CILEX-APOLLON PERSONNEL SAFETY SYSTEM*

Jean-Luc Veray, Jean-Luc Paillard, Alexandre Bonny, Laboratoire LULI, Ecole Polytechnique, route de Saclay, 91128 Palaiseau

Abstract

Cilex-Apollon is a high intensity laser facility delivering at least 5 PW pulses on targets at one shot per minute, to study physics such as laser plasma electron or ion accelerator and laser plasma X-Ray sources. Under construction, Apollon is a four beam laser installation with two target areas. Such a facility causes many risks. The Personnel Safety System (PSS) ensures to both decrease impact of dangers and limit exposure to them.

Based on a risk analysis, Safety Integrity Level (SIL) has been assessed. The PSS is based on four laser risk levels corresponding to the different uses of Apollon. Independent from the main command-control network the distributed system is made of a safety PLC and equipment, communicating through a safety network.

The article presents concepts, the client-server architecture (from control screens to sensors), actuators, interfaces to the access control system, the synchronization and security system [1].

RISK ANALYSIS

According, to the MOSAR method (Risk Analysis Systemic Organised Method), the entire laser chain has been divided into sub-systems (considering the topology and the role of each element) to study interactions with each others.

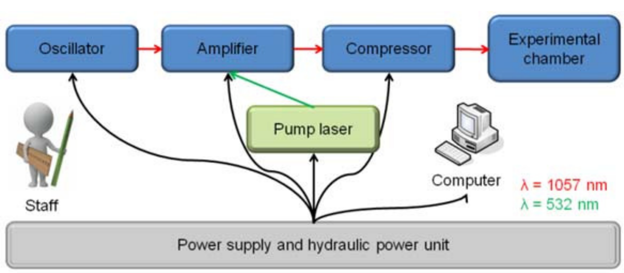

Figure 1: sub-divisions of Apollon laser chain.

As shown above, there are eight sub-systems : oscillator, amplifier, compressor, experimental chamber (experimental room), pump lasers, computers, staff and environment. Danger analysis has been conducted for the whole life cycle of sub-systems. Then, scenarios of risks are listed and ranked according to gravity and frequency of occurrence.

Two main dangers have been identified : laser radiation and ionizing radiation. A typical scenario of risk is that a person hits an optical mirror and causes laser reflections which could damage eyes of someone who does not wear safety glasses. Skin may also be burnt because of the high energy (between 75 and 150 Joules).

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SAFETY INTEGRITY LEVEL

Apollon's control-command team assessed the Security Integrity Level (SIL) for both laser radiation and ionizing radiation dangers.

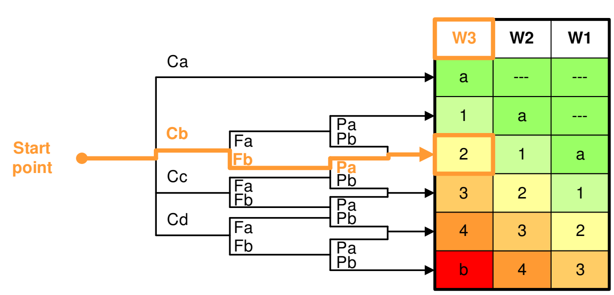
An Adapted Reliability

The Safety Integrity Level (SIL) measures the performance required for safety functions. It implies to take it into account from sensors to actuators, via the safety program, wires and cabling.

SIL has been evaluated according to two norms derived from norm CEI 61508 [2] : norm 61511, created in 2003, dedicated to industrial processes ; norm 62061, created in 2005, for security of machines.

This paragraph describes how SIL has been evaluated with norm CEI 61511 :

- a person exposed to a class IV laser beam may suffer skin carbonization and severe eye damage. However, no lethal effect is possible (also applicable for ionizing radiation) ;
- staff working with lasers needs to be near laser beams at least once a day for day to day operation ;
- thanks to safety glasses, it is possible to avoid danger in particular conditions (low energy). Regarding ionizing radiation, there is no other solution than locking areas ;
- laser accidents have already occurred in laboratories.



Consequences	Ca Cb Cc Cd	Minor incident Reversible effects Lethal effects within the site Lethal effects out of the site
Exposure	Fa Fb	Rare exposure in the considered zone Regular exposure in the considered zone
Possibility to avoid danger	Pa Pb	Possible with particular conditions Impossible
Occurrence rate	W1 W2 W3	Low probability (accident may happen) Medium probability (accident already occured) High probability (frequent accident, occured more than once)

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--- = no safety requirements
a = no particular safety requirements
b = one safety system is not enough
1, 2, 3 and 4 = safety integrity level

Figure 2: CEI 61511 SIL assessment.

As a consequence, Safety Integrity Level is 2.

Safety Equipment to Meet the Needs

This equipment is designed to decrease exposure of staff to dangers (it is not possible to decrease gravity). Pieces of safety equipment are :

- non-contact, magnetic safety switches for doors and barriers ;
- emergency stop buttons ;
- laser beam shutters ;
- alarms ;
- laser interlocks.

Siemens' Programmable Logic Controller (ref. CPU317F-2 PN/DP) is dedicated to safety. This controller possesses autotest and autodiagnostic functions to check its safety state. Input/Output cards detect short circuits. Input electrical signals are double-checked. Program is realised with restrictive rules.

Figure 3: safety PLC and I/O safety card.

ANOTHER VISION OF SAFETY

In a laser facility, there are usually two different wavelength lights : ω = 1057 nm (red light) and 2ω = 532 nm (green light). Which are the more efficient protection glasses to wear ? PSS doesn't answer this question because there is no easy solution.
However, the system indicates if laser light is present and gives information about its level of energy (the choice of protection glasses is left to experts). Then, a system consisting in a four level danger designation has been created.

The following chart defines security conditions for the four levels of danger.

	Free access	**Risk level 1**	**Risk level 2**	**Risk level 3**
Laser presence	N	Y	Y	Y
Level of energy		L/H	L	L/H
Ionizing radiation presence	N	N	N	Y
Laser interlocks	O	C	C	C
Safety barriers	O	C	O	O/C
Protection glasses	N	N	Y	

C : Closed ; H : High ; L : Low ; N : No ; O : Open ; Y : Yes.

Figure 4: security conditions in hazardous zones.

For instance, here is the meaning if the blue light of a signal tower is lit on :

- laser may be present in the room (facility in operation) ;
- depending on the moment of the day, the energy of light may be low or high ;
- in a laser room, no ionizing radiation is possible ; however, it is possible in an experimental room ;
- depending on the moment of the day, laser interlocks may be in operation (closed) ;
- safety barriers must be closed to ensure staff security;
- finally, no protection glasses are necessary because light is kept under safety barriers.

A Programmable Access Control

The access control system has been customized to fit the philosophy of PSS. According to the safety state of the facility (one risk level among the four possible), the access control system applies different authorizations.
Authorizations are attributed to staff according to their role and safety training they have attended.

Free access	**Risk level 1**	**Risk level 2**	**Risk level 3**
Everyone	People with a level 1 authorization	People with a level 2 authorization	No one is allowed

Figure 5: Access control authorizations.

The difficulty was to set authorizations according to risk level in each laser zone. This was possible thanks to the programming of Nedap's access control controllers.

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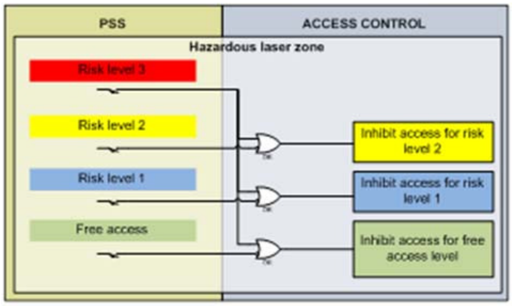

Figure 6: Inhibition of authorizations.

For example, the risk level is 1. Logic gates drawn above inhibit authorizations for risk level 2 and free access. As a consequence, staff authorized to work with a risk level 1 is allowed to open doors.
Note that if risk level is 3, all authorizations are inhibited.

A Distributed Architecture for a Total Control

The functional architecture is a typical automated system architecture :

- level 0 : level closest to safety (SIL2) and standard equipment. A particular attention is given to laser beam shutters because of very high laser power and ionizing radiations in experimental rooms. Material composing shutters needs to resist intensity of power in order to avoid damages. Macor might be a solution to this problem. Regarding safety key panels, a protocol has been written to control shutters safely and easily in experimental rooms ;
- level 1 : one safety Programmable Logic Controller and many deported stations compose this level. Stations may receive up to 63 I/O modules each. Extensions are possible to meet the needs. Communication between components is established via a safety Ethernet fieldbus. Power supply is secured to ensure availability of the system ;
- level 2 : this level is composed of monitoring computers and redundant servers. Today, there are four supervisory computers but the master-slave system has been designed to accept extensions. Graphical User Interfaces are conceived to supervise facility (default acknowledgment, laser interlock control, laser beam shutter control…), to archive defaults for statistics, to control each actuator and supervise each sensors while maintenance mode.

Interfaced with Other Functions

PSS is linked to other systems around the laser facility. Indeed, PSS is related to access control system as described above. Also, fire alarm system sends data via dry contact connectors : PSS secures laser and experimental rooms. Finally, PSS informs the Synchronization and Security System that a room is secured and ready to receive laser, when necessary.

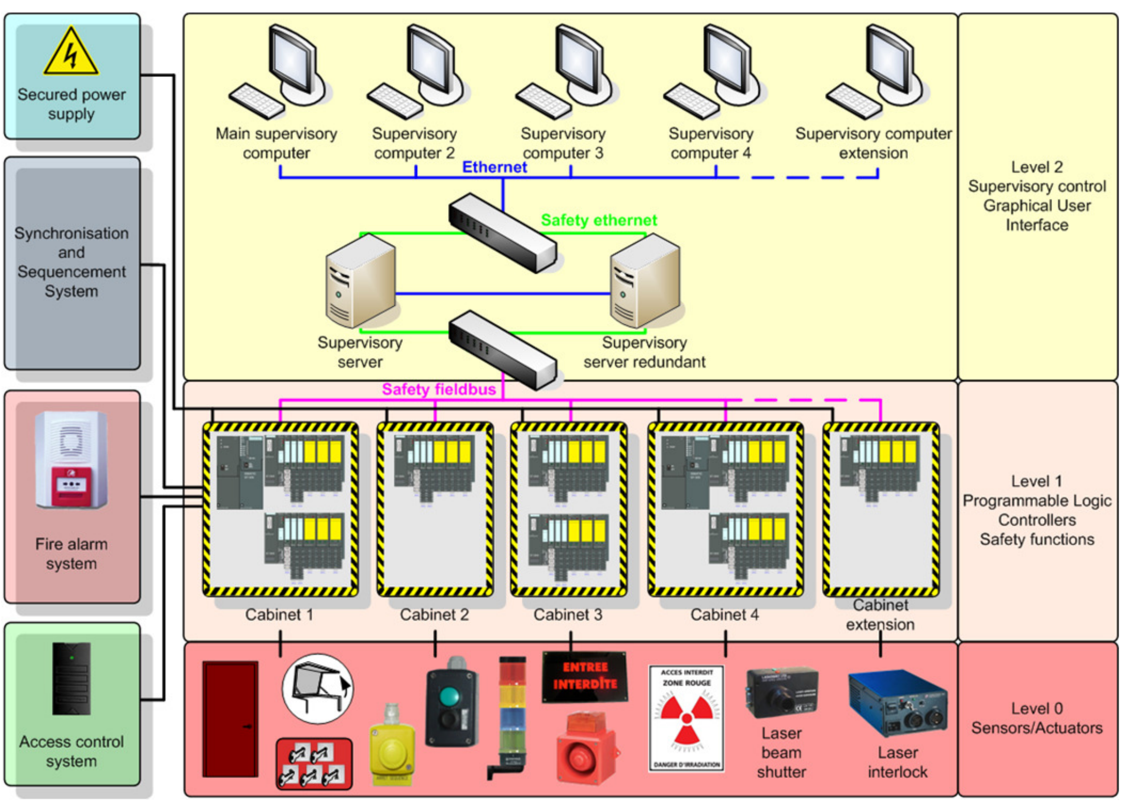

Figure 7: PSS architecture.

CONCLUSION

The Cilex-Apollon is a high intensity laser facility involving dangers such as laser and ionizing radiations.

Special safety devices have been implemented in a distributed hardware-oriented structure. PSS is totally dedicated to human safety. Security of laser equipment is managed by the Synchronization and Security System.

REFERENCES

[1] M. PINA et al., “Cilex-Apollon Synchronization and Security System, MOPP045, this conference, ICALEPCS13.
[2] Norm CEI 61508 : Functional security of electrical/electronic systems and programmable systems.

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