Preliminary analysis of the drive system of the CTA LST Telescope and its integration in the whole PLC architecture
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List of Abbreviations

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Abstract

This work aims to present a preliminary analysis of the drive system configuration for the CTA telescopes array and more specifically a possible architecture for the sub-array of Large Size Telescopes – LSTs. The first part of this document is focused on the control command architecture of the drive system dedicated to the LST including a view on some mechanical aspects concerning the telescopes of this class. In particular the current investigation on the interfaces between the drive system and the automatic system in charge of the camera mast control system (e.g. the arch damping) is presented. In the second part of this work the issue of the integration of the telescope drive system within a global PLC (Programmable Logic Controller) architecture for the CTA array is addressed with the corresponding links to the control software layer.

1. LST DRIVE SYSTEM:

1.1 Context :

One specification of the LST drive system is to perform the rapid positioning of the camera pointing direction in the sky to follow up astrophysics alerts in the shortest possible time interval, satisfying coherent safety conditions requirements and guaranteeing fast and efficient resuming of the data acquisition. Monitoring and control of the driving will be guaranteed by a software layer interface. The final mechanical conception of the large size telescopes is still in progress and the mechanical drive system is not yet defined since under investigation within the LST-WP. However here below we present those minimal specifications which are considered critical:

Weight: 50 tones
Focal distance: 23 - 24 m
Rotation speed (fast): 180° in 20s
Drive tracking position: <0.005 deg

In order to respect as well as possible the requirements, a conceptual architecture is developed, independent to the numbers and the power of the motors.

1.2 PLC analysis :

To insure motion independence for each telescope, a distributed control by means of PLCs is required. The solution is to consider each telescope as an independent automation subsystem with its own PLC, drive controller, sensors, instrumentation fieldbus, etc. This corresponds to a classical drive system work configuration [1] aimed to fulfill the requirements.
According to this view three are the most critical aspects to be investigated: synchronization, safety, and power.

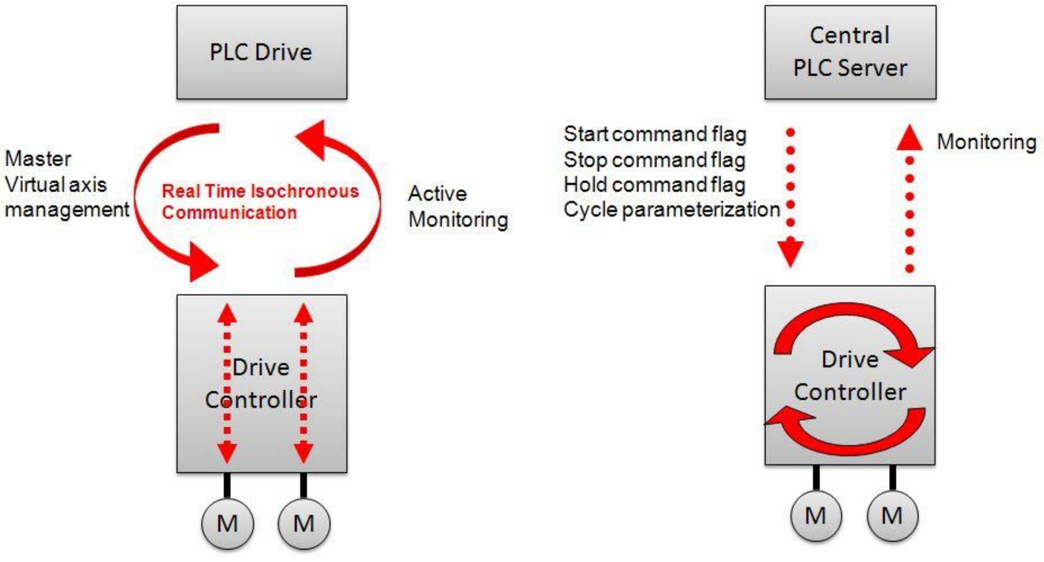
a. Drive and synchronization of the axes:

First of all, in order to reduce motors costs and dimensions, synchronization between motors is needed, so the drive controller has to be able to manage this synchronization. In order to achieve this specification, the two following approaches (PLC – drive controller) can be considered:

- *Motion control not integrated into the drive control unit:*
  The CPU of the PLC drive will manage motors synchronization using a dedicated automation network, which must be suitable with isochronous real-time. In fact, the CPU of the PLC will manage a virtual axis which will be the master of the real axes and next, achieve the synchronization between the motors.

- *Motion control integrated into the drive control unit.*
  The motor synchronization is directly managed into the drive controller (integrated in the variators configuration). The PLC server will only manage the start flag with the needed cycle parameters and will receive information of the motors (torque, speed, positions…).

The choice between the two solutions (shown and compared in the figure 1) will be given by the number of synchronized motors, the limitations of the network and the complexity of the process cycles. This will also determinate the needed number of PLCs: one PLC dedicated to the whole LST configuration or a PLC per LST telescope drive system.



Motion control integrated into PLC Drive

Motion control integrated into drive control unit

Figure 1: Flow-diagrams of the two proposed options implying PLC- drive controller at different stages.

b. Safety aspect:

In order to take into account and manage the safety aspects (e.g. management of the emergency stops for example), a safety centralized network with central safety PLC is foreseen (see figure 2). Note that the use of specific safety devices in this network is required in order to respect legal obligations. Some drive controllers have safety integrated functions (accessible from safety PLC). This must be taken into account for the final drive controller choice.

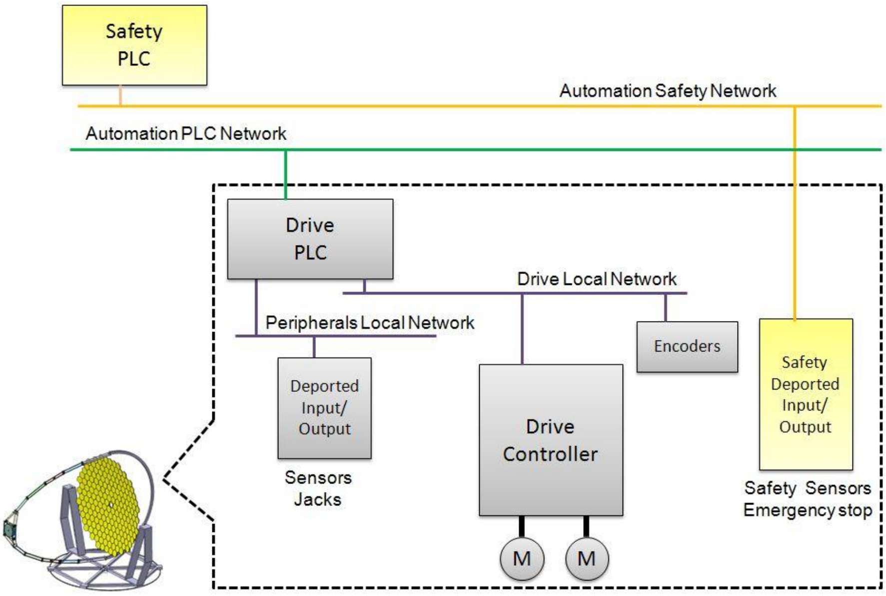


Figure 2: A view on the workflow of a telescope drive system

c. Power supply:

The last main aspect is the management of the power supply which is a critical aspect.
First of all, the configuration has to be able to manage a power cut. Indeed, if a power cut happens, the stop of the motors must be guaranteed with the synchronization of the axes until the end of the motion in order to avoid mechanical damages. For that, the drive configuration must have an electrical power saved (e.g. a capacitor module) which will be able, during a short time, to generate the required power which is needed in order to ensure the essentials motors functions for a safe break of the motors.
Furthermore, the motors will be successively generators and consumers of power supply. Considering the size of the complete CTA electrical installation, the total power supply has to be optimized. In this prospect, the drive configuration has to integrate an internal 4 quadrants power supply. In this manner, the power generated during motors brakes (if they are power generators) could be also injected into the main power supply for the other drive systems (or any others devices). Note that the system has to be able to manage the generation of power in the main electrical network, but also in a brake resistor if the motors become power generators during a power cut.

These main aspects and this type of setup are under control and are already developed in similar systems, for example the drive system of the loading – unloading of the HESS II camera [2].

1.3 Mechanical drive system investigations:

a. Configuration:

The aim of the current work is to compare the traditional approaches which consist in using boogies or rack-and-pinions (HESS, MAGIC telescopes…) with a hybrid solution. Considering the desired speed and the required accuracy, the idea would be to put the telescope on a rotation support which can be made of steel or of carbon fibers (figure 3). The disadvantage is that in such manner, the weight of the whole system will increase, and therefore the power of the required motors. However this solution presents two great advantages: it considerably decreases the interface between the drive system and the telescope which will become uncoupled and it greatly facilitates the tests campaign and so optimizes the duration of the on-site installation.

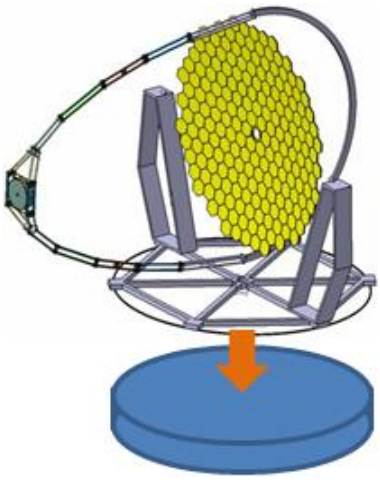


Figure 3: principle of a telescope put on an uncoupled rotation support

b. Dimensioning:

The aim of this paragraph is to briefly describe the aspects which have to be taken into consideration and which are under study in order to evaluate the required power and quantity of motors of the drive system.

In order to manage a gamma rays alert, the telescope has to able to move very quickly from a position to another one. This duration will integrate different parameters as it is described in the figure 4:

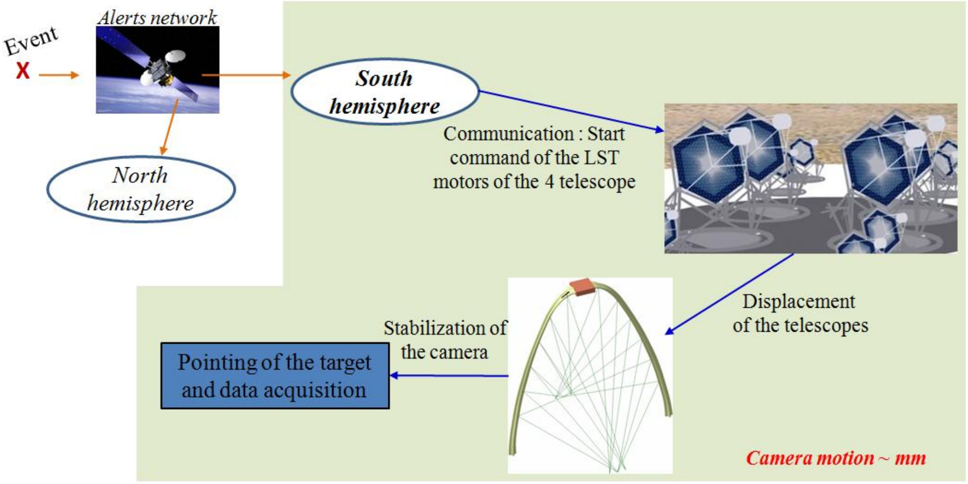


Figure 4: the critical cycle of a gamma rays alert management

Considering the desired speed, the motion of the telescope will create vibrations of the structure supporting the camera. Even if the conception of the telescope is studied in order to obtain quickly a stable camera, (it will eventually be damped by an active system [3]), it requires a specific duration as a function of the camera disturbances. For example, if one tunes the system in order to have a very fast motion of the camera, the vibrations will be important but it will give more time for the damping system in order to damp the camera motion. Next, the balance between the two main systems has to be considered as it is explained in the figure 5 below, with the different decomposed phases. Note that the duration of the communication is treated in the part 2.

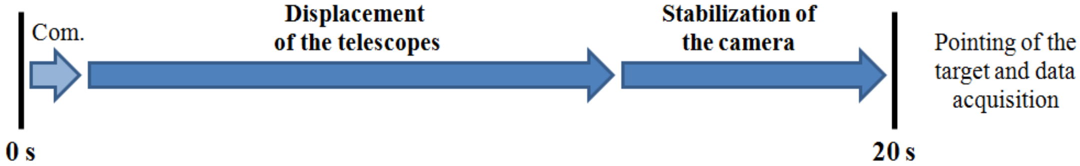


Figure 5: the different phases of a critical cycle

Furthermore, given that the telescope is an inertial system and in order to optimize the power and the number of the motors, the trajectory of the telescope has also to be optimized. The optimal trajectory has to be evaluated (see figure 6) and will probably be a compromised between the shorter trajectory (trajectory A) and a rotation done with the camera as close as possible to the zenith axis in order to reduce the inertial effects (trajectory B).

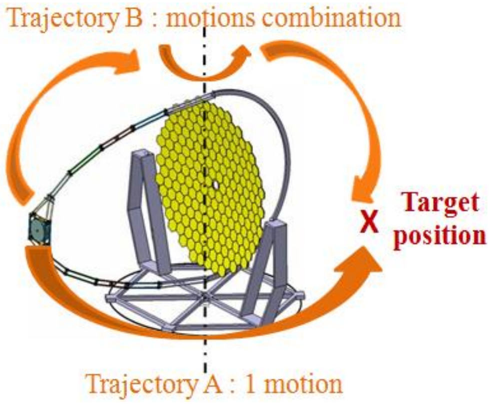


Figure 6: interpolation of the optimized displacement

At this moment, all these requirements and criteria are simulated and are under study in order to evaluate the best configuration and to define the required power and number of the motors.

2. PLC ARCHITECTURE:

This last part of the document aims to propose a conceptual architecture for the LST telescopes drive system (considering that at least four of such class telescopes are expected for each CTA site). Indeed, they will be integrated in an array composed by about 80 telescopes on a area of a few kilometers square and the PLC architecture will be connected to a software layer as many various devices. The goal of this paragraph is to give a brief analysis of the problem of homogeneity and the

different possible solutions which can be carried out.
One strategic aspect is to have the most homogenous architecture as possible. Indeed, there will be one main CTA partner institute per class of telescope which will be on charge to carry out an architecture which matches to the needs of a specific drive system. However, one has to optimize different specifications:

- Each sub-system (drive system of a telescope) has to be easily and uniformity connected to a software layer.
- The cost of the hardware and the implementation duration has to be as low as possible.
- The maintenance of the system (uniformity of the hardware and the software) has to be optimized.
- The integration of additional various devices (controllers, stations, smart instrumentation…) in the network has to be anticipated.

In order to follow these requirements, the first approach would be to develop architecture close to the ALMA architecture [4], [5]. This method consists to have a direct link from the software layer to each subsystem and the uniformity requirements can be avoided thanks to software developments as it is illustrated in the figure 7.

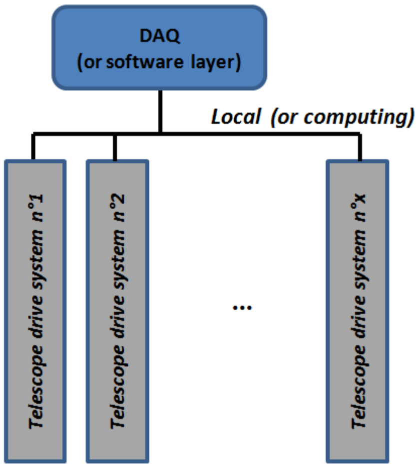


Figure 7: A possible configuration based on a software approach in direct link with the sub-systems

This solution reveals the advantages to be flexible and cheap from a hardware point of view. However, it requires very important developments which are specific for each type of devices, the maintenance of such system is very complex and it requires an important manpower.
In this part, one attempt to propose an alternative solution based on industrial products. The prospect is to compare the two approaches in order to point out the advantages and disadvantages of each one.
For the “industrial approach”, several solutions can be carried out. The solution proposed in this article is to have a multilayer architecture (see figure 8), as it is usually developed in the assembling or production manufacturers, which will be linked to the software layer thanks to a unified architecture OPC server.

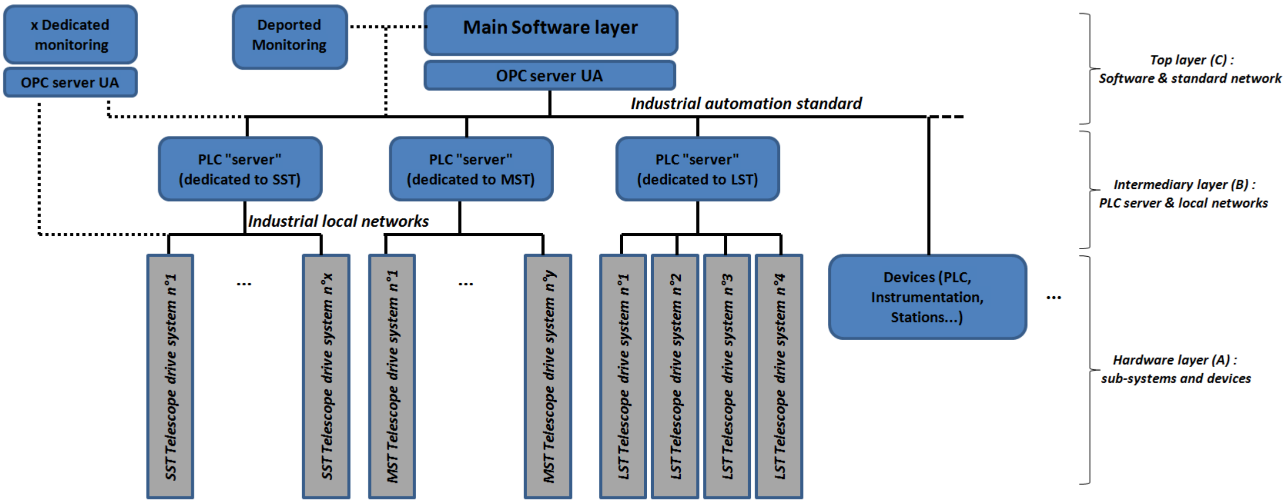


Figure 8: Proposal of a homogenous architecture

This architecture is composed of these following layers:

- *A "hardware" layer (A)*:

This is the set of the devices and subsystems which will compose the whole architecture. First of all, it will be composed on the different drive system sub-systems but the aim is to integrate a maximum of various devices which compose the installation (safety PLC, smart instrumentation, stations…)

- *A dedicated local network layer managed by a PLC server layer (B):*

The idea is to have a "processing node" of the data flow which comes from the software layer to a drive system. This configuration allows obtaining the advantage that the PLC layer, which is connected to the software layer, would be completely homogenous.

Next, it allows two possible approaches for the drive system configuration. First of all, it is completely conceivable to carry out 2 PLC manufacturers (one per PLC layer) considering that the local network will be a standard one (i.e. Profinet, Can Open, EtherCAT, DeviceNet…) in order to allow a large flexibility to the different laboratories in charge of a sub-system. This way, each laboratory in charge of a type of drive system can be carrying out its specific drive system sub-system independently to the others.
However, in order to have the most optimized configuration, the second approach could be to select a complete uniformity of the PLC manufacturers between this intermediary layer and the drive system which will be connected through a standard local network. Next, it allows an increasing of the possibilities. For example, depending to the choice of the PLC manufacturers, it is also feasible to carry out specific networks (i.e. Profinet Isochronous Real Time for example). In such manner, it is possible to manage simultaneously different subsystems in a deterministic way; next the communication in an alert case can be greatly optimized. However, by increasing the efficiency of the commands management, the monitoring of the desired data will result more constrained due to

the fact that there are different layers with specific data.

- *A industrial and standard link between automation and computing (C):*

The aim is to propose a unified layout with industrial products. In this prospect, a product is under evaluation: an OPC server UA (Unified Architecture). Indeed, mainly automation installations are managed by OPC servers. However, each OPC server is dedicated to a specific manufacturer and it is linked to the windows environment. The solution under evaluation will be based on a standard communication with different types of PLC (and with various automation devices) and also to implement a software independent to the windows environment. The communication would be based on a standard network which can be supported via optic fiber in order to successfully manage the important distances between each sub-system. This solution would be very flexible and homogenous for the implementation and it requires only having devices which are compatible with the OPC server UA standard.

3. FUTURE PROSPECTS:

In order to validate the proposed layout, a test bench will be realized at LAPP with a defined control command architecture which can be flexible. The main target is to test the configuration detailed in the figure 9, but other architectures could be evaluated.

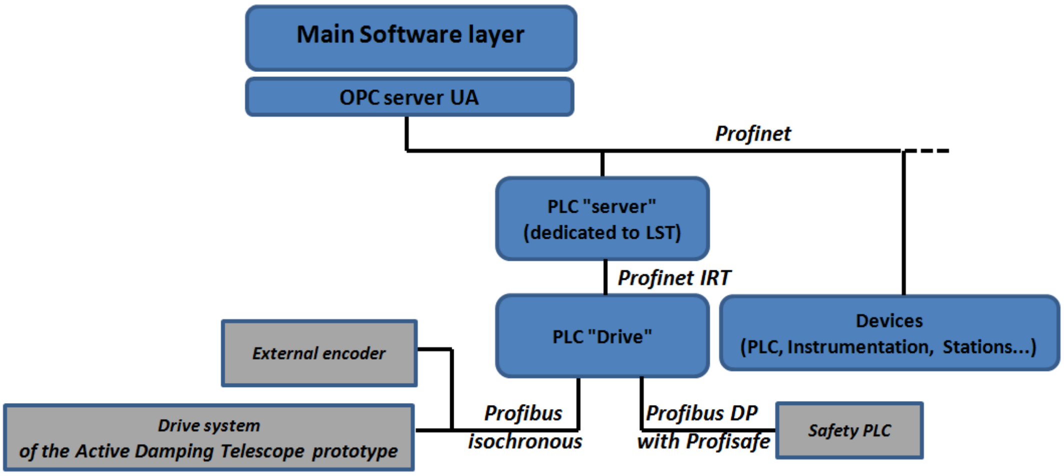


Figure 9: Example of configuration of the future control command test bench

This test bench will allow validating the efficiency of such an approach (cycle time, deterministic aspects, plug and play requirements…) and also equipping the drive system of the LST active damping vibration demonstrator [10] (shown in figure 10).

Figure 10: Demonstrator of the LST vibration active damping system

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