# Power Requirements

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# Power Requirements Concept

- CTA Power Requirements document circulated

cherenkov telescope array

# CTA Power Requirements

| This Version: | | | | |
|---|---|---|---|---|
| Ver. | Created | Comment | Distribution | Corresponding... |
| 0.2 | 2018-02-02 | Addition of Associated Requirements | CTA | Editor: *See Appendix 3.1<br>Checker: _____<br>Approver: _____ |

# Power Requirements Concept

- Categories:
  - Requirements on the power system (**B-INFRA-0500 – B-INFRA-0700**)
  - Requirements on telescope power consumption
    divided into Structure (**B-xST-0610 – B-xST-0640**) and Camera (**B-xST-1570 – B-xST-1600**)
  - Requirements on associated infrastructure
    (interface requirements, **B-INFRA-xxx** in section 3.3)
  - High level requirements
    (**A-GEN-xxx** and **A-OBS-xxx**) → not directly applicable but associated

# Power Consumption Requirements

# Telescope Power Requirements

- Power Consumption Requirements on Telescope Structures and Cameras in the Observing and Safe states
  - Camera budget includes the cooling system but not the Camera server (located in the on-site technical buildings)

- **Observing State**:
  - The System is an a state associated with observatory data taking, with configuration dictated by performance requirements. Calibration activities may take place.

- **Safe State**:
  - The System is in a configuration suitable for survival in extreme conditions, minimising use of power whilst still providing basic status monitoring, and maximising the instrument lifetime.

# Telescope Power Requirements

- **B-xST-0610 / 1580 Average Power Consumption during Observations**:
  The average power consumption by a single xST Structure/Camera during Observations must not exceed X kW.

- **B-xST-0640 / 1600 Annual Average Power Consumption in the Safe State**:
  The average power consumption over a full year by a single xST Structure/Camera in the Safe State must not exceed X kW.

- **B-xST-0620 / 1570 Peak Power Consumption during Observations**:
  The peak power consumption by a single xST Structure/Camera during Observations must not exceed X kW.

- **B-xST-0630 / 1590 Peak Power Consumption in the Safe State**:
  The peak power consumption by a single xST Structure/Camera in the Safe State must not exceed X kW.

# Telescope Power Requirements

| | Observing State | Safe State | Observing State Peak | Safe State Peak |
|---|---|---|---|---|
| LST Structure | 11 kW | 5 kW | 30 kW | 11 kW |
| LST Camera | 11kW | 5 kW | 18 kW | 11 kW |
| MST Structure | 5 kW | 500 W | 24 kW | 4 kW |
| MST Camera | 11 kW | 2 kW | 11 kW | 3 kW |
| SST Structure | 4 kW | 0.5 kW | 11 kW | 2 kW |
| SST Camera | 3 kW | 0.5 kW | 4 kW | 1 kW |

**Table 2.1** – Power allocations for the Telescope Power Requirements.

- Annual Average Power Consumption in Safe State
  - Assume ~ 1% of time in extreme conditions (peak usage)
- Average Power Consumption during observations
  - Assume ~ 1 repositioning per hour (peak usage) lasting for half the repositioning time

# Peak Power Load – LSTs

- LSTs will be supplied with additional power from a dedicated energy storage system (ESS)

- The power needed to charge the fly wheels will not occur simultaneously with the LST fast repositioning
  - Fast repositioning makes use of the ESS
  - Recharging of the fly wheel occurs after fast repositioning is complete
  - Two uses will not occur simultaneously

- Peak LST power consumption is 46 kW → propose **48 kW**
- Dimensioning the power system for **60 kW** is consistent with providing at least the required power

# Infrastructure Power Consumption

- As well as telescopes, also need to consider power consumption by technical buildings and central infrastructure
  - Technical buildings include on-site computing needs and workshops
  - Central infrastructure includes interface cabinets and hardware deployed in the field (e.g. calibration and weather monitoring instruments)

- **B-INFRA-0580 / 0585 Technical Building Power**:
  Technical buildings and facilities located at the CTA-N (S) site must be compliant with the allocated power consumption budget of 150 kW (240 kW).
- **B-INFRA-0590 / 0595 Central Infrastructure Power**:
  The total power consumption by all distributed hardware (OES controllable systems) and Interface Cabinets deployed within the array must never exceed 15 kW (CTA-N) / 48 kW (CTA-S). The average total power consumption must not exceed 11 kW (CTA-N) / 40 kW (CTA-S).

# Total Array Power Needs

- Combined consumptions to provide totals for the CTA power needs at each site
- Input includes:
  - Average power consumptions for Observing and Safe states for different Telescope types
  - Number of telescopes at each site
  - Expected time per year in Observing, Standby and Safe states *(assuming observing for maximum possible time per telescope type and including availability budgets. In Standby state, Camera consumes as for Observing, Structure as for Safe.)*
  - Infrastructure power needs

| Telescope Type | CTA-S | CTA-N |
|---|---|---|
| LST | 4 | 4 |
| MST | 25 | 15 |
| SST | 70 | - |

| Telescope Type | Observing Average | Safe Average |
|---|---|---|
| Combined LST | 22 kW | 10.2 kW |
| Combined MST | 16 kW | 1.6 kW |
| Combined SST-1m | 6.8 kW | 0.52 kW |
| Combined SST-GCT | 2.5 kW | 0.43 kW |

# Total Array Power Needs

- **B-INFRA-0500 / 0530 Peak Power**:
  The peak electrical power required for southern/northern observatory operation (due to simultaneous movement of telescopes in adverse wind conditions, lasting at most 2 minutes and occurring at most 10 times per night is X MW.
- **B-INFRA-0510 / 0540 Power during observations**:
  The average electrical power required for southern/northern observatory operation during observations is X MW.
- **B-INFRA-0520 / 0550 Annual Energy Consumption**:
  The southern/northern site infrastructure must be capable of providing an annual electric energy supply of X GWh.

| Requirement | CTA-South | CTA-North |
|---|---|---|
| Annual Energy Consumption | 4.4 - 5.4 GWh | 2.6 GWh |
| Power during Observations | 0.9 - 1.3 MW | 0.55 MW |
| Peak Power Consumption | 1.8 - 2.5 MW | 1 MW |

**Table 2.4** – The power consumption by each of the CTA sites under the corresponding conditions must be less than the values given here. The ranges given for CTA-South correspond to the expectation for different SST designs, with the requirement given by the upper bound of the range.

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# Power System Requirements

# Power Quality

- Could use GEN-SPE-ESO-50000-5044 issue 2 as an applicable document

- **B-INFRA-0570 Power Distribution**:
  The nominal voltage of CTA three-phase low voltage power systems reaching the telescopes and buildings of (both sites 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-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 the instruments.

# Backup Power

- **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-0605 Backup Power Control**:
  The Power Provision System must incorporate a backup solution, capable of compensating for variations in the supply of power from the grid.

- **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.

# Power Upgradeability

- **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 1 MW.

- **B-INFRA-0600 Power System Adaptability**:
  The on-site power infrastructure of CTA must provide extra capacity 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).

# Power System Availability & Maintenance

- **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%

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

# Power System Safety

- **B-INFRA-0610 Power Cable**:
  Telescopes and OES Controllable Systems must be provided with a cable power supply, which must be protected against damage for the entire cable length (between system and building) without impeding access to the System.

- **B-INFRA-0620 Power Interlocks**:
  There must be an interlock system which operates to stop the power supply in case a hazardous situation arises.

- **B-INFRA-0630 Power Emergency Stop**:
  Emergency stop buttons to cut power must be placed within all Interface Cabinets and in the data centre.

# Questions?

# Backup

- Assume maximum number of hours in observing (given night sky brightness), corresponding to minimum time in Safe state
- This gives a maximum power consumption
- (Note – only SSTs observe up to 30x dark sky brightness)

| State | Conditions | No. Hours (CTA-S) | No. Hours (CTA-N) |
|---|---|---|---|
| Observing | dark | 1593 | 1564 |
| | $5\times$ dark | 804 | 788 |
| | $30\times$ dark | 875 / 0 | – |
| Standby | any | 715 / 663 | 663 |
| Safe | any | 4779 / 5706 | 5751 |

**Table 2.3** – Number of hours per year available for observations under the corresponding conditions; for high NSB, the additional number of hours with respect to the previous category is given. Time spent in the standby state is dominated by the time needed for Cameras to warm up prior to observations commencing. When not observing or in the Standby state, it is assumed that telescopes are in the Safe state. For CTA-S, where two values are given, the former corresponds to SSTs and the latter to LSTs and MSTs. An average number of 8766 hours per year is used.