Recommendations and Minutes
Concept Design Review
for the Power Distribution System for CTA North

Review Panel		**Observers**
Jorge Gmelch (JG)– Power Engineer IAC		Markus Garczarczyk (MG) - MST
Dimitris Kalaitzoglou (DK) Power Engineer ESO		Javier Herrera (JaH), through ezuce – LST Telescope Manager
George Prutenau (GP) – Head of RAMS CTAO		Otger Ballester (OB), through ezuce - LST
Cesar Ocampo (CO) – Risk Manager CTAO		Daniel Mazin (DM), through ezuce (until 11 am) – LST Work Package Manager
Presenters		Michael Panter (MP) – CTA PO Infra
Manfred Engelman (ME) – Fichtner Consultant		Stephen Brown (SB), through ezuce – CTA PO Infra
Jim Hinton (JH) – Project Scientist CTAO		Wolfgang Wild (WW) – Project Manager CTAO
Alison Mitchell (AM) – Change and Requirement Management CTAO		
Carla Crovari (CC) – CTA PO Infra Power design		

Chair of the Review Panel	David Bristow (DB) - Infrastructure Coordinator

Minutes	Carla Crovari (CC) – Power Design

1. Summary

The agenda, the Review documentation and the presentations, are available on the Indico page (https://indico.cta-observatory.org/event/1720/).
The following is a summary of the Recommendations that were received during the presentations. Action Items, a Comparative table of the two selected Variants and the Minutes of the meeting are also part of this report.

2. Recommendations from the Review Panel

1. Measure power consumption of LST1 (prototype) in order to clarify at least: peak power consumption from the power distribution system, duration of this peak, how much time after the fast repositioning occurs. These measurements will be input to the detailed design, both for the Short Project (3 additional LST, 1 MST) and for the Expansion stage 2 (4 LST, 15 MST).
2. Define as a requirement if a UPS is required for voltage stabilization. If so, it should be defined in the requirements that an on-line UPS should be provided (on line UPS provide AC-DC-AC conversion). Otherwise it is recommended to develop power quality requirements.
3. Measure harmonic generation of the LST prototype to the power distribution system, (including as part of LST1 the UPS with flywheel system).
4. Double check the additional budget that adds to the peak power expected for the power distribution system, for Requirement B-INFRA-0500/0530 Peak Power.
5. Measure during the Short project, the Harmonic contribution to the power distribution system of MST.
6. Include a preventive maintenance plan for the batteries of UPS, as part of the operational plan. This is particularly important if the Variant chosen is #4.
7. Specify in the Requirement B-INFRA-0605 if the power stabilization required is for the loads.
8. Check the Power Upgradability required for CTA-North (Requirement B-INFRA-0505)
9. For B-INFRA-0630 specify that 2 power emergency stop functionalities should be considered: for the moving parts and for all the telescope.
10. Specify in the Requirement B-INFRA-0610 which protection is required for power cabling
11. Include through a requirement the amount of time it is expected that the UPS provides power to the telescopes (5 minutes to go to safe state).
12. Measure from the Short project, the peak power consumption of both LSTs and MSTs, to include these values as input for the detailed design of expansion 2.
13. Check ESO general power quality specification "GEN-SPE-ESO-50000-5044_iss2". *Note of the author of the minutes: this document can be input to the Interfaces definition process that comes as next step of the design.*
14. Check to rephrase B-INFRA-0640 Power frequency stabilization in line with the different interfaces proposed, between LST and MST with the power distribution system (for LST, UPS is part of LST structure as it is included in the Energy storage system, and for MST is part of the power distribution system).
15. Use Circuit Breakers in place of load break fuses for personal safety considerations. To be considered in the Detailed design.
16. Verify during Detailed design, with the supplier of the flywheel system, if the flywheel system influences the Short circuit current.
17. Include the results of the Lightning protection study as input for the Detailed design of the Power system
18. Check the characteristics of the incoming feeders to Substations 1 and 2 to include in Detailed Design.

19. Update the schedule with the Review Recommendations and Action items.

3. Action Items

1. To be escalated: Definition of MST 15 as part of the "Short Project". (D.Bristow, W.Wild)
2. A new version of Power Notes doc (Power Requirements) will be distributed, considering the Recommendations from the Review (A.Mitchel)
3. A final version of the Concept study report will be distributed, considering the Recommendations from the Review (M.Engelmann)
4. In coordination with the LST team, measurements to the LST1 prototype will be taken: for the peak power consumption required from the power distribution system, and the harmonic contribution to the power distribution system. These values will be considered as input to the Detailed Design of the Power system. (C.Crovari).
5. When the Short Project is deployed, measurements of Peak power consumption will be considered as an input for the detailed design of expansion stage 2. (C.Crovari)
6. Check and define Interfaces of the Power system to the telescopes (C.Crovari)
7. Plan for Hazardous situations analysis and FMEA simulation in the Detailed Design stage. (C.Crovari to coordinate with G.Pruteanu)
8. Together with the minutes, a comparative table will be prepared, with pros and cons for Variants 3 and 4 (C.Crovari). (included in this report in item 4.)

4. Comparative table between Variants 3 and 4

Variant 3 - Power distribution system connects MSTs with double feeders, no interconnection between Substation 1 and 2, and a Centralized UPS system for MSTs. LSTs connected through UPS+ flywheel system.

Variant 4 - Power distribution system connects MSTs with single feeders, no interconnection between Substation 1 and 2, and a Distributed UPS system for MSTs. LSTs connected through UPS+ flywheel system.

Characteristic	Variant 3	Variant 4
Use of standard equipment?	(0) For Centralized UPS system, Special equipment (ATS, special tailored UPS, MCCBs) is necessary	(+) Standard equipment can be used
Power distribution system is able to move MSTs to parking position?	(-) No if there is a short circuit at the Interface cabinet (impact: one telescope)	(+) yes, as UPS are local to each telescope
Power Quality	(0) The long distance between the Point of power conditioning (Centralized UPS) and the point of use , increase the chances of disturbances on the AC line	(+) Power conditioning is implemented at the point of use, which mitigates any electrical disturbances that may be coupled into the distribution wiring of a centralized system.
Management/ Maintenance	(+) Batteries and associated air conditioning are available in a central point, easier to manage	(-) Batteries and air conditioning in the interface cabinets, are distributed on-site. Need a more careful planning and time consuming execution, including periodical preventive maintenance and replacements schedule for batteries.
Operations plan	(0) Skilled personnel for specially tailored equipment	(+) Identical equipment for 15 MSTs, same case of single feeders connections for all MSTs and LSTs. Standard operation to conmute to UPS
Single point of Failure?	(-) Modular UPS are foreseen. The single point of failure identified is the ATS In the Interface cabinet, which impacts one telescope. The impact needs to be considered as the telescope would not be moved to parking position by the power distrib. System	(0) Single cable is a single point of failure which impacts one telescope. This failure will impact the observation but the telescope will move to parking position.
Cost effective	(-) Need to buy central parts of UPS system in advance.	(+) Buy each UPS only when a new telescope is installed
Remote Monitoring	(0) Required. Fibers from the Centralized UPS to Datacentre need to be included	(0) Required. Fibers between Interface cabinet and Datacentre are already considered
Environmental impact	(0) Double trenches increase impact to nature, in a protected zone that is ORM	(0) Bigger size for the Interface cabinet incuding UPS and climatisation system increases the Visual impact
Cost	(-) 3% more than Variant 4 due to the double cabling (the cost of double trenches is not included)	(+) Assumption was 2 batteries exchange in 30 years lifetime

5. Minutes of the Review Day 23.02.2018

Overview presentation (DB)
JH asked the status of considerations on the inclusion of MST 15 construction as part of the "Short project or 1st phase (presented as LST 2,3,4 and MST 3). **(See Action Item #1)**

Introduction presentation (CC)
DK recommended to take real peak power measurements from the LST prototype, when this LST is available. **(Recommendation #1)**

Power requirements presentation (AM)
- A new version of the *Power Notes* document will be delivered including the feedback received from the reviewers **(see Action Item #2)**
- Regarding the UPS system, DK commented that for backup between a grid failure and diesel generator operation, the current estimation of one minute is OK. Regarding the requirement B-INFRA-0640 Power Frequency Stabilisation, if UPS are required for voltage stabilization and conditioned power, an on-line UPS should be specified in the requirements **(Recomm #2)**
- Regarding Power Quality requirements, is it recommended to develop a set of requirements on this topic? DK commented that it depends, as it is a matter of costs, whether to specify an on-line UPS system (AC-DC-AC conversion) as part of the requirements (which will provide conditioned power to the telescopes), or to define a set of power quality requirements, and afterwards define a suitable solution. At this point ME commented that the current cost analysis of the Power Concept study included the value of an on-line UPS.
- As part of the Power Quality concept, harmonic contributions of the telescopes to the power distribution system still need to be measured, as the impact of harmonics is that it may affect the Power quality of the power distribution system and of the grid. **(Recomm #3 and #5)**
- Regarding the requirement B-INFRA-0600 Power System Adaptability (dimensioning of the power distribution system), DK recommended to specify a percentage for the extra capacity required. It must consider the peak power need, and an extra budget. To be studied carefully if a 10% extra margin is enough, as underestimating consumption has the serious negative impact of insufficient cabling width or transformer capacity. **(Recomm #4)**
- About Harmonic contributions; MG commented that MST prototype measurements have not detected harmonic contributions, but DK and ME explained that a different situation may occur in a weaker network (30MW in La Palma compared with 250MW in Germany) **(Recomm #5)**
- DK mentioned that in ALMA, the power distribution system includes a UPS local to each telescope. The experience is that batteries need preventive maintenance in order to ensure good operation when they are needed. **(Recomm #6)**
- DK asked why not consider a Low Voltage connection to Endesa, and that the operational costs of a Medium Voltage/ Low Voltage (MV/LV) transformer should be considered. ME explained that IAC provides a substation connection in ORM, and besides the distance to an Endesa point of connection would be too long for a LV power distribution system.
- ME clarified that for the LSTs, the peak consumption of 350 kW will not be taken from the grid in case the flywheel system fails, because the power in this point of connection will be limited to 60 kW. AM also commented that there is a requirement for the LST that limits the peak power consumption from the grid.
- Regarding the requirement B-INFRA-0605 Backup Power Control, DK recommended, if the intention is to require voltage stabilization for the loads, to change the wording in order not to ask for stabilization in the grid. **(Recomm #7)**
- JH asked for B-INFRA-0690 Power System Grid Connection, if the size of the diesel tank, for 48 hours of operation in safe state was ok? No negative answers were received, considering

that this aspect of the system is easy to upgrade later.
- Regarding the requirement B-INFRA-0505 Power Upgradability, CO asked if a power upgrade of 1 MW both for CTA-North and CTA-South was needed, as for CTA North seemed big. **(Recomm #8).** DK commented that for the Northern site it would also be possible to consider an extra connection to ORM when needed.
- For Requirement B-INFRA-0630 Power Emergency Stop. GP asked to use “functionality” in place of the explicit reference to a “button”. It was discussed if a button in the interface cabinet is needed to stop all power to the telescopes for maintenance purposes (MP), but also to cut the power to moving parts. Recommendation was that both should be considered for the telescopes. **(Recomm #9)**
- For Requirement B-INFRA-0610 Power Cable, DK recommended to specify the solution desired (cables in tubes in underground services). **(Recomm #10)**
- JG commented that regarding cable failures, no damage due to animals has been registered at ORM.

Concept design study presentation (ME)
- ME commented that UPS to operate for six minutes, came from 1 minute to wait for diesel generator to begin, plus 5 minutes required for the telescopes to go to safe state (if power from the central part of the distribution system is not available). DK recommended that this time is specified for the power distribution system through requirements **(Recomm #11)**, and also agreed that the control system for the UPS should be programmed for this purpose.
-ME commented that due to budget reasons, the infrastructure for LST1 (Energy storage system, Transformer, Automatic Transfer Switch (ATS) and Diesel generator for Substation1) was ordered by the LST team, in parallel with the elaboration of this Concept study, and implemented independent from the ongoing study.
- ME commented that the Earthing design should be according to the results of the lightning protection study. Reviewers agreed. (**Recomm #17**)
- Trenches to be shared between data (fibre) and power cabling. DK commented that it is a standard practice to put them in same trenches but different ducting. ME commented that the Concept study stated that ORM have them in different trenches on each side of the road (MV distribution power lines and fibres); but no problem is foreseen in sharing trenches in different ducts.
- GP asked, for Variants 2 and 3, how to switch between infeeds (variants with redundant cabling). ME answered that special switches were considered for the central part (Centralized UPS system), and the cost is included in the Concept study (in the 0.4 kW substation item)
- ME commented that for Variant 2 and 3, a disadvantage is a particular short circuit condition
- ME commented that Variant 4 is the recommended one. DK agreed because it is simpler. Only disadvantage is in case of cable failure, but would affect only one telescope, and in Low Voltage (LV) networks, standard time for reparation is within 24 hr. No big risk in operation is foreseen, as the functionality is quite standard. To be considered good planning for batteries maintenance.
-GP also prefers Variant 4, as it uses standard equipment, from easier maintenance point of view, and in case of failure (cable) only one telescope is affected.
- ME commented that for Variant 4, UPS would go inside the Interface Cabinet, and needing for the Cabinet included a climatization solution. ME also commented that the cost of the cabinet including an air conditioning system for a 30 kW UPS is included in the cost analysis of the Concept study.
- MG asked if the interface cabinet to host a UPS and an air conditioning system was still considered standard equipment, and ME answered yes, these shelters can be found in the market.

- MG asked if Variant 4 would comply with the 99.5% availability in case of cable failure? ME reminded about the good capacity of using a portable diesel generator.
- MG asked, in case flywheel for an LST failed, as they are dedicated devices to each LST, is it an advantage for Variant 3, considering that centralized UPS could supply LST? ME commented that each LST will have 2 flywheels. And besides Variant 2 and 3 do not consider supplying LST from the centralized UPS system.
- JH asked why is there a need of a second substation? ME commented that first substation is central to the array, and the second one will be beside a big power consumer which is the Technical building with the Datacentre inside.
- ME commented that the peak power consumption for Substation 1 can be bigger than Transformer 1 size. But it is not expected that the peak consumption is simultaneous for all the telescopes, even if all the telescopes reposition at the same time, because the peak power consumption of the LSTs will be for reloading the flywheels. ME also added that the risk for transformers is high temperature, and transformers may be overloaded 120% for a small time. Still was recommended to measure during the Short project, the peak power consumption of both LSTs and MSTs. **(Recomm #12)**
- JH asked if there are any constraints to consider for MST 15 instead MST 3. ME answered that no constraints have been identified from the power system point of view.
- MG asked if Variant 3 needs all the UPS capacity since the beginning. ME answered no, as the solution is modular not all the electronics and batteries would be required from the beginning; only for the initial telescopes.
-For Variant 4, DK also commented that it is cost effective considering that UPSs will be bought only when each MST is implemented, and for maintenance it is an advantage to have 15 identical equipment.
- MG asked for the environmental impact for Variant 4? Considering the Interfaces cabinets with batteries for the UPS. DK commented that a plan for batteries replacement should be considered, but with no environmental impact is identified. ME commented that on the other hand for Var 3 there may be environmental impact associated with double trenches (for the backup cable).
- It was discussed that the peak power for MSTs may occur in repositioning, and not in fast repositioning as it was first understood. The impact of this is that for Substation1, when 12 MSTs are connected (for Expansion stage 2), they may not be able to begin repositioning at the same time. A solution proposed by ME is that the transformer and the diesel gen from Substation1 should be relocated to Substation 2, and bigger equipment will be installed in Subst.1. JG commented that it will be possible to install a 1000 kVA transformer in Subst.1. **(Action Item #5)**

Interfaces Presentation CC
- JH asked if WW agreed with different interfaces to the LST than to the MST? (as the current proposal is for the LST before the Energy storage system and for the MST after the UPS). WW answered it will be checked. **(Action Item #6)**
-The Analysis of Hazardous situations together with a FMEA simulation should be done when one of the four Variants is selected, as was recommended by GP. **(Action Item #7)**

Concept Review Presentation CC
The Excel document “180220_Concept_Design_Review_for_Power_CTAN_-_DKA -CO Rejoinders” that circulated before the Review day, with Questions from the Reviewers and answers from the presenters were discussed, for all the questions that did not end in an “ok” from the Reviewers. The referred document is in the Indico link (https://indico.cta-observatory.org/event/1720/).

Following a summary of this discussion based on the Excel. The numbers of the questions of the following summary, refer to the number of the question in the excel document referred.

Q#2 Peak Power demand from the power distribution system for LSTs (considering Energy storage system as part of LST):
48 kW is expected, but will be measured from the LST prototype in La Palma (see **Recomm #1** and **Action Item #4**)

Q#4 Margin in Requirement B-INFRA-0600, to be specified as a percentage and checked if 10% was enough. AM commented that the current values in B-INFRA-0500 already included a buffer but the requirement will be checked (See **Recomm #4** and **Action Item #2**)

Q#6 Power Quality requirements for CTA-N. It is recommended by DK to check ESO general Power Quality specification. **(Recomm #13)**

Q#7 Rephrasing for Requirement B-INFRA-0520/ 0550 Annual Energy Consumption. Agreed to rephrase, see **Action Item #2**.

Q#11 Rephrasing for Requirement B-INFRA-0605 Backup Power Control. Agreed to rephrase (see **Action Item #2**, **Recomm #7**).

Q#12 Rephrasing for Requirement B-INFRA-0610 Power cable: Agreed to rephrase (see **Action Item #2**, **Recomm #10**).

Q#14 Rephrasing for Requirement B-INFRA-0640 Power frequency stabilization: it is recommended to better clarify distinguishing LST and MST (in line with the interfaces proposal which are different for MST and LST). (**Recomm #14**)

Q#16 Reliability expected for the Substations as stated in the Concept study. Agreed to rephrase, see **Action Item #3**

Q#19 Requirement for the time UPS need to supply to the telescopes. Agreed to include (see **Action Item #2**, **Recomm #11**).

Q#25 Frequency variations allowed for systems with no synchronous connection to an interconnected system, according to EN 50160 (that may apply for islands) need to be considered. Agreed on including a Requirement for on-line UPS (see **Action Item #2**, **Recomm #2**)

Q#29 Values for power available after derating factor (due to altitude) for transformer and diesel generator included in the Concept study, provided by the provider for the LST Energy storage system, need to be checked. Agreed that the values will be verified (see **Action Item #5).**

Q#30 The incoming feeders of each Substation, will have Circuit Breakers or load switches? Bus tie will be used for the connection of the 630 kVA transformer? Who would provide the switchgear to connect the transformer to the ORM MV network, and who operates it? JG commented that currently ORM provides load switches that are manual ones, in each Substations´ input and output. There is a protection device in Residencia (which is the point of distribution). ME pointed out that a visit to ORM is foreseen to check on-site these connections, and a report will be provided. (**Recomm #18**)

Q#33 The designer of the power distribution system shall ensure that the UPS + flywheel system for the LSTs is able to provide power for the time required by the separate standby generator to resume supply (20-30 sec, as indicated in the Concept study, or longer). Agreed that during Detail design this needs to be confirmed (see **Action Item #4)**

Q#37 Use of Circuit Breakers (CB) versus fused load break switches is encouraged by DK, considering easy and safety during connecting/ disconnecting operation. ME commented that switching actions are in any case restricted to special trained personnel. ME agreed that personal safety increases when implementing CB, but are more expensive. DK recommends using CB. (**Recomm # 15**)

Q#38 peak power consumption for MSTs. MG and JH clarified that there is no "fast repositioning" for MSTs different to repositioning with respect to power consumption. MG commented that a use case could be created for this topic
ME commented that considering this condition, the current size of transformer for Substation 1, would not allow the 12 MSTs to reposition at the same time. ME proposed to first measure the real peak power consumptions in the Short Project, and if needed, for the Detailed design of Expansion stage 2, a change of the current transformer and diesel gen from Subst1 to 2, can be considered; and a bigger transformer of 1 MW and new diesel gen would be recommended. (see **Action Item #5**, **Recomm #12**)

Q#40 For Variants 2 and 3, "Damage of equipment due to sudden power cut is possible", is this risk acceptable? MG said it is acceptable as telescopes are required to prevent for damage beyond the serviceability limit state in case of a power loss. JH commented that power distribution System is required to provide power to move telescopes to parking position. The consideration is that only a distributed UPS solution protects against some catastrophic central event (e.g.serious fire) moving telescopes to parking position. (See **Action Item#8**)

Q#46 Use of line filters for LSTs, to prevent a high harmonic contribution. It is recommended by DK to consider that the use of flywheel system in each LST, is expected to drastically reduce harmonics. Then the recommendation is to measure in LST prototype before including line filters. (see **Action Item #4**, **Recomm #3**)

Q#47 Influence of the available short circuit power by the Flywheels of the LSTs. It is DK recommendation to verify with the supplier for the Detailed Design of the Short Project, if the flywheels will increase the short circuit current. The need to use harmonic filters shall be evaluated when all characteristics of the LST flywheels system are well known. Agreed, **Recomm #16**

Q#53: Regarding the Standard that apply to electrical systems, besides de IAC standards from the Hosting agreement that are included also in the Concept study, are there any additional recommendation from the Reviewers? Agreed, see Recomm #13.

Q#54: Could the current LST prototype put any constraint in any of the Variant implementation? ME commented that it is not foreseen that this happens, but a visit to the site will help to verify.

Q#55: CO commented that a schedule will help to visualize constraints if any for the implementation of the phases. (**Recomm #19**)

Questions from the Review Plan

1. Have the system performance requirements, concerning the power system, been defined? Are they complete?

The Review Panel agreed that at this stage of the design, Requirements look as a good start to continue to the Detailed design, with the recommendations already discussed, and any outstanding issues will be resolved at the Detailed design stage.

2. Have all interface requirements been captured? Is the operational environment considered?

Same as 1.

3. Have system utilization requirements been defined? Number of operating hours? Life time?

Same as 1. For the Detailed Design, batteries lifetime needs to be further studied.

4. Has the anticipated concept of maintenance been identified?

The Reviewers agreed that the Concept study has considered reasonably measurements for Maintenance. GP commented that after the Variant is chosen, and for the Detailed design stage, it is expected a Risks and Hazards Analysis, and Analysis for Recovery time for the system.

5. Are all requirements verifiable?

DK commented that some Requirements need to be clearer in line with the Recommendations given.

6. Do system requirements all trace to upper level requirements?

JH commented that this is an ongoing work, but some of them are defined.

7. Have RAM requirements been defined?

JH commented that this is an ongoing work, but some of them are defined. GP added that FMEA analysis needs to be done during the detailed design stage, with the Variant selected.

8. Have hazards been identified and ESH (Environment, Safety & Health) requirements been defined?

JH commented that Safety and Health requirements have been developed only at a high level, and GP commented that next step is to include more detailed Safety requirements.

9. Has the architecture of the system been defined?

Reviewers agreed that at this stage the Architecture of the Power distribution system seems well defined, more details are expected in the Detailed design.

10. Do the Variants proposed in the Conceptual study: Variant 1, 2, 3 and 4, comply with the power system requirements? If not, please comment which Variant and in what sense may not comply with which requirement.

Variant 2 and 3 may not be able to take the MSTs to parking position if there is a short circuit at the Interface cabinet. A mobile generator connected in the Interface cabinet may be a mitigation.

11. Besides requirements, do you foresee any risk of the following, to any of the 4

Variants. Considering both implementation and operation & maintenance: Risk in Schedule, Risk in Cost, Risk in Quality, Risk in scope. If so, please comment which Variant has what kind of Risk

In line with the Recommendations, risks for the next stages will be mitigated with measurements for LST prototype and for MST.

12. Based on your experience, in case you see clear advantages for any of the four Variants, please comment which one it is and which are the advantages you identify.

The Reviewers commented during the day the advantages that were identified for Variant 4. JG commented that he found advantages to Variant 3 but thought that Variant 4 would be easy to operate as well, and found no problems in case Variant 4 was selected.