Construction Project

Requirement Specification
for
On-Site Power Distribution
for CTA North – Short Project

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		Date

Change Log

Issue	Revision	Date	Section/Page affected	Reason/ Remarks / Initiation Documents
1	a	10-12-2018	all	New document
1	b	14-12-2018	all	Feedback from LSE
1	c	10-01-2019	Section 2 Applicable documents updated to include TRE Emergency stop Section 3.1.2. Interface #3 and Figure 3.1.2-2 updated for the inclusion of a Switch for Cabinet maintenance	System Safety Engineer request to include “Emergency stop” functionality

List of Contributors

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Contents

List of Abbreviations

CTA	Cherenkov Telescope Array
ACE	Array Common Elements
LST	Large Sized Telescope
MST	Medium Sized Telescope
ORM	Observatorio del Roque de los Muchachos
CTA-N	CTA Northern Array
CTA-S	CTA Southern Array

1 Scope

This specification establishes the performance, design, development and test requirements for the **On-Site Power Distribution System for the CTA-North Short Project**.

2 Applicable Documents

The following documents of the exact issue shown form a part of this specification to the extent specified herein. In the event of conflict between the documents referenced herein and the contents of this specification, the contents of the specification shall be considered a superseding requirement.

[1] "CTA Power Requirements", 13.04.2018 (PowerNote7.pdf)
[2] "Study for Electrical Power Distribution for CTA Northern Array", 29.03.2018 (Study for Electrical Power for CTA North_2.pdf)
[3] "Instalacion Electrica en Baja Tension para Suministro al Telescopio LST-1 de la red Cherenkov Telescope Array (CTA)", developed by Onazol &F4 Ingenieros for LST-1 team, approved by Colegio Oficial de Ingenieros Tecnicos Industriales de Santa Cruz de Tenerife, on 27.11.2017. (bt_suministro_LST1.pdf)
[4] "Environmental Requirements for the CTA Sites SYS-REQ/161123", 25.04.2017. (EnvFEArangesv0.5.pdf)
[5] "Proyecto de Linea de Media Tension subterranea y Centro de Transformacion de 630 KVAS" developed by Onazol &F4 Ingenieros for LST1 team, approved by Colegio Oficial de Ingenieros Tecnicos Industriales de Santa Cruz de Tenerife, on 14.08.2017. (lmt_subt_y_ct_630_lst.pdf)
[6] TRE Emergency Stop v1, 18.12.2018.

3 Requirements

3.1 Power Distribution System Definition

3.1.1 Power Distribution System Description & Diagrams

The Cherenkov Telescope Array (CTA) is a multi-national endeavour to build the next generation observatory for very high energy astronomy.
CTA will be split across two sites (at Armazones, Chile in the Southern hemisphere, and La Palma, Canary Islands in the Northern hemisphere), abbreviated as CTA-S and CTA-N. At each site, there will be an array of telescopes, of up to three different sizes; Large, Medium and Small Sized Telescopes (LST, MST, SST) with small telescopes deployed at the Southern site only. For CTA-N the final layout will have 4 LSTs, 15 MSTs and instruments needed for calibration and monitoring environmental conditions called Array Common Elements (ACE).

This document serves to define the CTA requirements for the electrical power distribution system for the first phase of CTA-N (CTA-N "Short Project"), proposed to be delivered for the detailed design of the CTA-N Short Project.

The electrical power distribution is the final stage in the delivery of electric power; it carries electricity to individual consumers. Distribution substations lower the voltage to the utilization voltage used by final consumers.
At La Palma island, ENDESA operates a 20 kV distribution grid. The nearest point of the ORM area to the public grid is in Hoya Grande (1100 m above sea level). From there a private 20 kV line (owned by IAC) goes to the ORM area. Within this area several 20 kV cables feed the individual telescope locations in a radial way. The 20 kV cables are buried underground beside the existing roads.
The installed transformer capacity in the ORM area is 3065 kVA. The normal running load is 760 kVA, the peak load 800 kVA. (according to the information collected for AD 2).
ENDESA informed about a planned extension of the 20 kV grid in near future. The public 20 kV grid will be extended up to the top of the mountain and a 20 kV distribution substation will be installed at ORM. For this purpose the private IAC line will be taken over by ENDESA and will be amended by a second cable. The IAC cables shall then be connected to the ENDESA switchgear, ideally in a ring structure starting at both busbar sections.

For the CTA project, the first LST (LST-1 prototype) was erected in the last year, together with a new transformer station connected to the 20 kV grid of the Instituto de Astrofísica de Canarias (IAC).
The Transformation Center was designed through 2 projects:
1. Medium Voltage project (in AD5) for the 20/0.4 kV transformer of 630 kVA, and a 20 kV switchgear connected to the IAC network
2. Low Voltage project (in AD3), for the 0.4 kV switchgear (with a single busbar system), with infeeds to the 20/0.4 kV transformer and to a stand-by diesel generator for backup. Both infeeds are provided with circuit breakers and an automatic transfer system (ATS). In case of power failure at the incoming transformer or grid, the supply will be automatically transferred to the stand-by generator. The stand-by generator will resume the supply after a time

of approximately 20 to 30 seconds. The outgoing feeders of the 0.4 kV switchgear are provided with fuses for protection of the cable and the connected consumers. To the 0.4 kV switchgear it is also connected a power quality measurement equipment.

The Short Project will connect to the Transformation Center provided by the LST-1 prototype, as has been designed in the Conceptual study in AD 2.

The electrical power distribution for the CTA-N Short Project consists in the power cables to connect the instruments included in the Short Project to the Transformation center of the LST-1 prototype, including the interfaces cabinet at the instrument location and the connection to the 0.4 kV switchgear at the Transformation Center. For backup purposes, an on-line UPS is included for the MST at the Interface Cabinet.
For the LSTs, UPS is not provided as part of the power distribution system, because the LSTs include their own dedicated system consisting in an on-line UPS and 2 flywheels for each LST. LSTs have their own UPS because when a transient phenomena such as gamma ray burst occurs, each LST will be rotated fast in order to perform a follow-up observation. The peak power supply functionality (UPS + flywheels) must be able to supply power of 470 kW per telescope within the duration of 10 seconds.

The CTA-N Short Project, includes the following instruments and elements that need a power infeed:

- 3LSTs additional to the LST1 prototype (LST 2,3 and 4)
- 1 MST (MST 3)
- Array Common Elements (ACE), needed for calibration and monitoring environmental conditions:
  - 3 Weather Stations
  - 1 Fram
  - 1 Raman Lidar
  - 1 Ceilometer
  - 1 Illuminator
- Safety and security elements:
  - Interlocks or Access control for the fence around each telescope
  - CCTV on each fence
  - Emergency Lighting on each fence
- 1 Interface Cabinet for MST3, that will host the electrical power and networking interfaces, together with the UPS for backup. Elements that need a Power supply inside the Interface cabinet include:
  - 1 ethernet switch and a wireless access point for Wireless LAN connectivity
  - 1 power metering instrument
  - Lighting
  - On-line UPS
  - Air conditioning system for the UPS and its batteries
- 1 Interface box for each LST.

The Power distribution system requirements for CTA-N were studied and can be found in AD 1. Based on these requirements, a Conceptual design was developed, and can be found in AD 2. For the Power distribution system, in AD 2, four different alternatives were analyzed, and one of them, the Variant 4, was selected.

Main conclusions of the AD 2 Concept study and a description of the variant 4 are presented in this document.

In the next expansion stage the telescope array will be completed (15 MSTs in total) and the Operation Building will be installed (Expansion 2). In this stage the Datacentre that is currently installed in a Container beside LST-1 prototype, will be moved to its final position in the Operation Building, and a second transformation center will be installed.
The Expansion stage 2 array layout can be seen in Appendix 2.

Appendix 1 shows a preliminary layout with the cable topology for the Short Project.
It must be noted that the drawings are referential and the final coordinates for the telescopes and civil works may have small changes. The same applies to the Instruments such as Weather stations, FRAM, Lidar, Ceilometers, which final positions are pending confirmation.

3.1.2 Interface Definition

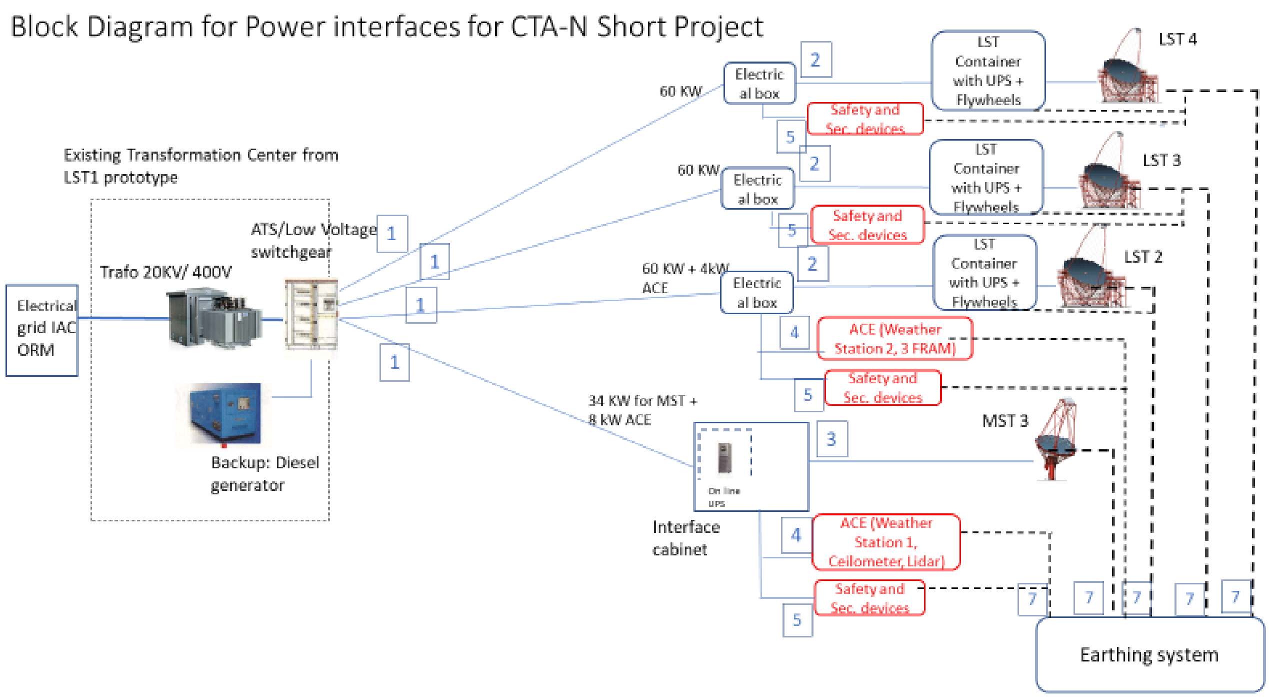


Figure 3.1.2-1 Interfaces for the Power Distribution System for the CTA-N Short Project

Interface #	Interface part #1	Interface part #2	Description
1	LV Power distribution cabling	Transformation Center	Connector to Low Voltage Switchgear
2	LV Power distribution cabling	LST	Electrical Interface box
3	LV Power distribution cabling	MST	Power connectors at the Interface cabinet
4	LV Power distribution cabling	ACE	Electrical box (connected to nearest telescope interface box) - to be confirmed
5	LV Power distribution cabling	Safety and security elements	to be defined
6	LV Power distribution cabling	Devices inside Interface Cabinet (ethernet switch, AP por WLAN)	Power connectors inside Interface cabinet
7	Earthing system	Civil structures	Copper interconnection
8	LV Power distribution cabling and Grounding system	Trenches and ducts	ducts

Table 3.1.2-1 List of Interfaces for the Power Distribution System for the CTA-N Short Project

Interface 1 Low Voltage Power Distribution cables to the 400 V Switchgear in the Transformation Center

The Transformation Center is shown in Appendix 3 (based on AD 3 and visit to the site).

The Transformation Center includes a 20kV/400V Transformer and a Diesel Generator for backup purposes, both connected to a 400 V Switchgear with an Automatic Transfer Switch (ATS).

The 400 V switchgear consists of a double cubicle with two doors. The left part contains the incoming feeder from the emergency diesel generator, the right part the incoming feeder from the transformer. Both infeeds are provided with circuit breakers of make ABB and type SACE Emax 2. Both incoming circuit breakers are provided with an automatic transfer system DSE335.

In the same cubicle the 400 V busbar with 7 outgoing feeders is installed. All seven feeders are provided with Molded Case Circuit Breakers (MCCBs) SACE Tmax, which can be operated by rotary switches without opening the cubicle doors.

The 7 outgoing feeders currently supply:

- LST1
- IT Container (Datacenter)
- Commissioning Container
- Testing purposes (available for the Short Project)

For the Short Project, the remaining 3 feeders plus the “Testing purposes” feeder will be used to connect the following:

- LST2
- LST3
- LST4
- MST3.

A Power Quality measuring device is connected to the 400 V Switchgear. This measuring device also measures the power consumption of the devices connected to this Transformation Center.

The remaining elements of the Short Project will be connected to the Interface cabinets/boxes of the nearest telescope.

For the Power distribution cabling, the peak power consumptions are indicated in Table 3.1.2-2

Short Project Power consumption	
Instrument	**kW (peak power from the power distribution system)**
LST 2	60
LST 3	60
LST 4	60
MST 3	35
Weather station 1	0,1
Weather station 2	0,1
Weather station 3	0,1
Raman Lidar	6
FRAM	3
Ceilometer	pending
Illuminator	not connected to the Power distribution system
Safety and security devices	pending
Interface Cabinet for MST 3 (including UPS, air con, ethernet switch, power meter)	6
Total in kW	**230,3**

Table 3.1.2-2 Power consumptions for the Short Project

The Transformation Center shall comply with the following statements:

- **B-INFRA-0605 Backup Power Control**: The Power Provision System must incorporate a backup solution, capable of continuously providing power to Array Elements for the average required loads.

– **B-INFRA-0690 Power System Grid Connection**: In the event that the connection of the power system to the grid is lost, the power system must be able to supply sufficient power for continued observations for up to 2 hours, and for the Safe State for up to 48 hours before the connection is restored.

Note: For the power consumption for Observation, see Appendix 5.

On the main 0.4 kV busbar the transformer infeed as well as the stand-by generator connection will be equipped with circuit breakers with overcurrent-time protection relays. With this equipment the busbars are protected.

Interface 2 Low Voltage Power Distribution cabling to the LST Interface box:

At the LST location, each LST has a UPS with 2 flywheels that serves 2 purposes:

- Provides energy in case if power failure for some minutes
- Provides power for the peak power consumption of around 400kW, associated to the fast repositioning.

The Power distribution cabling will connect to the LST at an electrical box connected outside

of the container with the UPS and flywheel system, as shown in Figure 3.1.2-1.
The electrical box shall be mounted over a concrete base and shall have openings in the below part for the connection of the underground cabling both for the input and output power cables.

The Interface to the LST shall comply with the following statement:

– **B-INFRA-0660 Peak Power Provision LST**: Extra power required by the LSTs, beyond the 60 KW to be provided by the Power Provision System, must be provided by the LST Energy Storage System.

Interface 3 Low Voltage Power Distribution cabling to the MST Interface Cabinet:

At the MST location, an Interface cabinet will host the connections for the electric power, and for the data and networking signals. Both of these will need to be separated and have different access doors to the Cabinet to comply with Spanish regulations.

For the electrical power interconnection, Figure 3.1.2-2 shows the elements foreseen to be included in the Interface cabinet and correspond to the following list:

a. An online UPS with batteries, for power backup purposes. The MSTs need a safe power supply for at least 6 minutes. If after 1 minute there is no return of power from the grid or the emergency diesel generator the telescope needs power for 5 minutes to go to safe position. Local UPS system with at least 30 kW power for 6 minutes at each MST will be needed.
b. An Air conditioning system, to regulate the temperature for the batteries
c. A disconnector switch for Cabinet maintenance with isolation function, which together with the Molded Case Circuit Breakers (MCCB) at the 400V Switchgear at the Transformation Center, provide compliance with the Emergency Stop functionality required in AD 6.
d. A disconnector switch to locally "power off" the telescope for maintenance
e. Power outlet of 400 VAC, 50 Hz for the infeed of the Telescope and Camera
f. Power outlet of 230 VAC, 50 Hz for safety devices in the telescope.
g. Power outlet of 230 VAC, 50 Hz for a power metering device, for power quality information
h. Power outlet of 230 VAC, 50 Hz connection for an ethernet switch
i. 2 power outlets (400 VAC) for tools for maintenance and to connect a local generator if required
j. A connection to the earthing system
k. A 230 VAC, 50 Hz Power outlet for the Safety and security elements at the fence (access control device, and CCTV when needed)
l. Power outlet for the Ceilometer (400 VAC), Raman Lidar (230 VAC) and Weather Station 1 (230 VAC).

The disconnector switch for Cabinet maintenance with isolation function indicated in c), provides compliance with the following statement.

– **B-INFRA-0630 Power Emergency Stop**: Emergency stop buttons to cut power, both to moving parts and to Array Elements as a whole, must be placed within all Interface Cabinets and in the data centre.

Block Diagram for Power Interfaces in Interface Cabinet for CTA – N for MST 3

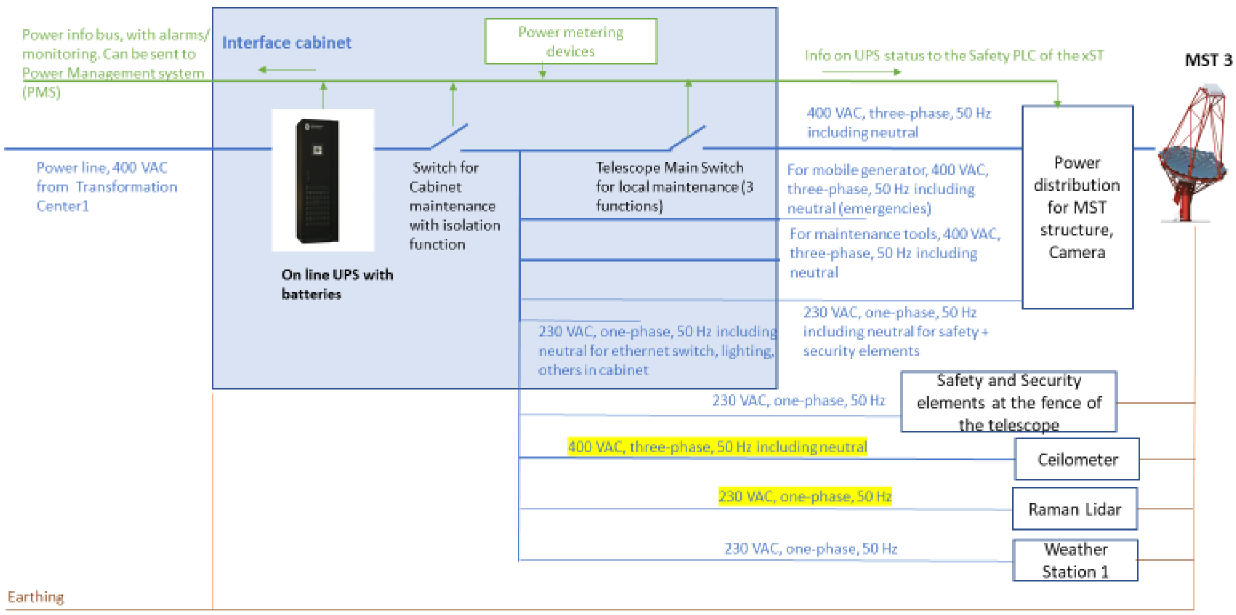


Figure 3.1.2-2 Interface Cabinet for MST 3

In order to have a standard Interface cabinet for the MSTs, the design for the Cabinet for MST 3, shall consider space and constrains associated to bending radius for the power cables of the more distant MSTs that will be included in Expansion 2. As per Appendix 2 can be seen that the biggest distance will be in Expansion 2 between the MST14 and the Transformation Center 1, with a distance of 800 m aprox, and estimated cables of 4x95 square millimeters of cross section.

Interface 4 Low Voltage Power Distribution cabling to ACE

The Array Common Elements of the Short Project will be connected with power cables from the nearest telescope interface box.

Table 3.1.2-3 shows the point of connection to the Power system for each ACE, together with requirements for the connection, assuming that the indicated list is part of the Short Project.

The Illuminator will not be connected to the power distribution system because it will be located on a remote site on top of ORM.

It is pending the design of the interfaces between the power distribution and each one of the 4 ACE elements in the list. Will be a 3 point interfaces for each case, between each instrument team, civil and power/data.

ACE	Power Supply from interface box at telescope:	Power consumption	Voltage infeed	Characteristics of the connection	Others	Needs UPS backup?
Weather station 1	MST 3	0,1	220V (to be converted to 12 or 24V DC)			no
Weather station 2	LST 2	0,1	220V (to be converted to 12 or 24V DC)			no
Weather station 3	LST 2	0,1	220V (to be converted to 12 or 24V DC)			no
Raman Lidar	MST 3	6	220-250 V, 32 A, 50 Hz	connector of type: 32 A, 3 Pin interlocked socket with plug waterproof IP67, 220-250 V, located at the center of the side part (the one which measures 7m)	both data and power ducts (separated) need to arrive in the middle of the side part (the one which is 7m long)	pending. Need to go to park position and close
FRAM	LST2	3				no, Power backup systems provided internally.
Ceilometer	MST 3	pending	2 infeeds, one for measurement unit 100V or 115V or 230V, 45-65 Hz, 10A max. fuse size, (3 phases + Neutral) . and other for PTU (24 VDC or 240 VAC)	Power Line : 4-pole, connector Type Binder series 693, 99-4222-70-04 (fe- male) elbow		pending, Need to go to park position before sun comes out
Illuminator	not connected to the Power distribution system					

Table 3.1.2-3 Interfaces for ACE and characteristics for the connection

Interface 5 Low Voltage Power Distribution cabling to Safety and Security elements

The Short Project shall include safety and security elements at the fence around each telescope, that will be supplied from each interconnection box. Pending requirements, pending for the ACE definition, will they have a fence?.

Interface 6 Low Voltage Power Distribution cabling to On site ICT devices inside Interface cabinet

For MST3 the devices will be supplied from the Interface Cabinet as shown in Figure 3.1.2-2.

For the LSTs needs to be defined

Interface 7 Interface between earthing system and Civil structures

The planned low voltage power network will be designed as TT type as usual in Spain. That means that the cables will have four wires without a PE wire. Within a TT grid each item will be earthed individually.
The TT grid has the advantage that for the rocky soil no minimum requirements for the ground resistance are necessary. Nevertheless it is recommended, that within the cable trenches an earth wire shall be laid to connect all the individual foundation earth electrodes of the telescope positions and other buildings to a meshed grid.

This earthing grid can also be used for the lightning protection concept.

Interface 8 Interface between Low Voltage distribution lines and grounding to trenches and ducts

Section 3.2.2 defines physical characteristics for the ducts and spare ducts to be included, for expansion 2.

3.1.3 Major Component List

a. UPS for MST3

The MSTs need a safe power supply for at least 6 minutes. If after 1 minute there is no return of power from the grid or the emergency diesel generator the telescope needs power for 5 minutes to go to safe position.
An online Local UPS system with at least 30 kW power for 6 minutes at each telescope shall be included.

b. Air conditioning system for the UPS's batteries at the Interface Cabinet. TBD

3.1.4 Customer Furnished Property List

Not applicable

3.1.5 Customer-Loaned Property List

Not applicable

3.2 Characteristics

3.2.1 Performance Characteristics

a. Characteristics for the Power cabling

B-INFRA-0570 Power Distribution: The nominal voltage of CTA three-phase low voltage power systems reaching the telescopes and buildings of the CTA Observatory must be 230/400 V, with 230 V being the phase-to-neutral and 400 V the phase-to-phase voltage. The nominal frequency of CTA power systems must be 50 Hz.

B-INFRA-0500 / 0530 Peak Power The northern site infrastructure must be capable of providing the peak electrical power required for observatory operation of X MW at the required power quality. Peak consumption occurs due to simultaneous movement of telescopes in adverse wind conditions, expected to last at most 2 minutes and occurring at most 10 times per night.
(X for the Short Project is 231 kW from Table 3.1.2-1. This is additional to the power consumption of the LST1 prototype and associated facilities).

– **B-INFRA-0650 Peak Power Load**: The installed electrical equipment (in the Power Provision System) must be able to carry the estimated peak power. The peak power for LST fast repositioning is excluded from this estimate and will be supplied by a dedicated storage system.

The power consumptions for the Short Project, per instrument, are described in table 3.1.2-2.

For upgradability, the following concept shall be considered:
B-INFRA-0505 Power Upgradability: Provision must be made for a possible upgrade of the peak power provision to both CTA sites, to accommodate extensions, by an additional 40%.

b. Characteristics for the UPS

An on-line UPS is needed at the location of each telescope, in order to comply with the following statements:

B-INFRA-0560 Backup Power: Both sites of the CTA Observatory must have suitable backup power supplies as redundant systems which ensure that at least enough power is available to move all telescopes to the parking position in case of external power failure and the power needed to ensure the safety of personnel.

– **B-INFRA-0640 Power Frequency Stabilisation**: Voltage and frequency stabilisation must be considered in Power supply design, such that even on millisecond timescales, no disturbances may cause damage to Array Elements or the central system. For this purpose, an online UPS must exist.

The UPS for the MST is part of the power distribution system, and for the LST is part of the LST structure (see section 3.1.2 Interfaces definition).

c. Characteristics for the Peak power demand

During commissioning of the LST 1 prototype and again after completion of Stage 1 measurements should be done to determine the real peak power demand.
In addition the LSTs should be programmed in such a way, that the 60 kW peak demand does not occur at the same time as the repositioning of the MSTs.

d. Protection concept

The protection scheme shall be adequate for the equipment and provide protection for equipment and operation staff.

The maximum short circuit power at the Transformation Center main boards is 25.5 kA (For the selected Variant 4). From AD 2.

The short circuit power on the telescopes varies with the used cable cross section and length. The rating of the power interface board on each telescope must be determined during detail design, considering the used cable type and length.
All outgoing feeders from the 0.4 kV busbars will normally be equipped with fused load break switches. The fuses will ensure the short circuit protection of the feeders in case of a short circuit on the cable or on the subordinated busbars. Of course it is possible to use switches with internal fuses for easy handling without personnel safety equipment.
In addition all outgoing feeders from 0.4 kV busbars shall be equipped with RCDs (Residual Current Device) of 500 mA or less to protect against earth faults. This requires a maximum permissible earth resistance of 100 Ohm. If in any case equipment needs a less sensitive leakage current detection the appropriate earth resistance must be adapted in this feeder. Some manufacturers offer combined MCCB/RCD devices which will save space and installation work.
The switchboards used in the cable cabinets and in the telescopes are often equipped with a fused load break switch in the incoming cubicle to protect the switchboard against faults. This might not be necessary as the upstream fuse will fulfill this requirement. Nevertheless a disconnector shall be provided to isolate the switchboard for maintenance.
To protect the whole installation against overvoltages due to lightning strikes or switching overvoltages all incoming cables shall be provided with appropriate surge protection devices. This is recommended on both voltage levels 20 kV and 0.4 kV.

To reduce electromagnetic influences through short circuit currents, all cable traces shall be provided with a reduction conductor in parallel to the power cables and connected to the appropriate earthing grid of the telescope and substation. As the direction of the earth fault current flowing in this reduction conductor is opposite to the direction of the cable current the electromagnetic field will be reduced remarkable.

Pending power requirement from Safety and Security for the following requirements

B-INFRA-0130 Access Control	All access to the site and to individual buildings must be controlled, with the access control system connected to the Safety and Alarm System.
B-INFRA-0260 Fire Safety	All infrastructure supporting Telescopes and other on-site hardware as well as buildings and access routes on site must be designed and constructed in compliance with the applicable fire safety regulations.

3.2.2 Physical Characteristics

– **B-INFRA-0610 Power Cable**: Telescopes and instruments must be provided with a cable power supply, which must be ducted in order to protect against damage to the cable between system and building.

From the AD 2 the preliminary estimations for the cross section and the length for the power cabling for the telescopes are indicated in Table 3.2.2-1. The length of the cables and consequently their cross sections will be rectified in the Detailed design phase.

Telescope	Cross Section in square mm	Transformation Center	Estimated length in m
LST 2	4 x 50 sm	TC 1	100
LST 3	4 x 50 sm	TC 1	150
LST 4	4 x 50 sm	TC 1	120
MST 3	4 x 50 sm	TC 1	230

Table 3.2.2-1 Cross section and lengths for the power cabling for telescopes for the CTA-N Short Projects, estimated in AD2.

To limit the voltage drop the cable cross-section is selected according to the cable length. The following cross-sections are used.
up to 400 m 4x50 mm²
400 to 700 m 4x70 mm²
above 700 m 4x95 mm²

The ACE shall be connected to the nearest telescope interface box or cabinet. For the Short Project this is indicated in Table 3.1.2-3.

The safety and Security elements located at the fence of each telescope, shall connect to the Telescope's own Interface box.

Regarding the paths for the cabling, the existing electrical infrastructure of the ORM area, consisting of 20 kV cabling, 400 V cabling and data cabling is laid, as far as possible, along the roads.
The planned cable routing of the new telescope array is also orientated along existing and new roads.
During construction of the new roads to the individual telescope sites, ductwork can be implemented to one or both shoulders of the road. This will avoid extra digging of trenches across the whole area.
The empty pipes of the ductwork shall be provided with taut wires during the construction for easy cable pulling later. Cable pits (manholes) must be provided in narrow bends, junctions as well as in straight sections within a suitable distance of 50 meters or less.
Within the existing ORM infrastructure cable pits with pipes of 200 mm diameter are used. If possible, the same diameter and similar cable pits shall be used for the new ductwork.
Near the 400 V substations a lot of cables will be necessary. Within this narrow area parallel pipes shall be used. In the first pipe all power cables of the Short Project stage shall be placed. The second and may be third parallel pipe shall be foreseen for the second expansion stage of the telescope array.
In the peripheral zone of the telescope array, where only few cables are necessary, a smaller pipe diameter can be used. It shall be avoided to pull additional cables in a partly filled pipe. All planned cables should be pulled at one time through the empty pipe.
The dimensions of the proposed cables shown in Table 25 shall be considered during the cable routing:

Cross section mm^2	Diameter mm	Bend radius mm
4x50sm	30	360
4x95sm	38	456
4x240sm	59	708
4x300sm	65	780

Table 3.2.2-1 Diameter and bending radius for different cross sections of power cabling

As far as possible the data cables (optic fibres) shall be laid separately from the power cables, maybe in the other shoulder of the road or, if only a few cables are needed, at least in a separate pipe.
Special intention has to be paid when laying cables along the main road from the entrance of the Astrophysical Park to the summit of the Roque de los Muchachos. As shown in AD2, several high voltage, low voltage and data cables are laid along this road. Between the planned positions of MST3 and MST10 new power and data cables have to be added on this route, mainly near the position of the new Transformation Center 1.
Another critical point is the route along the public road LP-4. Due to higher traffic volume as on the other roads, only one trench on the southern shoulder of the road should be used for data and for power cabling.
In the section from the Operation Building to the first bend near the planned position of LST4 the maximum number of data cables is needed. Therefore at least 3 empty pipes for data cabling shall be foreseen.

For the Short Project, a proposal for the number of ducts is included in Appendix 1, that considers the ducts for the cabling for the expansion stage 2.

3.2.3 Reliability

3.2.3.1 Functional Lifetime

– **A-GEN-2510 System lifetime**: The design lifetime of the system as a whole is 30 years, all individual assemblies must meet this requirement (see Lifetime) unless specified separately below.
For batteries of the UPS for the MST3, Lifetime shall be 15 years.

3.2.3.2 Reliability

The reliability requirements for the CTA Instrument are expressed in terms of MTBF.

For Availability, the following Requirement must be complied.
– **B-INFRA-0670 Power System Availability (per Telescope)**: The availability of the power provision system at the telescope during observation time, including any back-up system, must be more than 99.5%

For Adaptability and future upgrades, the following Requirement must be complied
B-INFRA-0600 Power System Adaptability: The on-site power infrastructure of CTA must provide extra capacity of at least 10% beyond that needed by the baseline design. The power infrastructure must be flexible, adaptable and upgradable, with the possibility for additional instrumentation to be included (as well as adaptation to new technology).

3.2.3.3 Failure Definitions

The following functional mishaps are considered as failure:

Regarding the reliability of the power supply the following subjects are to be highlighted:
• There is no information about the reliability of the 20 kV grid, neither from ENDESA nor from IAC, only the statement, that the grid is very stable. No figures have been provided.
• In case the 20 kV grid fails, the stand-by diesel generator of the Transformation Center will supply the whole telescope array with sufficient power to continue observation.
• In the selected Variant 4 the outage of a dedicated cable to a telescope will result in an observation stop of the affected telescope and a shut-down to safe parking position.
• A short circuit at the interface cabinet or box of the telescope itself will cause a safe shut-down in Variant 4 due to the local UPS.
International error statistics for low voltage equipment are not available. In literature only a small statistic derived from some German public utilities can be found. The failure rates of the main equipment are the following:

Item	**Specific failure rate Unit**
LV cable	0.06 1/(a*km)
Substation	(LV part) 0.0007 1/a

Regarding the rates for substations it can be stated that statistically an outage will occur once in 50 years.
Depending on the different cable lengths, single cable will fail once per year or per 2.5 years. As the infrastructural conditions in the IAC area cannot be compared directly with German public utilities in urban areas this statistical value is is in a more adverse scenario. The failure rate of the new cables in the telescope array is only influenced by damages through civil activities with excavators or other heavy machines.
As civil works are restricted to the erection of the telescopes and the associated road works, it can be assumed that only few failures will occur during the 30 years lifetime of the project. The outage of one cable will cause no damage to the telescope equipment, as the local UPS will move the telescope to safe parking position.

3.2.3.4 Maintainability

– **B-INFRA-0680 Power System Maintenance**: The maintenance of the power system on-site must require on average less than 10 person hours / week

For the UPS:
The UPS modules as well as the batteries are more or less maintenance free. The VRLA batteries used for UPS systems are normally of the low maintenance type. Beside the change at the end of lifetime only a visual inspection once a year is necessary.
The same can be assumed for the electronic devices of the UPS system. Nevertheless the air condition system of the Interface cabinet needs yearly maintenance.
It is assumed that the inspection and maintenance for a local UPS system need 1 hour per year. Taking in account the approach and departure time 5 distributed UPS shelters can be maintained within an 8 hour working day.
All 15 local UPS need then a maintenance effort of three days per year.
The battery exchange can be performed in the same time and needs two or three days twice during the 30 years lifetime of the telescope array.

The following requirements shall also be included in the detailed design:

B-ONSITE-0510 Maintenance Plans	Maintenance planning and procedures for covering access to, and repair / replacement of, any LRU must be provided.
B-ONSITE-0520 Spare Parts	The level of spare parts needed for long-term System maintenance must be documented.

3.2.4 Environmental Conditions

The environmental conditions for the site are available in the document AD 3.

3.2.5 Transportability

Not applicable

3.3 Design and Construction

3.3.1 Materials, Parts and Processes

For the selection of materials, parts and processes, the localization and the remoteness of the observatory site shall be considered.

For environmental, equipment and occupational safety and health: the European Union (EU) law shall be applied, e.g. RoHS 2 Directive 2011/65/EU

Particular attention shall be paid to the altitude of the observatory sites above 2400 m and the risk of earthquakes.

The following CTAO-wide standardized existing components shall be used: TBD

The following parts and materials shall NOT BE used: the EU Directive RoHS 2 Directive 2011/65/EU is applicable.

Only cables that do not generate toxic gases in case of a fire shall be used.

3.3.2 Electromagnetic Compatibility (EMC)

The CTA system shall meet the requirements defined the European Directive 2004/108/EC and the associated Harmonized Standards, see https://ec.europa.eu/growth/single-market/european-standards/harmonised-standards/electromagnetic-compatibility_en

3.3.3 Name Plates and Product Marking

a) The subsystems and auxiliary equipment shall be labeled or engraved with name-plates visible after installation of said subsystems or equipment. The labels shall contain as a minimum the following information:
b) Assembly / component name and sequential number wherever applicable.
c) Manufacturing month and year.
d) Name and /or logo of manufacturer.
e) Labels to guide disassembly or handling, if deemed necessary
f) All dismountable parts, except standard parts like screws or washers, shall be marked or equipped with identification plates. The markings and identification plates shall be visible after installation and shall contain the following information:
    a. Custom manufactured parts, or modified purchased parts:
        i. Part/assembly number which shall include the product code number
        ii. Drawing number including revision
        iii. Manufacturing month and year
    b. Purchased parts:
        i. Name and address of manufacturer
        ii. Part number / Serial number
        iii. Manufacturing month and year
g) All name plates and indication labels shall be permanently marked, made of metal or laminated plastic, and be attached to the 4LGSF by means of screws or rivets.
h) All the cables, connectors and electrical equipment shall be marked following the recommendations in the applicable document (to be defined)

The marking requirements of the relevant harmonized standards shall be fulfilled.

3.3.4 Workmanship

Only methods and procedures which are state-of-the-art in electrical and electronics engineering shall be used for the design, construction and test of the CTA power distribution. These methods and procedures shall be appropriate for the applicable extreme environmental conditions and the long life time of the Observatory. Preferable are those technologies which have been proven to lead to high reliable equipment for application at remote astronomical observatories at an altitude of >2400m above sea level.

3.3.5 Interchangeability

The design shall consider interchangeability requirements related to the long lifetime of the power distribution. In particular the probable non-availability / -procurability of electronic components over the long lifetime shall be taken into account.

3.3.6 Safety

All CTA Subsystem shall comply with the European Union (EU) product safety related legislation. The relevant EU Directives and the harmonized European standards are listed at https://ec.europa.eu/growth/single-market/ce-marking/manufacturers_en.

– **A-GEN-2180 Safety regulations**: Construction, operation and decommissioning of the CTA systems must comply with European or host country regulations, whichever is more stringent, concerning health, human safety, as well as with the health and safety requirements described in sections 1, 3, 4 and 6 of Annex I of the directive 2006/42/EC on machinery.
– **A-GEN-2320 On site Operation Conditions**: Outdoor operations on site must be performed only during daytime and under safe weather conditions. No personnel will be available on-site during darktime observations. Instrumentation on-site must be designed such that manual intervention is not required during this time.
– **A-GEN-2350 Electrical safety**: Electrical installations, equipment and components must be provided with safety mechanisms and signalling to avoid any kind of human injury to personnel during installation, maintenance, regular use, inadvertent operation, human error or any kind of system failure.
– **A-GEN-2450 Electrical Elements**: Protection measures and devices must be used to guarantee that none of the observatory components and assemblies suffer permanent damage due to any reasonably foreseeable electrostatic discharge, power cut, electromagnetic disturbance or human error in cable connections.

3.3.7 Human Performance, Human Engineering

The requirements of the relevant harmonized standards - see Section 3.3.6 - shall be fulfilled.

3.4 Documentation

3.4.1 General Requirements

All documentation shall comply with applicable DIN or similar standards and with the EC Product Safety Legislation requirements.
All documentation necessary for the operation and maintenance of the On-Site Networking Infrastructure shall additionally be prepared in Spanish.

3.4.2 Instructions and CE Declaration

3.4.3 Operation and Maintenance documentation

In addition to the documentation required by an EU Directive, the following documents shall be supplied:

1. Logbook(TBD)
2. A complete set of as-build construction and verification documents, including all specifications, drawings, ordering instructions, plans, procedures, manuals, hand-books etc. of all hardware and software down to piece part / component level. This documentation shall allow long term maintenance and logistic support activities. (delivery form and detailed contents are TBD.

3.5 Maintenance

CTA-North: CTA-O personnel will do the maintenance.

3.5.1 Use of multipurpose test equipment

For maintenance and repair only standard tools available at the observatory shall be used. In case special tools are unavoidable, these tools shall be provided by the equipment supplier.

3.5.2 Parts replacement

Only exchange of Line Replaceable Units (LRUS) is foreseen as in-situ repair method.

3.5.3 Maintenance and Repair Times

Only daytime maintenance and repair shall be foreseen.

3.5.4 Definition of Serviceability Limit State

Not applicable

3.5.5 Definition Collapse Prevention Limit

Not applicable

3.5.6 Accessibility

The power cabling in the Array shall be accessible through cable pits as described in Section 3.2.2 “Physical Characteristics”, and at the interface points described in Section 3.1.2.

3.6 Personnel and Training

For CTA-N special operation processes and procedure will be defined by the Detailed designer. In particular if there are special tools and a special training, this needs to be part of the detailed design.

3.7 Major Component Characteristics

Not applicable

3.8 Precedence

No special precedence requirement has been identified.

4 Product Assurance Provisions

4.1 General

The verification shall follow a systematic verification approach.

4.1.1 Conceptual Design Phase

Not applicable

4.1.2 Detailed / Final Design Phase

The detailed design for the On-site Networking Infrastructure shall be subject to design reviews. The successful passing of these reviews is mandatory for the release of the subsequent project phase.

4.1.3 MAIV Phase

Not applicable

4.2 Quality Conformance Verifications

(this section does not consider the QA activities required by the applicable EU product safety directives)

4.2.1 Subsystem Verification Plan

The analyses, tests and inspection requirements necessary to demonstrate that all requirements of Section 3 of the specification have been achieved shall be included in the detailed design.

4.2.2 Preliminary Acceptance Supplier

Not applicable

4.2.3 Preliminary Acceptance Observatory PAO

Not applicable

4.2.4 Final Acceptance Observatory, FAO

At the end of the guarantee period, CTAO performs an official Final Acceptance at the Observatory FAO.

5 Preparation for Delivery

Not applicable

6 Notes

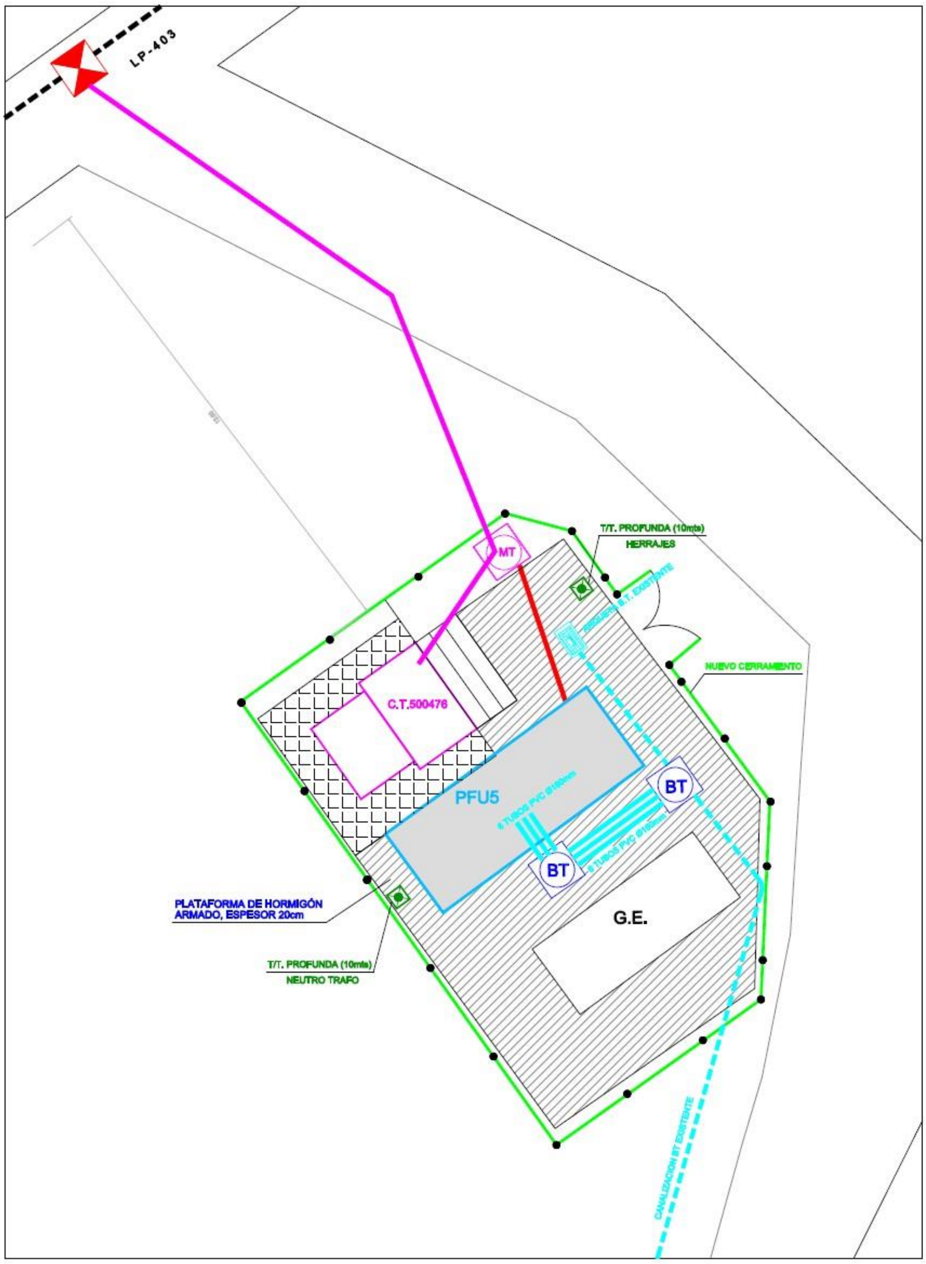
No notes are included.

7 Appendixes

Appendix 1 Short Project layout, cabling and preliminar ducting calculations (in another document)

Appendix 2 Layout for the Expansion 2 including cabling routes (in another document)

Appendix 3 Details for the existing Transformation Center



The parts painted in magenta are the existing MAGIC transformer station and the existing 20 kV connection. The rectangle painted in dark bluerepresents the new transformer station. The white rectangle marked G.E. is the emergency diesel generator container.

The red line shows the new 20 kV cable, the light blue lines represent the new 400 V cables including the manholes. The whole area is fenced (light green line). All the new equipment is installed on a platform made of concrete.

The two dark green points behind the transformer station and near to the gate show the locations of the earthing rods. In addition the concrete platform is provided with a foundation earthing with multiple connection points.

Appendix 4 List of Standards included in IAC-CTAO Hosting Agreement (IAC-CTA Hosting Agreement, 09/09/2016)

Reference to Standards (electrical / mechanical / safety / environmental) required for components to be installed at ORM

• Reglamento Electrotécnico para Baja Tensión e Instrucciones Técnicas Complementarias, aprobado por el R.D. 842/2002 de 2 de agosto de 2002.
• Decreto 141/2009, 10 noviembre, por el que se aprueba el Reglamento por el que se regulan los procedimientos administrativos relativos a la ejecución y puesta en servicio de las instalaciones eléctricas en Canarias.
• R.D. 2267/2004, de 3 de septiembre por el que se aprueba el Reglamento de seguridad contra incendios en los establecimientos industriales.
• Ley 34/2007, de 15 de noviembre, de calidad del aire y protección de la atmósfera.
• R.D. 1627/1997, de 24 de octubre, por el que se establecen disposiciones mínimas de seguridad y salud en las obras de construcción.
• R.D. 614/2001, de 8 de junio, sobre disposiciones mínimas para la protección de la salud y seguridad de los trabajadores frente al riesgo eléctrico.
• Norma UNE-EN 60617: Símbolos gráficos para esquemas.
• Norma UNE 21144-3-2: Cables eléctricos. Cálculo de la intensidad admisible. Parte 3: Secciones sobre condiciones de funcionamiento.
• Sección 2: Optimización económica de las secciones de los cables eléctricos de potencia.
• Norma UNE 12464.I: Norma Europea sobre iluminación para interiores.
• Guía Técnica para la evaluación y prevención de los riesgos relativos a la utilización de lugares de trabajo, que adopta la norma UNE 12464 y ha sido elaborada en virtud de lo dispuesto en el artículo 5 del R.D. 39/1997, de 1 de enero y en la disposición final primera del R.D. 486/1997, de 14 de abril, que desarrollan la Ley 31/1995, de 8 de noviembre, de Prevención de Riesgos Laborales.
• Real Decreto 1215/1997 Disposiciones mínimas de seguridad y salud para la utilización por los trabajadores de los equipos de trabajo.
• Real Decreto 485/1.997, sobre Señalización de Seguridad y Salud en los centros de trabajo.
• Real Decreto 486/1.997, sobre disposiciones mínimas de Seguridad y Salud en los centros de trabajo.
• RAEE (Directiva 2002/96/CE): R.D. 208/2005, de 25 de febrero, sobre aparatos eléctricos y electrónicos y la gestión de sus residuos. Version 22-06-2016 18
• ROHS Directiva 2002/95CE: Restricciones de la utilización de determinadas sustancias peligrosas en aparatos eléctricos y electrónicos.
• R.D. 2135/1980 de 26 de Septiembre sobre liberalización industrial.
• RD 2060/2008, de 12 de diciembre por lo que se aprueba el Reglamento de equipos de presión y sus instrucciones técnicas complementarias modificado por el RD 560/2012, de 7 mayo.
• R.D. 838/2002. Requisitos de eficiencia energética de los balastos de lámparas fluorescentes.
• Real Decreto 1435/1992 de 27 de noviembre que traspuso la Directiva 89/392/CEE relativa a la aproximación de las legislaciones de los estados miembros sobre máquinas, modificada por la Directiva 91/368/CEE del Consejo, 20 junio, y se fijan los requisitos esenciales correspondientes de seguridad y salud. • Real Decreto 1367/2007, de 19 de octubre, por el que se desarrolla la Ley 37/2003, de 17 de noviembre, del Ruido, en lo referente a zonificación acústica, objetivos de calidad y emisiones acústicas.

• REAL DECRETO LEGISLATIVO 2/2008, de 20 de junio, por el que se aprueba el texto refundido de la Ley de suelo.
• Ley 38/1999, de 5 de noviembre, de Ordenación de la Edificación. • D.L.1/2000, de 8 de mayo, TR Leyes de Ordenación del Territorio de Canarias y de Espacios Naturales de Canarias.
• Reglamentos de desarrollo de la Ley 1/2000, de/ 8 de mayo, por el que se aprueba el TRLOTCENC.
• Código Técnico de la Edificación (RD 314/2006, de 17 de marzo y RD 1371/2007,
de 19 de Octubre) Version 22-06-2016 19

Appendix 5

Power consumptions per telescope

	LST				MST w NectarCam				MST w FlashCam				SST 1M				GCT				ASTRI			
	Daylight		Operation		Daylight		Operation		Daylight		Operation		Daylight		Operation		Daylight		Operation		Daylight		Operation	
Device	Mean Power (KW)	Peak Power (kW)	Mean Power (KW)	Peak Power (**) (kW)	Mean Power (KW)	Peak Power (kW)	Mean Power (KW)	Peak Power (kW)	Mean Power (KW)	Peak Power (kW)	Mean Power (KW)	Peak Power (kW)	Mean Power (KW)	Peak Power (kW)	Mean Power (KW)	Peak Power (kW) (##)	Mean Power (KW)	Peak Power (kW)	Mean Power (KW)	Peak Power (kW)	Mean Power (KW)	Peak Power (kW)	Mean Power (KW)	Peak Power (kW)
Camera and chiller	**4,9**	**10,3**	**10,6**	**18,0**	**2,0**	**4,5**	**11,0**	**11,0**	**1,5**	**7,5**	**7,5**	**7,5**	**0,0**	**0,3**	**3,0**	**3,3**	**0,0**	**0,0**	**1,9**	**1,9**	**0,3**	**0,6**	**0,3**	**0,4**
Camera 400V and 230 V (##)	1,3	1,3	7,0	9,0	1,0	1,0	7,5	7,5	0,5	4,5	4,5	4,5	0,0	0,3	1,8	2,0	0,0	0,0	0,9	0,9	0,2	0,2	0,2	0,2
Chiller	3,6	9,0	3,6	9,0	1,0	3,5	3,5	3,5	1,0	3,0	3,0	3,0	0,0	0,0	1,3	1,3	0,0	0,0	1,0	1,0	0,2	0,4	0,2	0,2
Structure + Energy storage System (*)	**5,0**	**11,0**	**11,0**	**42,0**	**3,0**	**3,3**	**4,0**	**23,6**	**3,0**	**3,3**	**4,0**	**23,6**	**0,1**	**1,5**	**3,7**	**9,9**	**0,4**	**0,4**	**0,5**	**0,9**	**1,3**	**1,3**	**2,8**	**6,5**
Total	**9,9**	**21,3**	**21,6**	**60,0**	**5,0**	**7,8**	**15,0**	**34,6**	**4,5**	**10,8**	**11,5**	**31,1**	**0,1**	**1,8**	**6,7**	**13,1**	**0,4**	**0,4**	**2,4**	**2,8**	**1,6**	**1,9**	**3,1**	**6,9**

(*) Energy Storage system only for LST

(**) Power from CTA Power ditribution system, excluding the power supplied by Energy Storage system

(***) includes Chiller standby and chiller operation

(#) For SST 1M, Camera off during day time. This scenario does not include calibration light source and Sky CCD, as they will occur for only 30 min per observing

(##) Camera for SST 1M Includes "Heating for PDP" on for peak power