customized filters and groups for categorization of faults and events.

Views of the current status of faults will be provided. The view will show all current faults, their severity, status (new, acknowledged, and accepted), End user(s) affected (optional) and timestamps.

Comprehensive fault statistics will be available. The statistics will include:

- Top 10
- Failures per device
- Failures per device type
- Fault types

- Mean Time To Repair (MTTR) based on historical data
- Mean Time Between Failure (MTBF) based on historical data
- Downtime
- Time of day where faults occur based on historical data
- Devices that have exceeded a threshold
- Interfaces with increasing error counters
- Unreachable interfaces during the last two polling periods

Narrowing down the scope of statistics to equipment vendor, device type, port, VLAN or End user will be possible.

The operator will be able to define the time-period for the statistics.

The NMS will have support for the ability to monitor performance in real-time or for trending of a specific device, port, or interface including port status, link integrity, capacity utilization, service level adherence, QoS, traffic types and usage statistics. Performance and trending will be visually presented in graphs or charts.

Thresholds regarding specific parameters of a connection such as utilization, QoS, traffic types, delay, packet loss and jitter will trigger an alert when crossed.

Thresholds will be configurable as either 'real-time' or 'time over threshold'.

The NMS will be able to generate service level reports based on the performance of key criteria both per connection, port, VLAN, device and of the network as a whole.

It will be possible to generate the reports both automatically and on demand.

It will be possible to view all interfaces that meet user selectable criteria like type, device, bandwidth, location and End user.

Reports on utilization, delay, packet loss and service delivery trends will be available for capacity planning and optimization purposes.

Reports will be customizable concerning the layout and text and it will be possible to add graphics (i.e. a logo or similar) to the report templates.

The NMS will include tools for the creation of new reports and report templates.

It will be possible to view the reports on screen as well as in print. Support for printing/viewing the report in PDF will be supported.

Export of report data to CSV will be supported.

To limit polling of SNMP data from the network equipment, measurements of the above parameters will be collected through Netflow/IPFIX where possible.

The NMS will have support for the ability to update software images on network devices from within the NMS including software flash upgrade via Trivial File Transfer Protocol (TFTP, RFC 1350).

The need for software image updates on the network devices will be monitored automatically by the network management system. If a device has an old or obsolete software image version then it will be indicated through a notification to the network operator.

The NMS will support manual and automated software image upgrades.

It will be possible to define time schedules in which software image upgrades will take place automatically.

Both automatic and manual bulk updates of several devices at the same (scheduled) time will be possible.

A TFTP server will be provided and configured as a repository for all network device configurations. The TFTP server will reside on, and be accessible only, from the management VLAN.

Software images and configurations for download to the networking devices will be stored as read-only.

The NMS will use SNMP v2c and SNMP v3 for management of all network devices.

RMON and SMON will be supported.

Automatic statistics polling using SNMP will be performed regularly on devices that cannot perform the collection of statistics themselves through RMON/SMON and Netflow/IPFIX.

14.3.4.2 Cable Management System

A cable management system will be provided. The primary use of the cable management system will be for documenting the physical network, to create work orders when there are changes to the network, and as an aid in troubleshooting the network.

Proper documentation of the cables is crucial for obtaining high network availability.

The cable management system will be able to show a graphic representation of the cable layout including cable numbers, strands in each cable, splices, pathways/ducts, man-/hand holes, patch panels and termination points.

The cable management system will show patched ports with opposite end identification.

The cable management system will show device references connected to a cable.

It will be possible to import or link to CAD drawings as well as photos, test reports and other documents into the cable management system and relate the imported documents to one or more assets in the database.

An XML or ODBC interface or similar will be present for integration with 3rd party systems.

The user interface will be intuitive and easy to use.

The cable management system will be flexible and allow for user-defined fields.

The cable management system will support at least two access-right levels – Read-only and read/write.

14.3.4.3 Telecommunications Management System

Systems for managing the telephony and the TETRA system will be included.

The telephony management system will be similar in function to the NMS (where applicable). It may be part of the NMS but it will have the following additional functionalities:

The System Management tool will provide maximum flexibility for rapid, efficient and cost-effective configuration changes affecting personnel and associated telephony equipment through a standard browser-based interface (including but not limited to formatted screens, pull down menus, valid entry choices, online help, templates, batch processing, transactions scheduling and database import/export).

Administration, system monitoring, diagnostic and maintenance operations for all locations will be supported using a centrally located server(s) with distributed client workstations. Simultaneous access from multiple locations by multiple users will be provided.

Online system administration will not disrupt service. The telephone system will remain operational during backups, updates and upgrades.

The system will be provided with full configuration management services and capabilities to simplify the provisioning of network devices, gathering and storing configuration data, tracking and scheduling changes. The system will support centralized configuration management that includes, but not limited to, the following:

- Station user moves, adds, and changes
- Endpoint/subscriber profiles and parameters
- Group definitions and assignments
- Call restriction assignments
- Class of service definitions and assignments
- Dial plan and routing parameters
- Call Admission Control (CAC) parameters
- Trunk group definitions and individual trunk circuit programming
- Trunking Gateways
- Statistics:
- Average Mean Opinion Score (MOS)
- Average time to get a dial tone (call setup)

- Average time to get a ring back tone (time to connect)
- Percentage of calls completed successfully
- Jitter (measured during calls)
- Delay (measured during calls)
- Packet loss (measured during calls)
- Distribution of used codec's
- The System will provide fault management capabilities and services necessary to recognize, isolate, correct and log all faults. The management solution will support centralized fault management that includes, but not limited to, the following:
- Performing diagnostics and troubleshooting
- Provide monitoring and filtering of alarms, faults and associated logs
- Provide real-time statistics regarding system performance, including checking server and process status
- Support SNMP traps to external umbrella management systems, i.e. the NMS

The System will provide accounting management services and capabilities to track service usage and costs. The management solution will provide centralized call detail records, which will be utilized by external call accounting, as well as external financial management applications. The equipment, software, and features needed to provide the cost accounting services, and the interface to the external financial management system will be included. The system will be provided in compliance with overall accounting management requirements and address each of the following areas and provide the following functionality:

Call Detail Recording (CDR): The system will generate CDR for both incoming and outgoing calls on trunk facilities and for station-to-station calls.

Call Accounting Applications: An accounting application will be provided that will allow an external financial management system to collect and analyze data by means of predefined and customized reports and allocate costs to various departments/organizations.

The usage data will be available for other applications through an XML API or alternatively the telephony management system will be able to communicate with external systems in real-time by being able to write records directly into an Oracle or MySQL database.

The contractor will provide performance management services and capability necessary to collect, analyze and report on a variety of system operations. This will include but not be limited to the following:

- A traffic tool providing graphical and numerical data for call attempts, traffic load, incoming/outgoing calls and busy hour call attempts (BHCA) for selected periods
- Traffic measurements (statistics and counters) on business groups call usage and patterns, feature usage, hunt groups and call admission control (CAC)

14.4 Radio Communication System

14.4.1 Assumptions

It is assumed that the radio communication system is only for the Operation & Maintenance staff of the Bridge.

Further, it is assumed that Police, Rescue and other emergency services have their own radio communication systems and that their respective technical organisations will provide the necessary radio coverage.

Further it is assumed that provision of all railway signalling and railway radio communication is outside the Scope of Works, and that design and planning hereof is done by the railway operator.

14.4.2 Functional Specifications

The radio communication system will provide two way wireless communications for the use of the bridge's operation and maintenance personnel.

Radio communication facilities will be established to cover the Bridge deck and access roads including the road and the area around the Control Centre building and Toll Station.

Further, there will be established radio coverage inside the buildings as well as inside the bridge girders, the towers and the anchor blocks

The radio system will provide voice and low-speed data communication with full privacy between mobile/hand held radios and the operators in the Control Centre of the Bridge. Direct communication between handheld radios or mobile radios will also be possible. Broadcast calls, group calls in predefined groups and in dynamic groups will be possible.

Further, the operator can patch telephone calls to and from the fixed telephone system (PBX) in the control centre building and can also patch calls to and from the Public Switched Telephone Network (PSTN).

Real time information about the geographical position of a hand held or mobile radio units will be transmitted to the operator in the Control Centre.

A Network Management System for the radio communication System will be supplied. The system will provide possibility to remotely monitor and configure the radio communication switch and the base stations.

14.4.3 Technical Specifications

The radio system will be based on the TETRA standard: TErrestrial Trunked RAdio as specified by ETSI. It is assumed that frequencies will be allocated by the frequency management authorities of Italy in the frequency range for TETRA systems, i.e. 450 MHz.

The radio communication system will provide adequate coverage to ensure satisfactory two way radio communication, i.e. adequate Signal-to-Noise ratio (S/N) and intelligible speech quality on more than 95 % of the specified coverage area.

The 5 % of the area where it is acceptable that the requirements are not fulfilled will not constitute a continuous area but will be small areas far away from the antenna systems or areas in the shadow of components of the bridge constructions.

The radio communication equipment will be highly reliable and the system will be designed with redundancy such that the availability will be at least 99.98 %.

Calculation of availability and link budgets are included in the Mechanical and Electrical calculation report, doc. no. CG1000-P-1R-D-P-IT-M4-GC-00-00-00-01.

The TETRA radio system consists of two base stations, located at each land site of the bridge. The radio coverage of the outside areas will be provided from panel antennas placed in the height of 25-30 m on the antenna masts and with direction towards the bridge.

The antenna system for coverage of the bridge girders, towers and anchor blocks will consist of leaky coaxial cables (radiating coaxial cables) combined with discrete antennas for coverage of the cross beams and the anchor blocks.. Fibre fed optic repeaters are installed to repeat/amplify the radio signal from the base stations. A small portion of the RF signal from the base station is picked up by a directional coupler and connected to an Optical Master Unit (OMU) which converts the RF energy into an optical signal and transfers it to the repeaters. In the uplink direction the radio signal is received by the repeater and transferred as an optical signal to the OMU which converts the signal into a RF and sends it back to the base station. The optical fibres connecting the OMU and the repeaters are single mode fibres laid in ring systems such that a repeater will be fed from two opposite directions ensuring that the repeater will not be affected in the case of a break of one fibre. The repeaters will be located in the QMT sub-stations at each side of the bridge deck, and in the Towers and anchor blocks.

Furthermore, half of the repeaters is connected to the base station at Calabria, the other half is connected to the base station at Sicily so that in the case of a total failure of one of the base stations there will still be areas with radio coverage inside the bridge and towers.

The TETRA communication switch will be located in the equipment room of the Control Centre. The operators console will be located in the control room.

The TETRA base stations are connected to the communication switch in the Control Centre via the Wide Area Network (WAN).

All radio equipment will be power supplied by 230 V AC from the Uninterruptible Power Supply (UPS) system.

The position of the mobile and hand held radio units at the outside areas will be established with GPS receivers connected to the radio unit. Inside the confined area of the Bridge it is not possible to use GPS receiver, therefore, tagging transmitters or similar technology will be used.

14.4.4 Equipment and cable specifications

The design is based on the following generic technical specifications (at 450 MHz)

Base station, output power:	Minimum 40 dBm
Optic fibre fed repeater, output power	Minimum 33 dBm
Small indoor antennas:	Minimum 6 dBi - typical dimensions: 300x300x80 mm
Leaky coax cable (½"):	Longitudinal attenuation: 5.7 dB/100 m
	Coupling loss (95%): 79 dB cf. IEC 61196-4
	Coaxial cable (½"):Attenuation4.5 dB/100 m

14.5 Telephone System

14.5.1 Functional Specification

A telephone system will be provided in order to establish voice communication between the users in the bridge deck, the towers, substations, equipment shelters, the Control Centre, the Toll Station and the Public Switched Telephone Network (PSTN), etc.

The telephone system comprises the switch and peripherals such as telephone sets and fax machines. Remote control and diagnostics will be included with the system.

As a minimum the following user facilities will be available:

- Voice mail and voice response
- Redial last number
- Abbreviated dialling
- Call pickup
- Call forwarding
- Automatic call back
- Direct inward dialling
- Direct outward dialling

- Call detail recording
- Blocking of selected prefixes and numbers

The telephones sets will be provided with display and hands-free option for connection of a head-set.

14.5.2 Technical Specifications

The telephone system will be based on Voice over Internet Protocol (VoIP) (IP-telephony).

Telephone sets will be connected to the LAN (Ethernet) by through 1000Base-T.

The telephone system will meet the following minimum requirements:

Session Initiation Protocol (SIP)-Based System Solution: The system and components will be industry standard, SIP-based solutions (RFC 3261). The proposed system will use SIP as the method of session initiation for calling activity and support SIP clients. The system will rely on the BAN to perform the switching required to make call connections.

Centralized Call Control, Applications and Management: The system will constitute a single system design with redundant centralized call control processors located in the data centre. Applications, including management solutions, will also be centralized in the data centre. All end users will have access to all common system resources, features and applications. Administrators will be able to easily perform necessary Moves, Adds and Changes (MAC), as well as maintenance activity, from a central location.

Capabilities for the solution will include:

Centralized user interfaces for managing and accessing all communications services, including primary access through a GUI client and additional TUI (telephony user interface) for mobile user convenience.

Presence management for voice and Instant Messaging (IM) communications across multiple end-user client devices such as desk phones, wireless phones, soft clients on PC, and mobile devices.

Priority-based contact management

Support for a single integrated or unified mailbox that supports email, fax and voicemail message types

Service Oriented Architecture: The system architecture will provide integration and communication between the system components and will allow other applications to integrate with the system, including but not limited to:

- Voicemail
- Mobility
- Presence service
- Service Desk system
- TETRA System

Support for Open System Standards: The system and solutions proposed will support open, international and non-proprietary standards, and will meet all relevant industry standards.

Performance: The telephony system will have an availability of 99.75% measured over one year. If one sub-component of the telephony is unavailable, the entire system is regarded as unavailable. The design of the telephony system and the components used will include sufficient failover and backup capabilities to make all telephony services operations continue undisturbed. The call-processing software will run on an extremely reliable platform.

The server platform will have the capability of handling a call capacity of 2 calls per second..

Language Support: The solution will support multiple languages, Italian and English at minimum.

Survivability: The call control system architecture will be based on a software application implemented on redundant servers at physically separated host locations. The host call control server will have active/active redundancy such that failure of a call controller results in seamless transition to a second call controller (i.e., maintains connections). The host servers will have no single point of system failure and provide carrier-grade reliability.

Overall Quality: The system, including all central components, end devices, and related equipment will include a quality of voice services equal to or superior to a standard TDM system with numerical indication of the perceived quality in mean opinion score (MOS) between 4.2 and 4.8

Security: The system will be designed with inherent security features and services to prevent the compromise of the system or elements of the systems. It will include a multi-level, tiered approach to security, from system administrators to individual users.

Backup, Recovery and Updates: System will be configured with automated capabilities for backup, recovery and update. The system will remain operational during all backups, recovery and updates with no loss of information or services.

Maintainability: The system will provide for ease of maintenance, with minimum service requirements, remote monitoring and diagnostic capability, and a modular approach to hardware allowing for simple and quick repair of the system.

Upgradeability: The solution will be a current model, with inherent upgrade capability without significant or major equipment replacement or augmentation, relying largely on software upgrades and limited equipment additions.

Industry Standard QoS Support: Implementation of systems that support industry standards for QoS, such as 802.1p, 802,1Q and DiffServ (Differentiated Services) are required.

Third Party Compliant Endpoints: The solution will support third-party industry standard endpoints (e.g., devices, gateways, soft clients, etc.) that conform to SIP standards.

The system solution will provide users with the option of routing and accessing all messages through a single, private mail service, such as Microsoft Exchange or Lotus Notes.

The system will support multiple email server types simultaneously (e.g., Exchange, Lotus, IMAP4 (Internet Message Access Protocol version 4, etc.)

The system will provide single and/or dual message store options on the same server and configurable at individual subscriber level

Telephones will be equipped with a switch port for connection of a PC.

Telephones will support Power over Ethernet.

The phones offered will automatically select Voice VLAN, phone QoS associated as well as power budget. No manual settings on physical IP phones will be necessary.

Phones located in uncontrolled environments will be hardened and/or put in a suitable protective enclosure.

Acoustic Requirements: All SIP speakerphone models will be both full and half duplex. Additionally, all SIP phones will support the G.722 wideband CODEC, silence suppression (VAD) and echo cancellation to ensure the highest voice quality

Applications Support Requirements: SIP phone models that support integrated application support for LDAP directories, a customized phonebook, call log and open standards customizable application download via XML, JAVA, HTML and WML. In addition, all phones provided will be able to support customized XML-based services.

The gateway to the PSTN will comply with the requirements of the public telecom service provider.

SIP soft phone capabilities will meet the following minimum requirements:

- Customizable graphical user interface (GUI)
- Support for the End User Voice features
- Dialling via the keypad, address books, call lists, using drag/drop or copy/paste
- LDAP integration
- Call lists (missed calls, received calls, attempted calls)
- Post-connect DTMF dialling
- Task-oriented on-line help
- Capability to add keys/lines
- USB, Headset and Video support capabilities
- Codec Support: G.711, G.729A/B, H.263, H.264
- Industry standard QoS (802.1p)

The System solution will support attendant services. A PC-based soft client application for the provision of these services for the attendant stations is required. The attendant services will meet the following minimum requirements:

- Provide an easy-to-use GUI with customizable views
- Provide attendant-specific function keys, speed dial lists and directory functionality
- Provide Call Queuing, Call Selection and Recall handling with call indicators and real-time Statistics (i.e., calls in queue, time in queue, etc.)
- Provide interposition transfer with real-time availability views of other attendants in attendant groups
- Provide overflow (to another attendant)
- Provide paging system access and provide interface to the Public Address System
- Provide soft phone call handling controls with one-click access (e.g., logon/logoff, answer, disconnects, hold, retrieve from hold, dial, transfer, consult, etc.)
- Provide a screen pop for incoming calls (e.g., calling party number, called number, queue name, wait time, etc.)
- Provide visual status of user's line (i.e., busy, ringing, idle)
- Provide night service capabilities.
- Provide Intrusion (break-in/override)
- Provide trunk-to-trunk transfer

14.5.3 Emergency Telephones

Emergency telephones (S.O.S. Colonne) will be located approximately each 500 m on both sides of the bridge deck. The telephones will provide communication with the Control Room. The telephones will be of the same type as used along the highways in Italy, and be suitable for use in the noisy environment of the road.

The telephones will be illuminated with a built-in lamp, and clearly marked with the text "Soccorso Meccanico, Sanitario e Polizia".

Further, the telephones will be marked with operating instructions in four languages: Italian, English, French and German.

It will be possible to identify the telephone that has been activated. Further, the nearby CCTV camera will be activated automatically and the image presented to the operator in the control room.

The emergency telephones will be provided with an IP-interface box and connected to the data communication network.

14.6 General application and system requirements, Server based systems

14.6.1 General

All server based systems specified in section 14 have some common requirements regarding hardware, operating systems, operator privileges etc. The requirements are outlined below.

14.6.2 Functional requirements

All network management servers located in the data centre will be hardware remote controlled through the network management VLAN.

It must be possible for an operator to remotely restart a server while still being able to watch the boot up sequence as if the operator was located beside the server watching its monitor. Remote keyboard and mouse support will also be available (KVM support).

The software provided will, as a minimum be a 32-bit based application and will be built around a compliant operating system.

The supplied software must be the latest released version with all manufacturer patches applied.

Supplied software will be delivered in a ready-to-run form, including all necessary utility programs and documentation.

All applications and systems will be adequately sized to perform their functions with enough spare capacity to handle a network 50% larger than the one specified in this document.

Equipment placed in the data centre will be easily mountable in 19" equipment racks accessible from the front and the rear.

Racks in the data centres are cooled from front to rear (hot aisle-cold aisle rack configuration) - equipment mounted in the racks will be compatible with this configuration.

User serviceable equipment such as servers and disk arrays will be easily accessible and serviceable when mounted in the racks.

Equipment mounted on sliders will have folding cable management attached to the rear end to avoid straining the cables or unintentional unplugging of the cables.

All applications used will generally have a response time of less than one second. If a task takes longer to complete, it is desirable that a visual indicator is be shown on the operators screen to indicate that the task is running but not complete. The indicator can include a 'percent done' bar.

Except for backup and batch operations, a response time of more than one minute for any given task is unacceptable.

The servers will be connected to the network management VLAN through gigabit Ethernet interfaces. Interfaces can be bundled if necessary to achieve higher bandwidth and availability using IEEE 802.3AX LACP or similar. The bundling technique will be supported by the Server Access switches.

Web browser based applications interface are preferred to alleviate the need for special software installed on the operator's workstations.

All network management users will log into the systems using a unique user name and password validated through AAA.

Depending on assigned user access privileges, the user will either be granted or denied access to individual applications, functions, forms, fields or data.

The system will provide an audit trail of all transactions. The audit trail will track on a per-user basis.

The audit trail file will indicate any changes that occurred to applications or network devices configuration, data structure, or database fields/records, and will contain date and time of the change, the identification of the user or the subsystem that made the change, and the details of the change.

All Servers will be selected from commercially available standard types.

The supplied hardware will be the “contemporary technical equivalent” of the specified hardware. “Contemporary technical equivalent” will be based on a comparison of technology at the time of publication of the specifications to the technology at the time of ordering the equipment.

All Server equipment will be maintainable under warranty locally by the Employer.

All Server equipment will be rated for continuous operation under the ambient environmental temperature, humidity, and vibration conditions encountered at installation sites.

14.6.3 Documentation

The following documentation will be provided with the systems described in section 14:

- Instruction manuals
- Software manuals
- Operation manuals
- Maintenance manuals
- System architecture guides
- Troubleshooting guides
- Rack elevation drawings
- Equipment lists
- Layout drawings of rooms and areas hosting IT racks
- Patch documentation
- Complete set of network drawings showing the physical network
- Complete set of network drawings showing the logical networks including VLAN and IP addressing information
- Complete set of network drawings showing primary and secondary routing of VLANs from Access switches to data centres
- VLAN plans

- IP addressing plans
- Dial plan
- Quality Control documents.
- Certificate of warranty

14.7 Interfaces

There will be interfaces between the different components/systems that must be taken into account during detailed design. Identified interfaces are as follows:

- Electrical
- Mechanical
- Structural
- Railway company (signage, alarms and emergency phones)
- Between IT Passive and IT Networks (racks, cabling and outlets
- Users (placement of specific outlets, redundancy requirements, bandwidth, physical interfaces, Quality of Service)
- WAN (active equipment on the WAN, protocols, distance to connections, fibre cable types)
- Emergency phones/VoIP interface to the CCTV system

14.8 Quantities

The quantise in the below list is not comparable with the amount of measurement point or the actual numbers of equipment that are going to be connected to the network. The quantities in the list represent the numbers of connecting point to the BAN. A lot of measurement points and equipments are going to share a connecting point to the BAN, so the quantities of connecting points to the BAN are less then the amount of measurement points and equipments.

The following table shows currently identified equipment that requires access to the network.

Table 14.3: Network connected equipment

Equipment	Quantities	Redundancy
CMS		
BAN Connections	TBD	Yes
Connections in server room	2	Yes
Traffic Management System		
BAN Connections	250	Yes / No
Connections in server room	2	Yes
Safety systems		
BAN Connections	100	Yes / No
Connections in server room	10	Yes / No
SHMS		
BAN Connections	40	No
Connections in server room	2	No
Power Management System		
BAN Connections	80	No
Connections in server room	2	Yes
Radio communications		
BAN Connections	TBD	Yes
Connections in server room	TBD	Yes
Telephone system		
BAN Connections	50	No
Connections in server room	2	Yes
IT-Network		

Equipment	Quantities	Redundancy
Connections in server room	25	Yes / No

15 Water Distribution System (Fire Fighting and Washing System)

15.1 Purpose

The system will be designed for the pressurized water distribution for the following purposes:

- Fire fighting on bridge and towers (Fire hydrant system and automatic Sprinkler system in pump houses)
- Washing system for steel structures.

15.2 Norms and Standards

Following norms and standards will apply:

EN 12845:2004 + A2:2009; Fixed fire fighting systems - Automatic sprinkler systems - Design, installation and maintenance

UNI 10779 Impiante de estinzione incendi, Reti di idranti, Progettazione, installazione ed esercizo. (Fire fighting equipment, Hydrant systems, Design, installation and operation).

UNI 11292 Locali destinati ad ospitare unità di pompaggio per impiianti antincendio. Caratteristiche construttive e funzionali.

The improvement for flow and pressure is argued due to the fact that the UNI 10779 (valid for buildings) was assessed not to be able to secure sufficient water and flow to extinguish a major fire in a train on the bridge from a long distance! - The UNI 10779 gives minimum requirements for Hydrant systems and the improvement could secure the rescue of people in case of a major train fire.
The flow and pressure in the towers compared to the bridge is implemented according to UNI 10779. Argued to the situation that the conditions inside the towers are alike to buildings. No long distances from hydrants to a possible fire.

15.3 System description

The water distribution systems consist of two main systems.

1. The fire fighting system which is split up in three systems:
   - One system for the bridge
   - Two systems for the towers. One for the lower part up to level 130 m and one for the high part from level 130 m up to level 380 m.
2. The utility water system which is split up in four systems:
   - Two for the bridge (one for each half of the bridge)
   - One for the lower part up to level 130 m (One for the high part from level 130 m up to level 380 m.)

Each water system comprise Pumps in the pump stations and distribution piping systems.

15.3.1 Pump stations

A pumping station will be located at the base of each tower for supply of water to the fire and washing main systems on bridge and in towers. The temperature in the pump house is maintained above 10 ^{o}C by electrical heaters.

Different independent water systems will be installed for fire fighting and washing systems.

The pump stations will be connected to water reservoirs which are filed from the public water network and will have a minimum capacity for six hours continuous fire fighting including filling up the utility tank on the maintenance gantry.

The pump stations shall be designed in accordance to EN 12845 and UNI 11292 standard. The fire hydrant system shall be fully redundant. The electrical power supply for the pump stations shall be realized by using a dedicated "city" line electrical supply.

The fire hydrant system on the bridge is supplied from the two redundant pumping stations (one located at each tower). The systems in each tower are supplied from the pumping station at the

respective tower. Each pumping station will for each system be equipped with two fire pumps (Electrical pump and diesel pump), one pump in operation and the other pump as spare. A jockey pump will be installed to maintain the operation pressure at all time.

The utility water system at the bridge is split up in two systems supplied from the pumping stations at each of the towers. The utility water main is however, interconnected at the centre of bridge. The utility water systems in the towers are supplied from one pump station, as mentioned above for the fire hydrant system. Each pumping station will for each sub-system be equipped with one pump, only.

15.3.2 Water Distribution

15.3.2.1 Bridge

FIRE WATER SYSTEMS

The main fire distribution pipes for the bridge are placed on both sides of the railway girder below the emergency walkway. The fire hydrants will be feed from the distribution pipe and are located at the road girders with a distance of approx one meter from the crash barrier.

The fire system is a wet system (water filled and pressurized) and cross connected at piers in order to create a ring system which allow for line partition for maintenance purposes. Sectioning valves will be located every 500 m.

The hydrants will serve both the railway girder and the adjacent road girder. For this reason the distance between the available hydrants for the railway is less than 90 m, whereas it is maximum 90 m for the roadways.

Sprinkler protection of the pumping station will be obtained from the bridge fire water system.

UTILITY WATER SYSTEMS

The utility water valves and the utility water distribution pipes for the bridge are placed on the one side of the railway girder next to one of the fire mains.

Wash valves will be placed with a distance of maximum 90 m along the utility water main for connection to mobile water reservoirs on the Inspection and maintenance gantry for suspended bridge.

15.3.2.2 Towers

FIRE WATER SYSTEMS

The fire water system in each tower comprise two separate systems:

- One system for fire hydrants up to 130 m and
- One system for fire hydrants in level 205 m and 380 m.

For each system a fire riser main will be placed in each tower leg and cross connected at each cross beam in order to create a ring system which allows for line partition for maintenance purposes.

Hydrants will be located at each cross beam and at the tower base.

Fire water will be supplied from the pump station located on ground site near the tower base.

Common pump stations covering pumps for both tower (low as well as high level) and bridge will secure easy access for maintenance staff during operation. Further are fire pumps (booster pumps) located in the tower requiring back up supply by diesel pumps and fuel storage evaluated to be an disadvantage for the safety.

UTILITY WATER SYSTEMS

The utility water system is split up in two systems similar to the systems mentioned above for the fire water.

Utility water to the wash valves in the tower will be supplied from the pump station located on ground site near the tower base.

The wash valves will be placed next to the gantry access doors inside the towers so they can be reached from the gantries, when the wash water tanks on the gantries are to be filled up.

15.4 Design requirements

15.4.1 Fire Hydrant system

15.4.1.1 Flow

The flow rate for the horizontal fire mains on bridge will not be required to exceed 2.000 l/min.

- 2,000 l/min (120 m^3/hour or 33 l/sec.)

Hydraulic calculations and pipe sizes for the bridge will be based on providing 1,000 l/min at each of the two most remote fire hydrants on one of the two horizontal mains.

(Reference to Mechanical and Electrical System, Calculation report; Doc. no. CG1000 P-1R-D-P-IT-M4-GC-00-00-00-01-A).

The flow rate for the fire riser mains in the towers will not be required to exceed 300 l/min.

- 300 l/min (18 m^3/hour or 5 l/sec.)

Hydraulic calculations and pipe sizes for the towers will be based on providing 300 l/min at the most remote fire hydrant in the top cross beam.

Minimum flow required from each fire hydrant:

- 1,000 l/min (60 m^3/hour or 16 l/sec.) - On the bridge
- 300 l/min (18 m^3/hour or 5 l/sec.) - In the towers.

15.4.1.2 Pressure

For the fire hydrants, the minimum residual pressure will be required to 6,9 bar (g) for the bridge and 4 bar (g) for the towers.

- 6,9 bar (g) (residual pressure for the bridge fire hydrant)
- 4 bar (g) (residual pressure for the tower fire hydrant).

The pressure requirement will be taken as pressure limitation to serve two fire hydrants simultaneously on the bridge.

15.4.2 Utility water System

15.4.2.1 Flow

Minimum flow requirement for each wash valve will not be required to exceed:

- 125 l/min (7.5 m^3/hour or 2.08 l/sec.)

15.4.2.2 Pressure

For the wash valves, the minimum residual pressure will be required to 4 bar (g) for the bridges as well as for the towers.

- 4 bar (g) (residual pressure for the bridge and tower wash valves).

15.4.3 Frost Protection

The frost protection of the water systems will be achieved as follows:

1. The horizontal water mains on bridge (fire main and utility water main) will not be insulated and heat traced. In case of the extremely rare situation (*) with temperatures below the freezing point a small flow in the pipes will prevent possible freezing. In case a section of the main is closed for maintenance by two sectioning valves and emptied, The water circulation of the remaining part of the main can be maintained by partial opening fire hydrants next to the closed valves

   - (*) CG1000-P-SR-D-P-GE-R5-00-00-00-00-04_A_ORA Natural hazards_ANX (Table 4-11)

2. The steady water in branch off connections for fire hydrants and wash valves will not be able to circulate. The branch off connections and dead ends will be insulated and heat traced.

3. The fire riser mains and utility water mains inside the towers and the terminal structures will not be frost protected. The indoor temperature in towers and terminal structures will not drop below freezing point. Further, will heat generated from the dehumidification system, electrical switchboards etc. contribute to a frost free indoor environment.

15.5 Function and operation - fire system

15.5.1 Operation mode

The following operation modes will be implemented:

- Normal operation
- Fire operation
- Leakage protection
- Frost protection
- Pump test
- Redundant el-supply
- Emergency operation

15.5.2 Normal operation

The normal operation includes the following cases:

15.5.2.1 Maintaining of system pressure

Jockey pumps are maintaining the design pressure in the systems. The necessary flow is obtained by the variable speed regulation. Pressure transmitters (PT) are placed in the system. The pressure transmitters measures the actual pressure in the respective pipes, and the pressure controls calculate the Variable speed regulation for the corresponding jockey pumps placed in the fire pump station.

15.5.2.2 Water filling up of fire water tanks

Filling of municipality water is controlled automatically by level controls in the tanks and remote operated valves in the water supply pipe.

15.5.2.3 Automatic/Alternating program

Switching between Sicily and Calabria fire pump station as supply to the pipes in the bridge, are controlled by an operating time schedule. - Allowing for extraordinary maintenance work in the "stand by" fire pump station.

15.5.3 Fire operation

Hydrants in use. The pressure controls calculates the Variable speed regulations for the corresponding jockey pumps to maintain sufficient pressure on the system.

In case the fire brigade opens one or more fire hydrants the system pressure will drop and the alarm and start of the fire pump will be activated. When the system pressure is regained the Jockey pump stops.

All fire pumps have a redundant back up diesel fire pump that will start in case of failure on the electrical driven fire pump.

15.5.4 Leakage protection

Flow meters on the bridge are detecting abnormal flow of water, during "Normal operation" or "Fire operation". In case abnormal flow is measured alarm will be given to the operator. Then decision can be made whether the remote operated valves in both ends of the respective riser will be closed and automatic activating of the fire pump in the "stand by" fire pump station.

15.5.5 Frost protection

A weather station measures and calculates the surface temperature, wind speed and water temperature in pipes. When temperatures are decreasing towards 0 ° Celsius, 'Frost function' will activate and open the remote operated valves on level 55m and switch the sectioning valves on level 75m to ensure sufficient flow to prevent blocking because of ice in the pipes. The Jockey pumps are sufficient to maintain pressure during this operation. When 'Sicily' fire pumping station is supplying the bridge with water, it is the frost valves on 'Calabria' that opens, and vice versa. All the branches (pipes) to the fire hydrants are frost protected with el-tracing (electrical heat on all branches).

15.5.6 Pump test

Testing of pumps will be performed in a "closed" loop where the water is circulated and flushed back to the water tank.

15.5.7 Redundant el-supply

All Jockey pumps and fire pumps in the fire pump station Sicily and fire pump station Calabria, are supplied by different power providers. Electricity supply to both fire pump stations also has back-up diesel generators to secure continues operation. Furthermore, one of the two fire pumps in each system is diesel driven.

15.5.8 Emergency operation

For emergency operation in case of system failure in the CMS a set of pressure switches will be connected for each of the main pumps directly to the LV switchboard. The set point of these switches will be above and below high and low alarm levels.

15.6 Function and operation - utility water system

The utility water systems will have no redundancy as they are maintenance systems.

The pumps are normally stopped.

When a maintenance work is planned for the bridge or the towers the respective utility water pumps will be started manually.

The function of frost protection of the utility water is similar to the function for the fire water, described above.

15.7 Material

15.7.1 Pumps

15.7.1.1 Electrical pumps

Performance requirement to fire pumps will be:

- Fire pump (High level): 300 l/min – 48 Bar
- Fire pump (Low level): 300 l/min – 21 Bar
- Fire pump (Bridge): 2,000 l/min – 19 Bar

- Jockey pump (High level): 30 l/min – 48 Bar
- Jockey pump (Low level): 30 l/min – 21 Bar
- Jockey pump (Bridge): 100 l/min – 19 Bar

Performance requirement to Utility water pumps will be:

- Utility water pump (High level): 150 l/min – 45 Bar
- Utility water pump (Low level): 150 l/min – 21 Bar
- Utility water pump (Bridge): 150 l/min – 17 Bar

15.7.1.2 Diesel pumps

Performance requirement to diesel driven fire pumps will be:

- Fire pump (High level): 300 l/min – 48 Bar
- Fire pump (Low level): 300 l/min – 21 Bar
- Fire pump (Bridge): 2,000 l/min – 19 Bar

15.7.2 Pipes

15.7.2.1 Stainless Steel - Utility & fire piping

All SS (Stainless Steel) materials to be used for pressure containing parts in the utility water piping systems in the pumping stations and in the distribution lines in the towers will be chemically, structurally and mechanically compatible with the materials specified in this specification.

The SS utility water piping systems will be designed in acc. with EN 13480 and to fulfil the following design conditions:

Design conditions	**Utility & fire pump station for tower distribution**	**Utility & fire pump station for bridge distribution**
Design pressure:	63 Bar (PN 63)	25 Bar (PN 25)
Design temperatures:	-2 / + 43 ºC	-2 / + 43 ºC

Nominal diameter:	DN50 / DN80 / DN100	DN50 / DN100 / DN150 / DN300
Fluid group:	2	2
Piping category:	I	I
Compliance module:	A	A
Support class:	S1	S1
Corrosion allowance:	Nil	Nil
Minus tolerance class:	± 12.5 % or ± 0.4 mm	± 12.5 % or ± 0.4 mm
Welding factor:	1.0	1.0

All SS pipe and fittings materials will be new, fresh and free from all detrimental defects and imperfections an only be used for production after having been controlled and approved by the manufacture in accordance with EN13480 "Metallic Industrial Piping".

All materials will be delivered with 3.1 material certificates according with EN 10204.

All materials must be protected with the aim to sustain the environmental conditions present in the Strait of Messina, without further maintenance for a period of min. 25 years. Due attention must be paid to the effects of mechanical wear, grease or other liquids, on inside as well as outside surfaces.

Due attention must be paid to the problem of galvanic corrosion by electric isolation, as required, between different materials.

All pipe and fittings materials will meet the requirements of atmospheric corrosivity category C5-M according to EN 12944.

The basic materials for pipes and fittings will meet the following requirements as minimum:

- Pipes will be made in steel grade 1.4404 +AT (316L), produced in accordance with EN10088-3, outside diameter serie 1 acc. to EN10220 and delivered in accordance with EN10217-7 or EN10216-5
- Pipe fittings will be made in steel grade 1.4404 +AT (316L), produced in accordance with EN10088-3, type B and delivered in acc. with EN 10253-4.

- Flanges will be made in steel grade 1.4404 +AT (316L), produced in accordance with EN10088-3, type 11 and delivered in acc. with EN 1092-1.

15.7.2.2 GRE (Glass-fibre Reinforced Epoxy) - Utility and fire piping at bridge girders

All GRE materials to be used for pressure containing parts in the utility water and fire fighting piping distribution lines at the bridge girders will be chemically, structurally and mechanically compatible with the materials specified in this specification.

The GRE utility and fire piping systems will be designed to fulfil the following design conditions:

Design conditions	**Utility & fire distribution at bridge girders**	**Applicable type & pressure class**
Design pressure:	25 Bar (PN 25)	DN50 EST40, DN150 EST25
Design temperatures:	-5 / + 43 ºC	
Nominal diameter:	DN50 / DN150	
Fluid group:	2	
Piping category:	I	
Compliance module:	A	
Support class:	S1	

All GRE (Glass fibre Reinforced Epoxy) pipeline materials will be new, fresh and free from all detrimental defects and imperfections an only be used for production after having been controlled and approved by the manufacture in accordance with ISO 14692 "Glass-reinforced plastics (GRP) piping".

Testing and controlling will be performed according to the relevant methods.

The basic materials will be combined into pipes and fittings which will meet the following requirements as minimum:

- The resin will be epoxy resin Epikote 828 or equivalent.
- The curing agent will be an aromatic or cyclo-aliphatic amine type depending on the RTRP-system and/or fabrication method.

- As reinforcement of the thermosetting resin, two types of glass with a low alkali content will be used.
- C-glass or polyester non-woven will be used as reinforcing material for the chemically resistant inner layer (liner) and the thickness will be 0.5 mm minimum.
- E-glass will be used as reinforcing material for the structural wall. This type of glass will appear in form of continuous roving or woven cloth. Roving will be used in the filament winding process for production of pipes and woven glass fabrics will be used for production of fittings and as local reinforcement for all products.
- The outer topcoat of the pipes and fittings will consists of a UV resistance resin rich layer with a thickness of 0.3 mm minimum.
- CJ (adhesive bonded conical joints) for DN < 80 will be jointed by use of a two component epoxy resin mixture.
- RSLJ (Rubber Seal Lock Joints) for DN ≥ 80 will be sealed by use of rubber ring made of NBR (nitril butadiene rubber).
- RSLJ locking strip will be made of PVC.
- FR (fire resistance) barrier integrated in the outer surface will be made of phenol coating and with a thickness of 5 mm (optional).
- CST pipes with electrical conductive liner will be made by a structural wall with integrated carbon fibres in order to avoid static electricity (optional).

All structural piping and fittings materials are assumed to have the following material characteristics (GRE materials (ω=55º)) :

Axial design stress	Sa = 40 MPa
Hoop design stress	Sh = 63 MPa (HDS=Hydrostatic Design Stress, 50 years acc. to ASTM D 2992 B)
Axial tensile modulus	Ex = 10000 MPa
Hoop tensile modulus	Eh = 20500 MPa

Shear modulus Es = 11500 MPa

Temperature correction factor $R_{E1\text{-}axial}$ = 0,87 and $R_{E4\text{-}hoop}$ = 0,90 for T=60ºC

Poisson ratio Nxy = 0,65 (axial/hoop)

Poisson ratio Nyx = 0,38 (hoop/axial)

Coefficient of exp. $\gamma_L = 2.0x10^{-5}$ mm/mmºC

GRE pipe density δ_{gre} = 1850 kg/m^3

15.7.3 Fire hydrants

15.7.3.1 Fire hydrants on the bridge

The fire hydrants on the bridge will be a type with pressure reduction to ensure the outlet pressure not to exceed 6.9 bar.

- Flow: 1,000 l/min (60 m3/hour or 16.6 l/sec.)
- Residual pressure: 6.9 bar (g)
- Dimension: DN 65

All hydrants will be provided with Fire hose connection (UNI70)

15.7.3.2 Fire hydrants in towers

The fire hydrants in the towers will be a type with pressure reduction to ensure the outlet pressure not to exceed 4 bar.

- Flow: 300 l/min (18 m3/hour or 5 l/sec.)
- Residual pressure: 4 bar (g)
- Dimension: DN 65

All hydrants will be provided with Fire hose connection (UNI70)

15.7.4 Wash valves

15.7.4.1 Wash valves on the bridge

The wash valves on the bridge will be ball valves.

- Flow: 125 l/min (7.5 m3/hour or 2,08 l/sec.)
- Minimum pressure: 4 bar(g)
- Dimension: DN 32

All wash valves will be provided with hose connections.

15.7.4.2 Wash valves in towers

The wash valves in the towers will be a type with pressure reduction to ensure the outlet pressure not to exceed 4 bar.

- Flow: 125 l/min (7.5 m3/hour or 2,08 l/sec.)
- Residual pressure: 4 bar(g)
- Dimension: DN 32

All wash valves will be provided with hose connections.

16 Drainage

16.1 Purpose

The purpose of the drainage system is to collect first flush of storm water from the bridge decks and treat it at land based facilities before discharge to the sea.

Secondly the purpose is to provide overflow possibilities at the bridge in order to better control flooding of the bridge deck.

16.2 Norms and standards

The drainage systems is designed according to rain intensity definition of First Flush as indicated in the reference code also "D.L. Regione Lombardia n. 62 del 27/05/1985 Art. 20".

16.3 System description

On each of the three bridge girders will water collection gullies be connected to longitudinal collector drain pipes located inside the structures. Drainage in pipes will be achieved by gravity.

To ensure self cleaning will the gully connection pipes be sloping towards the collector pipes.

The longitudinal collector pipes will follow the bridge slope and increase in diameter from the middle of bridge.

In order to compensate the major expansion of bridge at the terminal structures will the collector pipes be constructed with expansion loop arrangements. Further, will differences in thermal expansion of the steel bridge and drain pipes be taken up by anchor pipe supports and guided slide supports.

The bridge collector pipes will at the terminal structure lead the drain water through reception chambers, sand traps, reservoirs and oil separator before outlet to the Messina Strait.

16.4 Design requirements

16.4.1 Rain Intensity (First Flush)

First flush rain is 5 mm evenly distributed rain water supplied to the bridge surface during 15 minutes (Rain intensity 20 mm/hr.).

First flush rain will for each side of the bridge accumulate to a flow of 326 l/sec.

16.4.2 Catchment area

The bridge is sloping from the middle towards each shore sides. The middle of the bridge is therefore the start of the catchment areas.

The total catchment area for each road girder section is 2.2 ha (~ 1,833 metres in length x 12m of width).

The total catchment area for the rail girder is 1.4 ha (~ 1,833 metres in length x 7.5m of width).

16.4.3 Slopes

The design slope towards Calabria is 0.85 %.

The design slope towards Sicily is 1.5 %.

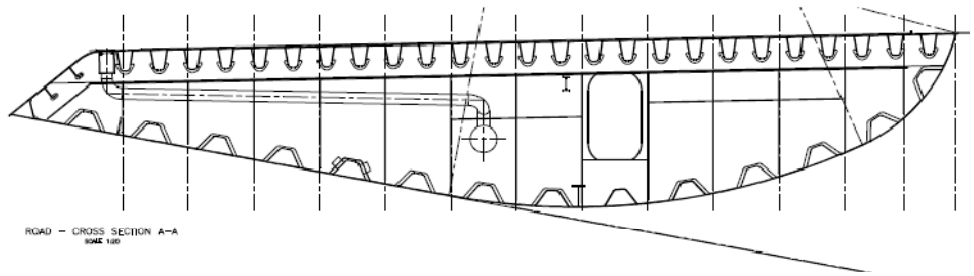
The design slope of gully connection pipes to collector pipes is 1.5 %

16.4.4 Spacing of Gullies

Gullies will be spaced every 15 meters.

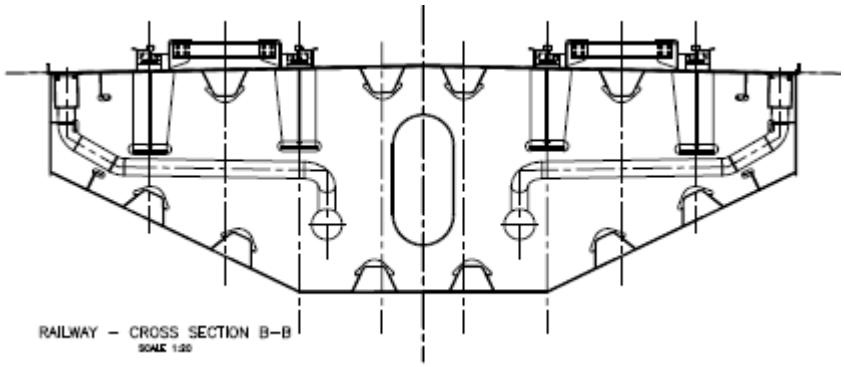
16.4.5 Drain pipes

The drainage of each road girder will be facilitated by one carrier drain pipe in the entire length of the bridge starting from the middle.

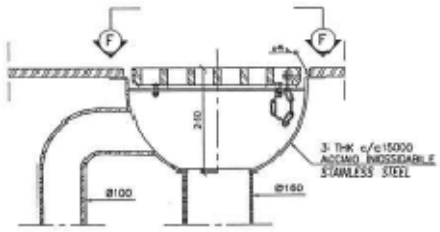


Section in road girder

The drainage of the railway will be facilitated by two carrier drain pipes in the entire length of the bridge starting from the middle.



Section in rail girder



Section showing overflow from gully to the sea

16.4.6 Vertical downpipes

Vertical downpipes at the expansion loops will be provided to discharge water from bridge deck level to facilities at ground level. Provisions will be made to ensure ventilation of the down pipes both at bridge deck and at ground level. The pipes are ventilated in order to keep minimise inflow velocity to the reception chamber.

16.4.7 Reception Chambers

Reception chambers in connection with sand trap will accommodate the large vertical drop from the bridge deck to ground level.

Down pipes from the bridge will discharge freely. Water level in the chamber will be below the invert levels of the discharge pipes from the bridge.

The reception chambers will distribute the design peak flow of 326 l/s to treatment facilities. Furthermore will the chambers be able to receive the full amount of discharge flow ~1000 l/s from the bridge which occurs when the drainage system at the bridge is surcharged.

The reception chambers will accommodate a high inflow velocity up to 8 m/s. The water velocity will in the reception chamber be reduced to 0.3 m/s before entering the sand trap.

16.4.8 Sand Trap

The sand trap will be designed for the design peak flow based on the first flush principle.

	Design flow [l/s]	Width [m]	Length [m]	Depth [m]	Pit for sand collection [m]
Sand trap dimensions	326	5	2.5	2	0.5

The minimum sand grain size to be settled is 0.5 mm.

16.4.9 Retention Reservoirs

The reservoir is designed to even out the flow to the oil and petrol separator thus maximizing the amount of drain water being treated before discharge to the sea.

The reservoirs will be designed for a higher return period than the gravity system on the bridge. This is to treat more drain water before discharge to the sea - without additional provisions of drain system on the bridge.

The storage volume of the retention chamber will therefore exceed the theoretically needed in order to even out the peak flows and be based on an estimated "first flush volume". - A 2,000 m^3 retention reservoir is selected.

16.4.10 Oil and Petrol Separators

Oil/petrol separation will comply with EN 858-1:2002 and EN 858-2:2003, Class I separators.

The capacity of the oil and petrol separator will have a capacity of 20 l/s.

16.5 Material - Drain pipes

All GRE materials to be used for pressure containing parts in the drainage piping distribution lines inside the bridge girders will be chemically, structurally and mechanically compatible with the materials specified in this specification.

The GRE drainage piping systems will be designed in accordance with EN 13480, ISO 14692 and to fulfil the following design conditions:

Design conditions	**Utility & fire distribution at bridge girders**	**Applicable type & pressure class**
Design pressure:	16 Bar (PN 16)	DN100 - DN400 EST25
Design temperatures:	-5 / + 43 ºC	
Nominal diameter:	DN100 - DN400	
Fluid group:	2	
Piping category:	I	
Compliance module:	A	
Support class:	S1	

All GRE (Glass fibre Reinforced Epoxy) pipeline materials will be new, fresh and free from all detrimental defects and imperfections an only be used for production after having been controlled and approved by the manufacture in accordance with ISO 14692 "Glass-reinforced plastics (GRP) piping".

Testing and controlling will be performed according to the relevant methods.

The basic materials will be combined into pipes and fittings which will meet the following requirements as minimum:

- The resin will be epoxy resin Epikote 828 or equivalent.
- The curing agent will be an aromatic or cyclo-aliphatic amine type depending on the RTRP-system and/or fabrication method.

- As reinforcement of the thermosetting resin, two types of glass with a low alkali content will be used.
- C-glass or polyester non-woven will be used as reinforcing material for the chemically resistant inner layer (liner) and the thickness will be 0.5 mm minimum.
- E-glass will be used as reinforcing material for the structural wall. This type of glass will appear in form of continuous roving or woven cloth. Roving will be used in the filament winding process for production of pipes and woven glass fabrics will be used for production of fittings and as local reinforcement for all products.
- The outer topcoat of the pipes and fittings will consists of a UV resistance resin rich layer with a thickness of 0.3 mm minimum.
- CJ (adhesive bonded conical joints) for DN < 80 will be jointed by use of a two component epoxy resin mixture.
- RSLJ (Rubber Seal Lock Joints) for DN ≥ 80 will be sealed by use of rubber ring made of NBR (nitril butadiene rubber).
- RSLJ locking strip will be made of PVC.
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- CST pipes with electrical conductive liner will be made by a structural wall with integrated carbon fibres in order to avoid static electricity (optional).

All structural piping and fittings materials are assumed to have the following material characteristics (GRE materials (ω=55º)) :

Axial design stress	Sa = 40 MPa
Hoop design stress	Sh = 63 MPa (HDS=Hydrostatic Design Stress, 50 years acc. to ASTM D 2992 B)
Axial tensile modulus	Ex = 10000 MPa
Hoop tensile modulus	Eh = 20500 MPa

Shear modulus Es = 11500 MPa

Temperature correction factor $R_{E1\text{-}axial}$ = 0,87 and $R_{E4\text{-}hoop}$ = 0,90 for T=60ºC

Poisson ratio Nxy = 0,65 (axial/hoop)

Poisson ratio Nyx = 0,38 (hoop/axial)

Coefficient of exp. $\gamma_L = 2.0x10^{-5}$ mm/mmºC

GRE pipe density δ_{gre} = 1850 kg/m^3

16.6 Function and operation description

The drainage systems will function and operate in the following way.

16.6.1 During a rain event with rain intensities below 20 mm/hr (First flush)

Rain water will collect at the bridge deck and runoff will be collected by gullies per every 15 meters. From the gullies the water will be transported towards land where water will be treated before discharge to the sea.

16.6.2 During a rain event with rain intensities above 20 mm/hr

Rain water will collect at the bridge deck and runoff will be collected by gullies per every 15 meters. From the gullies a amount of the water will be transported towards land where some of the water will be discharged to the sea without treatment (bypassing the treatment facilities).

The drainage system will be surcharged and overflows from gullies will discharge the excess water directly from the bridge to the sea. Overflow water will not be treated and is assumed to be clean water.

16.6.3 During a spill accident at the bridge

If a spill of fluids occurs at the bridge the fluids will be collected by gullies and transported towards land where treated before discharge to the sea. It will be possible to manually close off the outlet to the sea and intercept the pollution and transport it to appropriate treatment facilities elsewhere.

17 Safety systems

17.1 Fire detection in technical rooms/substations

17.1.1 General

All electrical substations will be equipped with automatic fire detection and fighting system.

The fire detection and fighting system will be established at following locations:

- Substation QMT-SS-Sicilia
- Substation QMT-SS-Calabria
- Substation QMT-G-Sicilia
- Substation QMT-G-Calabria
- Eight substations QMT-A1 to A8 on the bridge deck
- Two substation QMT-A-11&12 Torre Sicilia
- Two substation QMT-A-21&22 Torre Calabria
- Substation QMT-A-31 Anchor Sicilia
- Substation QMT-A-41 Anchor Calabria
- Substation Water Pump building Sicilia
- Substation Water Pump building Calabria

The design, workmanship, materials and equipment associated will comply with the latest issue, including all amendments, of the appropriate standard Specifications. Particularly relevant Standard Specifications are as follows:

Code/Standard	Title
Fire safety	Local authorities fire safety requirements
EN-54 & EN 15004.1	European norms of fire detection and alarm systems
EN 60947-1	Low-voltage switchgear and control gear
EN 15004.1	Fixed fire fighting systems - Gas extinguishing

	systems

17.1.2 Fire detection

The fire detection system will be based on independent, local fire alarm control panels (FACP) and fire detectors.

The detectors will be universal optical smoke detectors in accordance with EN 54-7 and EN 54-17.

The detector will comply with the following minimum specifications:

- Designed for suited to early detection of smouldering fires
- Equipped with built-in response indicator (red LED) for local status indication
- Addressable detector
- Will be secured in the base with a vibration-proof fitting
- Designed for industrial applications not less than IP 42 to IEC 60529

Detectors will be installed so that their sensitive elements are within the top 5% of the room height.

The operating radius of each smoke detector will not be more than 7,0 m, if nothing else recommended by the manufacture.

The fire alarm control panels will operate with smoke detectors installed in the rooms with equipment and rooms in the substation housing.

The fire alarm control panels will control also fire extinguishing system.

The fire alarm control panels will comply with international standards (EN 54-2/4, EN 12094-1,...).

Fire alarm control panel (FACP) will comply with the following specifications:

- FACP will be networked peer to peer, via system dedicated network (single mode optic fibers in BAN) that are distributed along the bridge
- FACP will have the capability of being integrated with the CMS/SCADA System for pre-alarm, fire alarm, faults and device warning signals.

- MFACP will incorporate a number of features to allow easy operation through a user-friendly menu. It will have a large graphical LCD display and durable switches/keypad. For reliability it will has its own on-board circuit protection and multiprocessor architecture.
- FACP will be programmable ON and OFF-site by using the keypad and, also by connecting a laptop PC to the communication port on the main processor/display board.
- All configured information will be protected from loss in the event of a total mains and stand-by power supply failure.
- FACP will be a modular construction capable of monitoring the detection loops (signaling line circuits) and notification circuits.
- Each Input device will have an allocated character text message, the message will be programmable, and also each device will be linked to a software zone.
- FACP will have integral facilities for control of outputs to alarm bells and auxiliary devices.
- FACP will have a walk test facility to periodically test the detectors without having to continually manually reset from the panel.
- FACP will have a graphical liquid crystal display. The display will illuminate to assist view under dim ambient lighting conditions.
- FACP will have internal memory lock to prevent unauthorized data entry and will also have enough memory events log for system information.
- Pre-warnings and faults will be indicated as for a fire alarm via a built in graphical LCD display along with an associated LED. A buzzer will sound in the event of an alarm, pre-warning of fault.
- Individual sensitivity selection for each detector.
- Sensitivity monitoring that complies with EN standards sensitivity testing requirements.
- Peak value logging allowing accurate analysis for sensitivity selection.
- Automatic environmental compensation.
- Multi-stage alarm operation.
- Enclosure not less than IP 42
- 230V, 50 Hz power supply

- The batteries and charger will maintain the entire system, plus 20% for a minimum period of 24 hours stand-by in the event of mains failure. After 24 hours has elapsed the system will be capable of initiating a full global alert and evacuate signal for a minimum period of 30 minutes.

FACP will be capable of field programming in two modes:

- Front panel programming through the use of the on-board display and the programming switches on the system control unit and the individual input and output circuits including zones, notification circuits, and relays. While in the programming mode, the control panel will provide a fire alarm over-ride to assure that no alarms will be missed or lost. Programming will be password protected and will not require the use of an additional programming appliance or tool

- Computer programming through the use of a field configuration program dedicated software package. The system configuration will be saved to a disk for easy access and field program modification without the addition of programming hardware. While in the programming mode, the control panel will provide a fire alarm over-ride to assure that no alarms will be missed or lost. A hard-copy of the final system configuration showing all inputs, outputs, descriptions, addresses, programming matrixes, etc will be provided

Fire detectors will be smoke detectors. The smoke detectors will be installed above the relevant electrical enclosure.

In bridge substations located inside enclosures on the bridge deck the fire detectors will be installed inside each section of the substation housing.

The fire alarms generated by the fire detectors will be transmitted to the CMS/SCADA system for indication of their status and location.

Between control panels optical fiber cables will be used. The fiber cable will be fire resistant type manufactured to BS 7629-1 and tested to EN50200 Class PH120.

17.2 Fire fighting in technical rooms/substations

The fire extinguishing system will be based on fire protection fluids and triggered by the automatic detection. The inert extinguishing agent will comply with the recommendations in REGULATION (EC) No 842/2006 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 17 May 2006 on certain fluorinated greenhouse gases.

The system will be stand alone clean agent Novec 1230 fire extinguishing system which consists of the extinguishing agent stored in high strength steel cylinders with actuators for automatic and

manual release of the agent into the hazard area. Novec 1230 fluid is a Flurorinaized Ketone (FK-5-1-12) Dodecafluoro-2-methylpentan-3-one) compound of carbon, fluorine and oxygen (CF3CF2C(O)CF(CF3)2). It is colourless, electrically non-conductive and has a low odour. It suppresses fire by a combination of chemical and physical mechanisms with minimal affect on the available oxygen. This allows people to see and breathe, permitting them to leave the fire area safely.

The agent will be distributed and discharged into the hazard area through fixed piping and nozzles.

The fire detectors will automatically activate the fire extinguishing system. The design concentration of 5% will be used. The cylinders for installation in bridge substations will be as follows:

- 1 cylinder 45 kg in tower substations
- 1 cylinder 45 kg in bridge deck substations

Fire detection and fighting in the substations outside the towers and bridge deck are belonging to the installations in the substations buildings and are described in other CdP.

A Manual call point (MCP) will be installed at emergency exits from substation in buildings on land.

Furthermore, MCP will be installed on both sides of enclosure of each substation on the bridge deck.

MCP will have a very low standby current, incorporating a status LED, which flashes when polled or is continuously lit when operated.

The addressable code for the device will be electronically programmed and stored in the call point.

The manual call point will be pull type or non-breakable glass, protection class IP 44.

17.3 Portable fire extinguishers

All substations will be equipped with portable fire extinguishers.

All portable fire extinguishers are provided with switches which signal the status of the extinguisher (in place/removed) to the operator via the SCADA system

FACP will have secured control switches for silence alarms, acknowledgement, and reset functions. Those switches will be accessible using high level of security password.

17.4 Control by CMS

Status information is exchanged with the CMS/SCADA.

The following signals will be sent to SCADA from each FACP:

- for pre-alarm,
- fire alarm, faults
- device warning signals
- portable extinguisher (in place/removed)
- automatic fire extinguishing system released
- automatic fire extinguishing system failure

18 Interfaces

18.1 External Interfaces

A number of the M&E systems will be connected to facilities which either are provided by the local utilities, or will continue outside the present contract limits.

The interfaces must be identified as early as possible in the design.

18.2 Internal Interfaces

A number of the M&E systems will be connected to facilities which are outside the bridge scope of work, influence other designs or continue outside the present contract limits.

The interfaces must be identified as early as possible in the design.

19 Installation and Testing

All equipment will be tested prior to delivery to the manufactures standard specification and as specified in the specification GCG.G.03.05 of 15 July 2004.

The equipment will be installed as required by the manufactures installation instructions and tested as part of the commissioning of the installations.

Appendix 1 - Contractual Documents Electrical and Mechanical

List of contractual documents for electrical and mechanical installations and systems.

Index	Title	Document No.	Rev. date
C Preliminary Design	Table of Contents		19.11.04
C-1	Table of Contents	PP1R 001	
	Illustrative Relations	PP1R 002	01.12.02
	Draft safety plan	PP1R004	01.12.02
C-2	Table of Contents	PP2RA0	01.12.02
	Climatic conditions	PP2RA25	
C-3	Technical Relations	PP 2R B0 001	01.12.04
D	Unit prices	No no.	No date
F Engineering	Scope of Works	GCGF01.01	07.10.04
	Codes and Standards	GCGF01.02	15.10.04
	Basis of Design and Expected Performance Levels	GCGF04.01	27.10.04
	Planning	GCGF05.02	10.06.04
	Development of design, requirements and guidelines	GCGF05.03	22.10.04
	System Context	No no.	
	Management & control system	GCGF06.01	12.10.04
G Construction	General	GCGG01.01	13.07.04
	Quality of Materials	GCGG01.02	13.07.04
	Requirements for navigation	GCGG01.03	18.07.04
	Electrical, mechanical and special works (installations)	GCGG03.05	15.07.04

Appendix 2 - Standards

TECHNICAL NORMS AND APPLICABLE LAWS

The main applicable Laws and Technical Norms for the design of the M&E installations are:

- DPR n. 547/55
- DPR n. 459/96….direttive d89/392/CEE, 91/368/CEE, 93/44/CEE e 93/68/CEE
- Legge n. 46 , 05/03/1990
- DPR n. 447/91….Legge n. 46 , 05-03-1990
- Legge n. 615 , 13/07/1966
- Legge n. 10 , 09/01/1991
- UNI EN 12845:2004 + A2:2009; Fixed fire fighting systems - Automatic sprinkler systems - Design, installation and maintenance
- UNI 10779 Impiante de estinzione incendi, Reti di idranti, Progettazione, installazione ed esercizo. (Fire fighting equipment, Hydrant systems, Design, installation and operation).
- UNI 11292 Locali destinati ad ospitare unità di pompaggio per impiianti antincendio. Caratteristiche construttive e funzionali.
- The drainage systems is designed according to rain intensity definition of First Flush as indicated in the reference code also "D.L. Regione Lombardia n. 62 del 27/05/1985 Art. 20".
- UNI EN 40 “Lighting Poles”
- UNI 10380 “Lighting Engineering. Internal Lighting with artificial Ligth”
- UNI 1838 “Application of Lighting Engineering – Emergency Lighting “
- UNI 10819 “ External lighting, requirements for the reduction of the upwards lighting”
- UNI 10439 “Lighting Requirements for motorized roads traffic”
- CEI 0-16 "Regola tecnica di referimento per la connessione utenti attivi e passive alle reti AT ed MT delle imprese distributrici di energia elettrica" (“Reference technical rules for the

connection of active and passive consumers to the HV and MV electrical networks of distribution Company")

- CEI EN 62305-1 **(CEI 81-10/1)** - parte 1 : principi generali
- CEI EN 62305-2 **(CEI 81-10/2)** - parte 2 : valutazione del rischio
- CEI EN 62305-3 **(CEI 81-10/3)** - parte 3 : danni materiali alla struttura e pericolo per le persone
- CEI EN 62305-4 **(CEI 81-10/4)** : parte 4 : impianti elettrici ed elettronici all'interno delle strutture
- Norma CEI 11-1 - "Impianti di produzione, trasporto e distribuzione di energia elettrica. Norme generali"
- Norma CEI 11-17 - "Impianti di produzione, trasmissione e distribuzione di energia elettrica. Linee in cavo"
- CEI 11-20 2000 IVa Ed. Impianti di produzione di energia elettrica e gruppi di continuita collegati a reti I e II categoria.
- CEI 11-25 2001 IIa Ed. (IEC 60909-2001): Correnti di cortocircuito nei sistemi trifasi in corrente alternata. Parte 0: Calcolo delle correnti.
- CEI 11-28 1993 Ia Ed. (IEC 781): Guida d'applicazione per il calcolo delle correnti di cortocircuito nelle reti radiali e bassa tensione.
- CEI 17-5 VIIIa Ed. 2007: Apparecchiature a bassa tensione. Parte 2: Interruttori automatici.
- CEI 23-3/1 Ia Ed. 2004: Interruttori automatici per la protezione dalle sovracorrenti per impianti domestici e similari.
- CEI 33-5 Ia Ed. 1984: Condensatori statici di rifasamento di type autorigenerabile per impianti di energia a corrente alternata con tensione nominale inferiore o uguale a 660V.
- CEI 64-8 VIa Ed. 2007: Impianti elettrici utilizzatori a tensione nominale non superiore a 1000V in corrente alternata e a 1500V in corrente continua.
- IEC 364-5-523: Wiring system. Current-carring capacities.

- IEC 60364-5-52: Electrical Installations of Buildings - Part 5-52: Selection and Erection of Electrical Equipment - Wiring Systems.
- CEI UNEL 35023 2009: Cavi per energia isolati con gomma o con materiale termoplastico avente grado di isolamento non superiore a 4- Cadute di tensione.
- CEI UNEL 35024/1 1997: Cavi elettrici isolati con materiale elastometrico o termoplastico per tensioni nominali non superiori a 1000 V in corrente alternata e a 1500 V in corrente continua. Portate di corrente in regime permanente per posa in aria.
- CEI UNEL 35024/2 1997: Cavi elettrici ad isolamento minerale per tensioni nominali nonsuperiori a 1000 V in corrente alternata e a 1500 V in corrente continua. Portate di corrente in regime permanente per posa in aria.
- CEI UNEL 35026 2000: Cavi elettrici con materiale elastomerico o termoplastico per tensioni nominali di 1000 V in corrente alternata e 1500 V in corrente continua. Portate di corrente in regime permanente per posa interrata.
- CEI EN 50272: Prescrizioni di sicurezza per batterie di accumulatori e loro installazioni.
- IEC 60287: Electric cables - Calculation of the current rating

Upon approval by the Owner, other Technical Norms and Standards which are more restrictive and recognized by an international authority committee can be used. Furthermore, these norms and standards must be independent from a specific supplier or manufacturer standard.

In the case that the National Laws are more restrictive than the Technical Norms or the ones suggested by the General Contractor, the National Standards will prevail.

In general, in case of conflicts, the most restrictive Standards or Laws will be applied.

The General Contractor will submit within 20 days from the beginning of the designing a detailed list of the Norms and Standards intended to be used for the Design, Manufacturing and testing of the materials and equipment.

Appendix 3 - Design Life

All materials and equipment will be designed for long life with a minimum of maintenance.

Routine maintenance will, as far as possible, not require the services of highly skilled personnel.

The required minimum design lives of individual items of equipment covered by this Design Criteria are as follows:

Electrical Power Supply		
11 kV HV on bridge Substation shelter	30 years	
11 kV HV Switchgear	30 years	
11 kV HV Transformers	30 years	
11 kV HV open air cabling	30 years	
11 kV HV underground cabling	50 years	
Instrumentation	15 years	
Electrical low voltage equipments (switchboards, control panels)	25 years	
Electrical low voltage cabling	25 years	
Road lighting luminaire	15 years	
Navigation lighting	10 years	
Ups Systems	20 years	
Batteries.	5 years	
Emergency Stand by Generators	25 years	
External parts of the lightning protection system	25 years	
Earthing and bonding system	30 years	
Control and communication Systems		
Fire detection systems	20 years	
CCTV systems	15 years	
Access control system	15 years	
Emergency telephone System	15 years	
Structural Health Monitoring Systems	25 years	
VMS and VS system	15 years	
Weather monitoring system	10 years	
Fibre Optic Cable & Accessories	25 years	
Fibre Optic transmission system	15 years	
Copper transmission Cable & Accessories	25 years	
Multiplex equipments	15 years	
Radio System.	15 years	
Antennas	15 years	
PABX Equipments	15 years	
Equipments Management Systems	15 years	
Telemetry Systems	15 years	

SCADA and Server Computers	5 years	
Mechanical.		
Block valves	25 years	
Check valves	25 years	
Drain valves	25 years	
Pressure relief valves	25 years	
Orifice plate	10 years	
Ductile Iron Pipe & Fittings	50 years	
GRE Drainage pipe	50 years	
GRE Water Fire Fighting networks.	50 years	
Plumbing network and equipment in building	25 years	
Flange adaptors	25 years	
Flexible couplings	25 years	
Air supply & Vent Pipe	25 years	
Booster pumps system	15 years	
Dewatering pumps	12 years	
Oil separator	25 years	
HVAC/dehumidification central Unit	15 years	
Air distribution system	25 years	
Fuel storage tank	20 years	
Road lighting poles	15 years	
Gantry for VMS & VS	20 years	
Access ladders & Platform	20 years	
Gate and barriers	15 years	
Under bridge motorised maintenance Platform	15 years	
Cable trays and cable supports	15 years	

Appendix 4 – UPS Calculated sizes

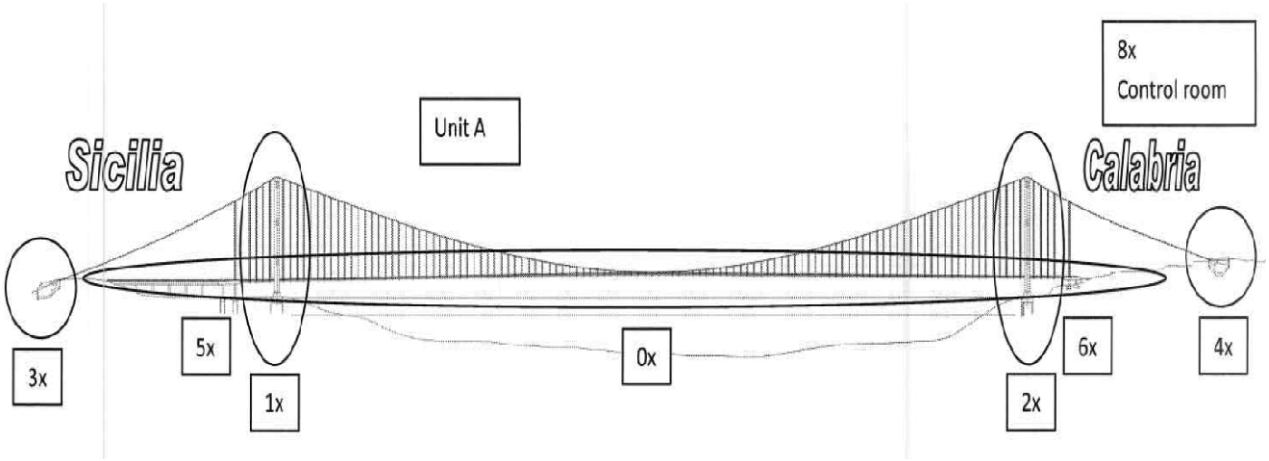
The calculated UPS sizes are presented in the table below.

UPS No.	Location	Power consump-tion [kW]	UPS size [kWh]
BNA01	QMT-A1	25	13
BNA02	QMT-A2	25	13
BNA03	QMT-A3	25	13
BNA04	QMT-A4	25	13
BNA05	QMT-A5	25	13
BNA06	QMT-A6	25	13
BNA07	QMT-A7	25	13
BNA08	QMT-A8	25	13
BNA10	QMT-G-Sicilia	8	8
BNA11	QMT-A11	11	15
BNA12	QMT-A12	15	8
BNA13	QMT-A13	15	8
BNA20	QMT-G-Calabria	8	4
BNA21	QMT-A21	11	15
BNA22	QMT-A22	15	8
BNA23	QMT-A23	15	8
BNA31	QMT-A31	8	4
BNA41	QMT- A41	8	4
BNA51	QMT-SS-Sicilia	8	4
BNA61	QMT-SS-Calabria	8	4

For background details please see Mechanical and Electrical Systems, Calculation Report CG1000-P1RDPIT-M4GC000000-01.

Appendix 5 – Tag numbering system

For the design the following tag numbers will be used



Unit number

The Bridge is regarded to be 1 unit (Unit A) with subsystems. The unit number is normally omitted from the equipment numbers shown on the drawings.

Sub-system

Sub-systems follow the lettering system of the tag number.

Sub-system number

The subsystem number consists of 2 digits. The first digit relates to the location on the bridge. See drawing above and text below.

0x – Bridge deck and girders; 1x – Tower Sicily; 2x – Tower Calabria; 3x – Anchor block Sicily; 4x – Anchor block Calabria;
5x – Pumping stations, Sicilia; 6x – Pumping stations, Calabria; 7x – Not used; 8x – Control building; 9x – Not used

Example (An electrical motor in the dehumidification system)

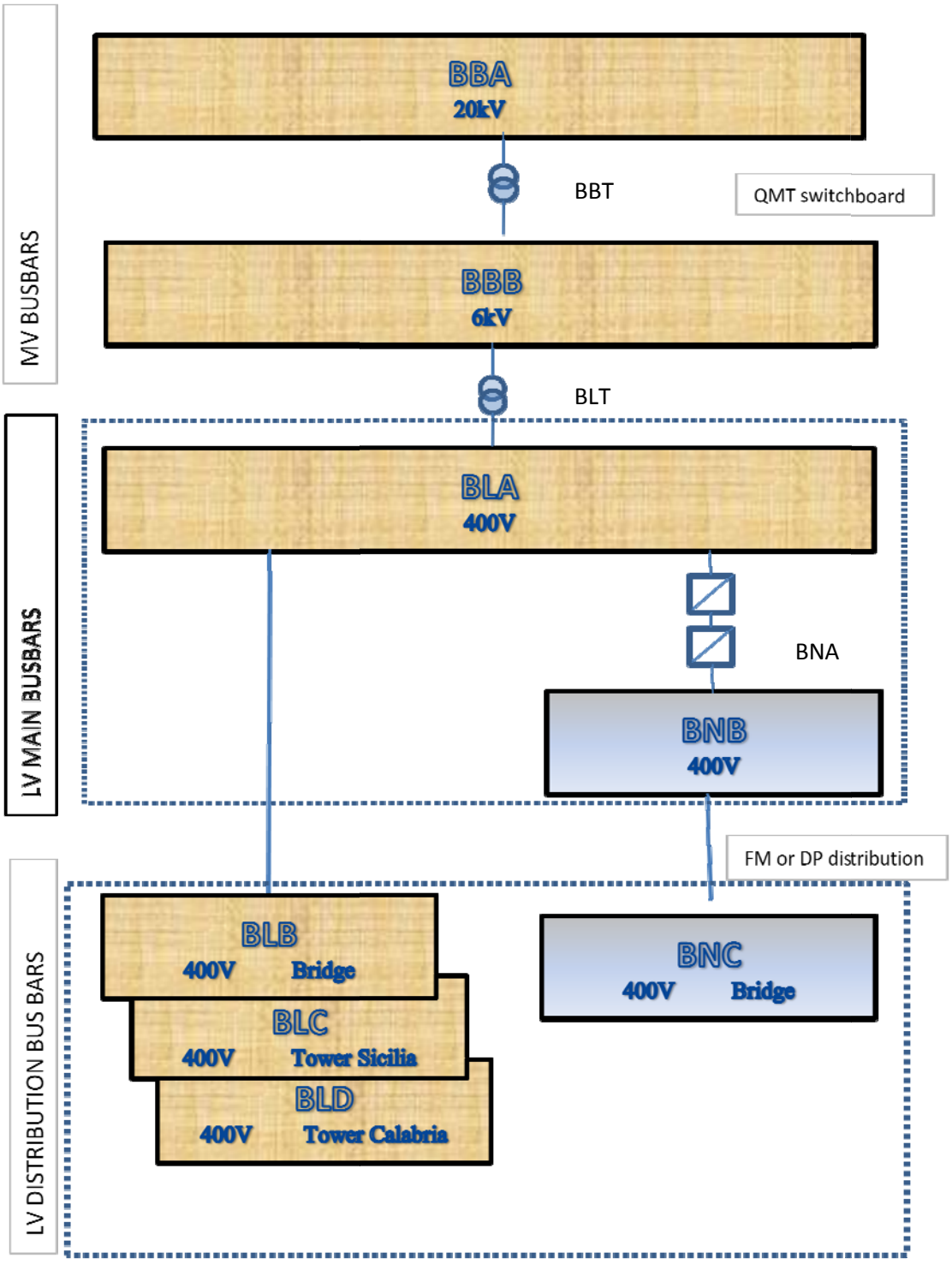
QMA05AH001A-M01	system	Dehumidification
QMA05AH001A-M01	Systems number	Located in the bridge girders
QMA05AH001A-M01		System no 5
QMA05AH001A-M01	Unit	Ventilation unit
QMA05AH001A-M01	Unit number	Unit 001A
QMA05AH001A-M01	Equipment code	Electrical
QMA05AH001A-M01	Item	Motor
QMA05AH001A-M01	Item number	Motor 01

SYSTEM	MAIN GROUP (1)	EQUIPMENT UNIT CODE (2)	ITEM
Buffers	MEY		
Power and control panels		GW	
Communication Transceiver		BZ	

Dehumidification system	QMA		
Ventilation systems	SAA		
Ventilation unit and AC (air condition unit)		AH	
Communication system	CY		
Lighting installations			
HF-carrier telephone system	CYK		
Telephone system	CYA		
Elevators	SNA	AEnnnA	-M
UPS (Charger – Converter)	BNA		
UPS Switchboards – level1	BNB		
UPS Switchboards – level2	BNC		
Fire fighting system	SGA	AP	KP The motor and pump is numbered as one integrated unit. Pump + electrical or diesel motor.
Fire fighting system – Fire hydrant	SGA	AZ	

Fire fighting system – Fire pump units	SGA	AP	
Water supply . (Is integrated with the fire fighting system)	GAD	AP (pump unit) AZ (hydrant)	KP (pump)

Electrical Switchboard hierarchy



SUBSTATIONS - QMT

Substation name	20kV swb	6kV swb	400V bus bar normal/essential	UPS bus bar	UPS
QMT - 01	---	BBB01	BLA01	BNB01	BNA01
QMT - 02	---	BBB02	BLA02	BNB02	BNA02
QMT - 03	---	BBB03	BLA03	BNB03	BNA03
QMT - 04	---	BBB04	BLA04	BNB04	BNA04
QMT - 05	---	BBB05	BLA05	BNB05	BNA05
QMT - 06	---	BBB06	BLA06	BNB06	BNA06
QMT - 07	---	BBB07	BLA07	BNB07	BNA07
QMT - 08	---	BBB08	BLA08	BNB08	BNA08
QMT - 11	---	BBB11	BLA11	BNB11	BNA11
QMT - 12	---	BBB12	BLA12	BNB12	BNA12
QMT - 13	---	BBB13	BLA13	BNB13	BNA13
QMT - 14	---	BBB14	BLA14	---	---
QMT - 21	---	BBB21	BLA21	BNB21	BNA21
QMT - 22	---	BBB22	BLA22	BNB22	BNA22
QMT - 23	---	BBB23	BLA23	BNB23	BNA23
QMT - 24	---	BBB24	BLA24	---	---
QMT - 31	---	BBB31	BLA31	BNB31	BNA31
QMT - 41	---	BBB41	BLA41	BNB41	BNA41
QMT - G - Sicilia	---	BBB10	BHA10	BNB10	BNA10
QMT - G -Calabria	---	BBB20	BHA20	BNB20	BNA20
QMT - SS - Calabria	BBA20	---	BHA61	BNB61	BNA61
QMT - SS - Sicilia	BBA10	---	BHA51	BNB51	BNA51

DISTRIBUTION BOARDS - DPB AND FM

Distribution board	Section	Essent/Normal bus bar	UPS busbar	UPS upstream bus bar	Upstram busbar	Section	Essent/Normal	UPS	UPS upstream bus bar	Upstram bus bar
DPB-06		BLB59	---	---	BLA05					
DPB-08		BLB49	---	---	BLA04					
DPB-10		BLB86	---	---	BLA08					
DPB-12		BLB87	---	---	BLA08					
DPB-52		BLC15	---	---	BLA11					
DPB-54		BLC16	---	---	BLA11					
DPB-72		BLD15	---	---	BLA22					
DPB-74		BLD16	---	---	BLA22					
FM 01	A	BLB11	BNC11	BNB01	BLA01	B	BLB21	BNC21	BNB02	BLA02
FM 02	A	BLB12	BNC12	BNB01	BLA01	B	BLB22	BNC22	BNB02	BLA02
FM 03	A	BLB13	BNC13	BNB01	BLA01	B	BLB23	BNC23	BNB02	BLA02
FM 04	A	BLB14	BNC14	BNB01	BLA01	B	BLB24	BNC24	BNB02	BLA02
FM 05	A	BLB15	BNC15	BNB01	BLA01	B	BLB25	BNC25	BNB02	BLA02
FM 06	A	BLB31	BNC31	BNB03	BLA03	B	BLB26	BNC26	BNB02	BLA02
FM 07	A	BLB32	BNC32	BNB03	BLA03	B	BLB27	BNC27	BNB02	BLA02
FM 08	A	BLB33	BNC33	BNB03	BLA03	B	BLB28	BNC28	BNB02	BLA02
FM 09	A	BLB34	BNC34	BNB03	BLA03	B	BLB29	BNC29	BNB02	BLA02
FM 10	A	BLB35	BNC35	BNB03	BLA03	B	BLB41	BNC41	BNB04	BLA04
FM 11	A	BLB36	BNC36	BNB03	BLA03	B	BLB42	BNC42	BNB04	BLA04
FM 12	A	BLB37	BNC37	BNB03	BLA03	B	BLB43	BNC43	BNB04	BLA04
FM 13	A	BLB38	BNC38	BNB03	BLA03	B	BLB44	BNC44	BNB04	BLA04
FM 14	A	BLB51	BNC51	BNB05	BLA05	B	BLB45	INCOMER	BNB04	BLA04
FM 15	A	BLB52	BNC52	BNB05	BLA05	B	BLB46	BNC46	BNB04	BLA04
FM 16	A	BLB53	BNC53	BNB05	BLA05	B	BLB47	BNC47	BNB04	BLA04
FM 17	A	BLB54	BNC54	BNB05	BLA05	B	BLB48	BNC48	BNB04	BLA04
FM 18	A	BLB55	BNC55	BNB05	BLA05	B	BLB61	BNC61	BNB06	BLA06
FM 19	A	BLB56	BNC56	BNB05	BLA05	B	BLB62	BNC62	BNB06	BLA06
FM 20	A	BLB57	BNC57	BNB05	BLA05	B	BLB63	BNC63	BNB06	BLA06
FM 21	A	BLB58	BNC58	BNB05	BLA05	B	BLB64	BNC64	BNB06	BLA06
FM 22	A	BLB71	BNC71	BNB07	BLA07	B	BLB65	BNC65	BNB06	BLA06

FM 23	A	BLB72	BNC72	BNB07	BLA07	B	BLB66	BNC66	BNB06	BLA06
FM 24	A	BLB73	BNC73	BNB07	BLA07	B	BLB67	BNC67	BNB06	BLA06
FM 25	A	BLB74	BNC74	BNB07	BLA07	B	BLB68	BNC68	BNB06	BLA06
FM 26	A	BLB75	BNC75	BNB07	BLA07	B	BLB81	BNC81	BNB08	BLA08
FM 27	A	BLB76	BNC76	BNB07	BLA07	B	BLB82	BNC82	BNB08	BLA08
FM 28	A	BLB77	BNC77	BNB07	BLA07	B	BLB83	BNC83	BNB08	BLA08
FM 29	A	BLB78	BNC78	BNB07	BLA07	B	BLB84	BNC84	BNB08	BLA08
FM 30	A	BLB79	BNC79	BNB07	BLA07	B	BLB85	BNC85	BNB08	BLA08
FM 72		BLD21	---	---	BLA22		---	---	---	
FM 74		BLD22	---	---	BLA22		---	---	---	
FM 76		BLD11	---	---	BLA21		---	---	---	
FM 78		BLD12	---	---	BLA21		---	---	---	
FM 80		BLD13	---	---	BLA21		---	---	---	
FM 82		BLD14	---	---	BLA21		---	---	---	
FM52		BLC21	---	---	BLA12		---	---	---	
FM54		BLC22	---	---	BLA12		---	---	---	
FM56		BLC11	---	---	BLA11		---	---	---	
FM58		BLC12	---	---	BLA11		---	---	---	
FM60		BLC13	---	---	BLA11		---	---	---	
FM62		BLC14	---	---	BLA11		---	---	---	

Appendix 6 –WiM and RWiM

WiM

A variety of Weigh-in-Motion (WiM) systems have been developed around a variety of technologies. New Weigh-in-Motion systems are being developed around new technologies. The Weigh-in-Motion market is dynamic. The most common Weigh-in-Motion systems include:

1) Load-cell

2) Bending-plate

3) Piezo-electric

Each system presents benefits but also limitations. The choice of system adopted is dependent on the requirements of the system. For example, high-precision weight measurement for law enforcement is achieved well with weigh-bridges based on load-cells. However weigh-bridges tend to require slow transition by the vehicle being weighed in order to achieve high accuracy. Clearly the installation of such a device for the measurement of all vehicles would require all vehicles to slow down in order to be weighed. This is feasible at gated toll stations, but would require a large number of devices to cover all of the toll lanes provided.

Bending-plate and piezo-electric WiM systems work to reasonable accuracies for traffic moving at motorway speeds. These technologies provide sufficiently accurate data for the statistical review of traffic and the development of Bridge Specific Assessment Live Loading. These sensors will detect vehicles without disrupting traffic flow. These sensors are ideal for installation on main thorough-fares such as motorways or dual-carriageways.

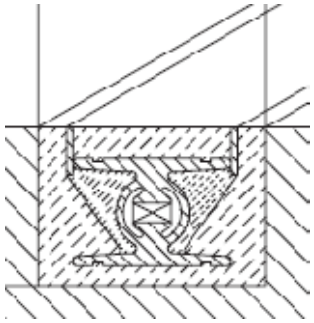
A variety of WiM systems can be adopted to present optimum solutions to a project's requirements. For example, if law enforcement is a requirement on a busy thorough-fare, then a lower accuracy WiM system could be adopted to filter out the traffic and identify those vehicles that are in exceedance of the limit, which can then be diverted onto a high-accuracy system for measurement as evidence for court.

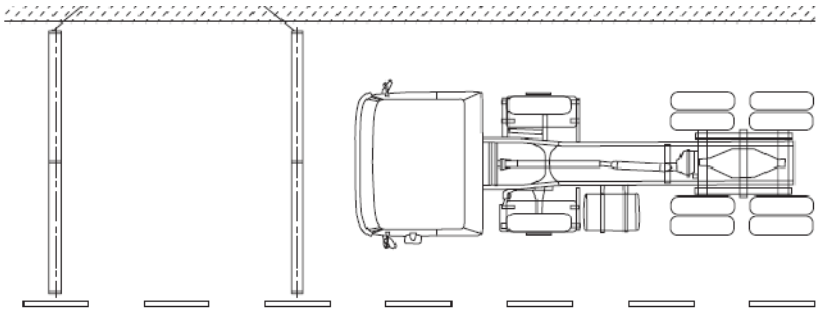
For the Messina bridge it is important to track the total traffic load on the bridge. An accurate assessment of total traffic load is best achieved by the measurement of weight of all vehicles. A WiM system that can operate without interfering traffic flow is therefore also appropriate. With the weighing of all vehicles, an accuracy on measurement of +/-10-15% would be sufficient for

determining the total traffic load on a bridge the size of the Messina bridge, and would also be sufficient for the purposes of post-statistical review for the development of Bridge Specific Assessment Live Loading. The WiM systems will therefore be designed in accordance with the design requirements for a Type II system as presented in ASTM E 1318-94. Other considerations to the choice of WiM system include maintenance requirements and system life-time. An example WiM system is that of the Kistler Linear Quartz Sensor, which is similar in form to piezo-electric WiM systems.

Example WiM system:

KISTLER - Lineas Quartz Sensor - Type 9195F





Technical Data

Sensor

Measuring range wheel load At a reference tire contact area (tread length x tread width)	kN mm	0 ... 150 200x320
Max. load-bearing capacity of the sensor surface	N/mm²	4,6
Sensitivity, nominal	pC/N	–1,76 +5 %
Max. sensitivity shift over sensor length	%	<±3
Threshold	N	<0,5
Linearity	%FSO	≤±2
Hysteresis	%FSO	≤2
Cable chunking resistance	N	300
Operating temperature range	°C	–40 ... 80
Temperature coefficient of sensitivity	%/°C	–0,02
Insulation resistance	Ω	>1 · 10^{10}

RWiM

As for the WiM systems, the Railway Weigh-in-Motion (RWiM) market is developing and is dynamic and is based on a variety of technologies. The systems that are available frequently require the slow passage of trains by the measurement of loads transferred from the rails to the sleepers, or from the sleepers to support structures. It is not suitable for trains to be slowed down for weighing prior to crossing the Messina bridge. A RWiM system that would allow the uninterrupted passage of trains is sought. Also, since the RWiM would be installed around a network that is managed by others e.g. RFI, a system that has minimal impact on the railways is also sought. Such a system is currently available in the form of the Kistler Rail WiM based on quartz sensor technology. This system provides the added benefit that RFI should be familiar with it, as it has already been adopted on a project undertaken at the Marshalling Yard in Marcianise**.**

Example RWiM system:

KISTLER - Rail WiM (using quartz sensor technology) - 9192A64

Technical Data

System

Measuring range wheel load	tons	0 ... 27
Operating temperature range	°C	40 ... 70
Speed Range	km/h	5 ... 350
Weight measurement accuracy (dynamic error on railcar weight)	%	≤±2 at 95 % confidence level