

Vacuum Control for the LINAC at ESS

Francois Bellorini

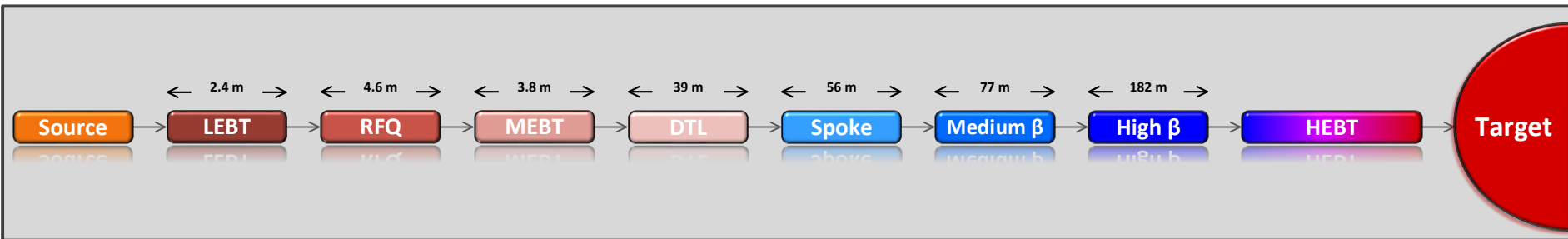
Integrated Control System Division

Hardware & Integration Group

www.europeanspallationsource.se

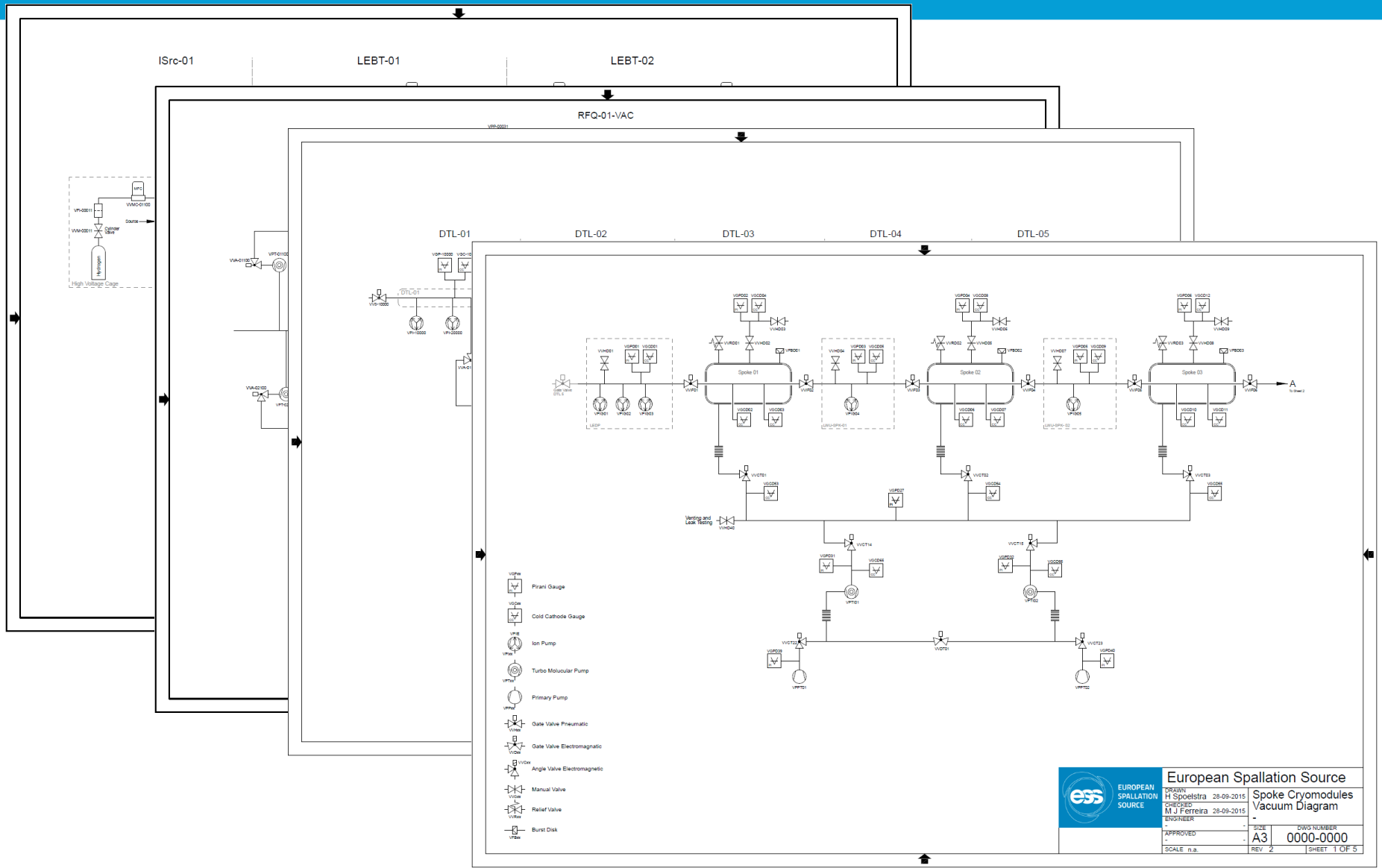
16-01-29

LINAC Section's



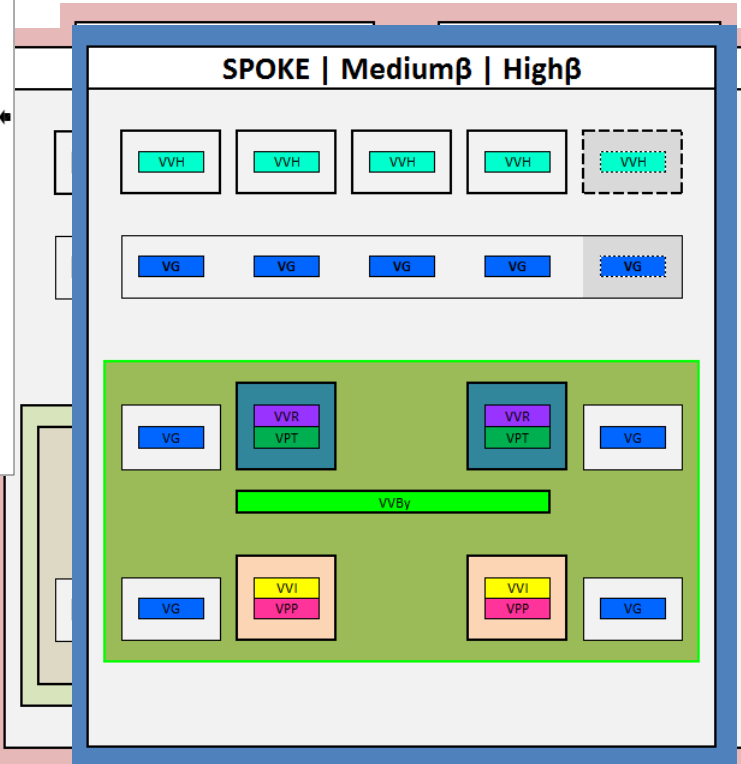
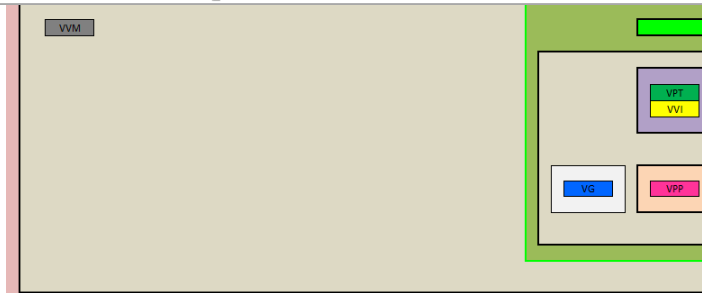
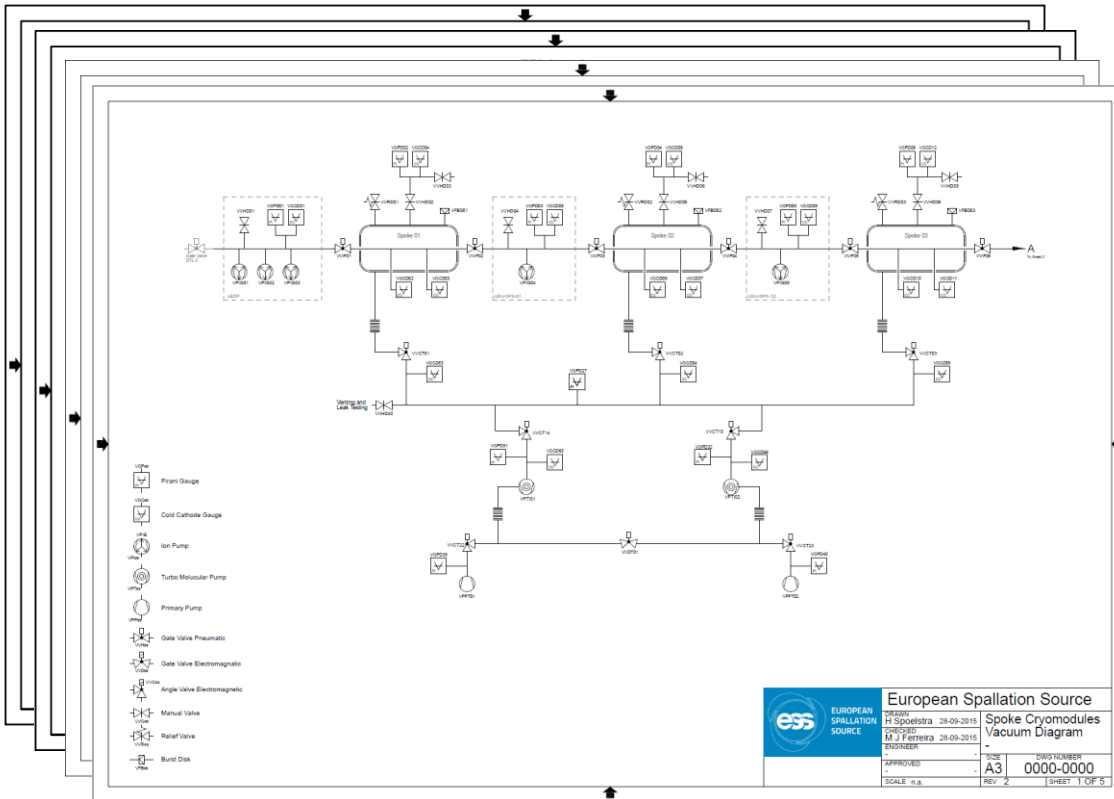
| | | Section | | | | | | | | |
|-----------------------|------------------|-----------|-----------|-----------|-----------|------------|----------------|--------------|------------|------------|
| | | LEBT | RFQ | MEBT | DTL | Spoke | Medium β | High β | HEBT | Total |
| Vacuum Sector | | 2 | 1 | 1 | 4 | 26 | 18 | 46 | 20 | 118 |
| Vacuum Devices | Gauges | 10 | 11 | 7 | 14 | 115 | 95 | 224 | 70 | 546 |
| | Mechanical Pumps | 6 | 14 | 2 | 4 | 7 | 8 | 20 | 0 | 61 |
| | Ion Pumps | 0 | 0 | 4 | 10 | 18 | 8 | 21 | 31 | 92 |
| | Angle Valves | 8 | 14 | 2 | 9 | 37 | 19 | 46 | 0 | 135 |
| | Manual Valves | 1 | 3 | 2 | 3 | 55 | 33 | 81 | 12 | 190 |
| | Fast Valve | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| | Gate Valves | 2 | 3 | 0 | 5 | 34 | 18 | 42 | 20 | 124 |
| Total | | 27 | 45 | 17 | 45 | 267 | 181 | 434 | 133 | |

Vacuum Layout



From Vacuum Layout To Vacuum Control

✓ **Developing a System for Pumping Modules & Pumps gas piping system**



ESS LINAC Vacuum Components

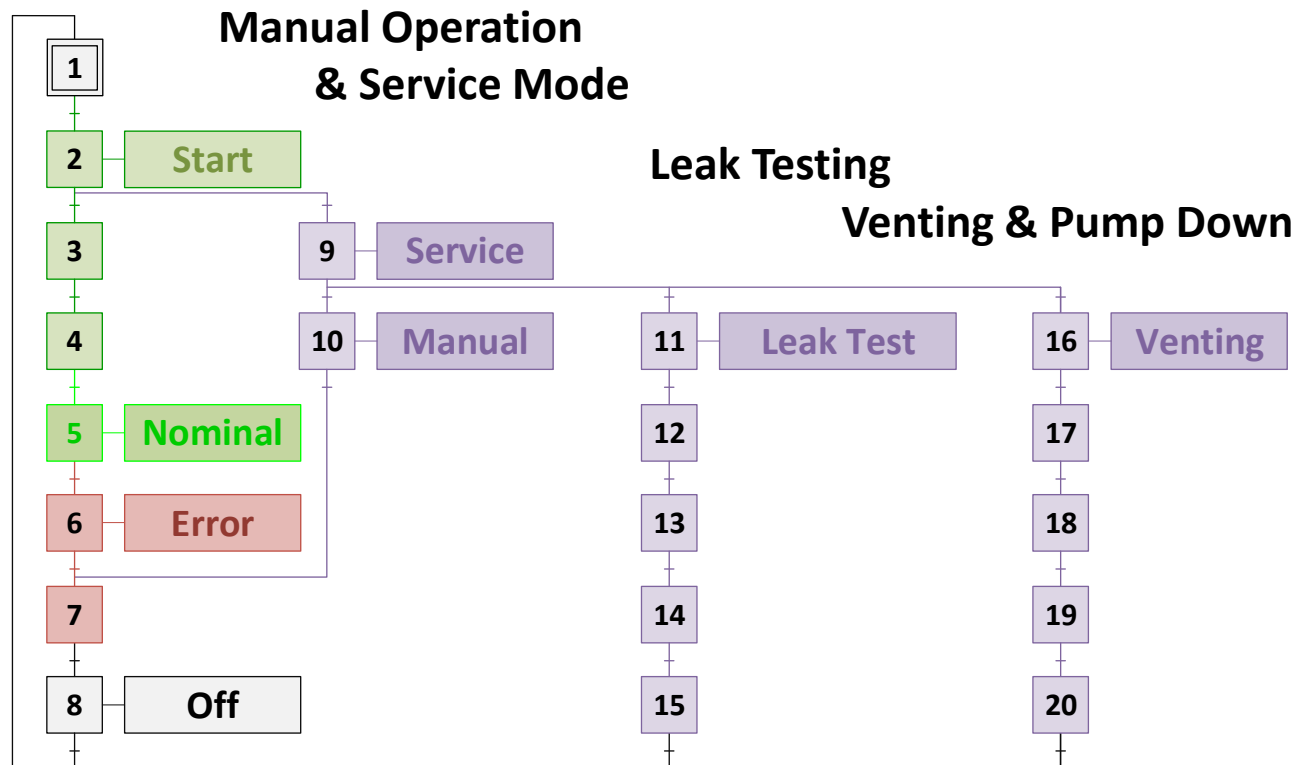
**Standardization
through a
procurement
process**



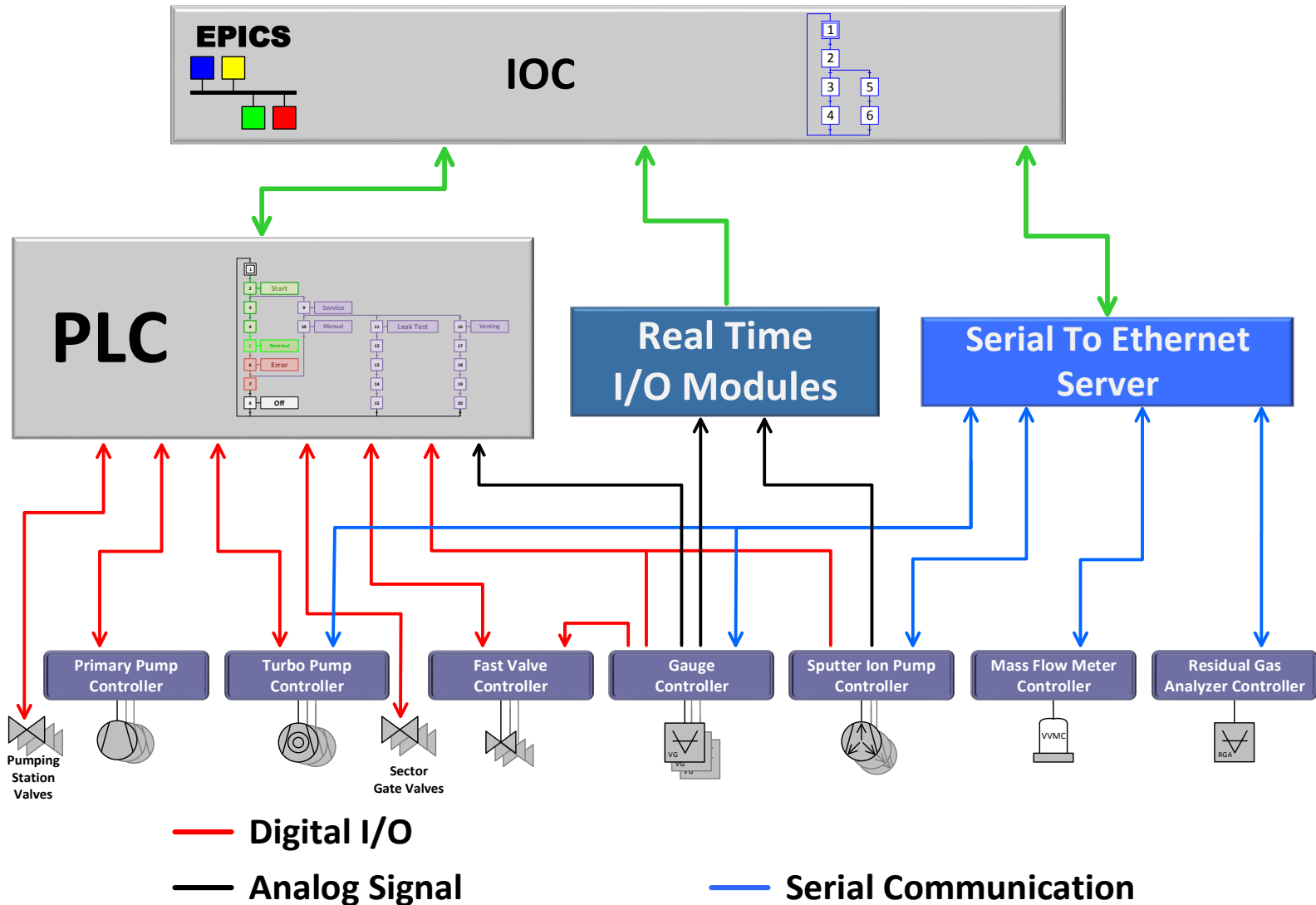
Vacuum Operation State Machine Diagram

State machine diagram = GRAFCET

“Normal” Operation



Vacuum Operation PLC & EPICS



Vacuum Operation PLC & EPICS

PLC:

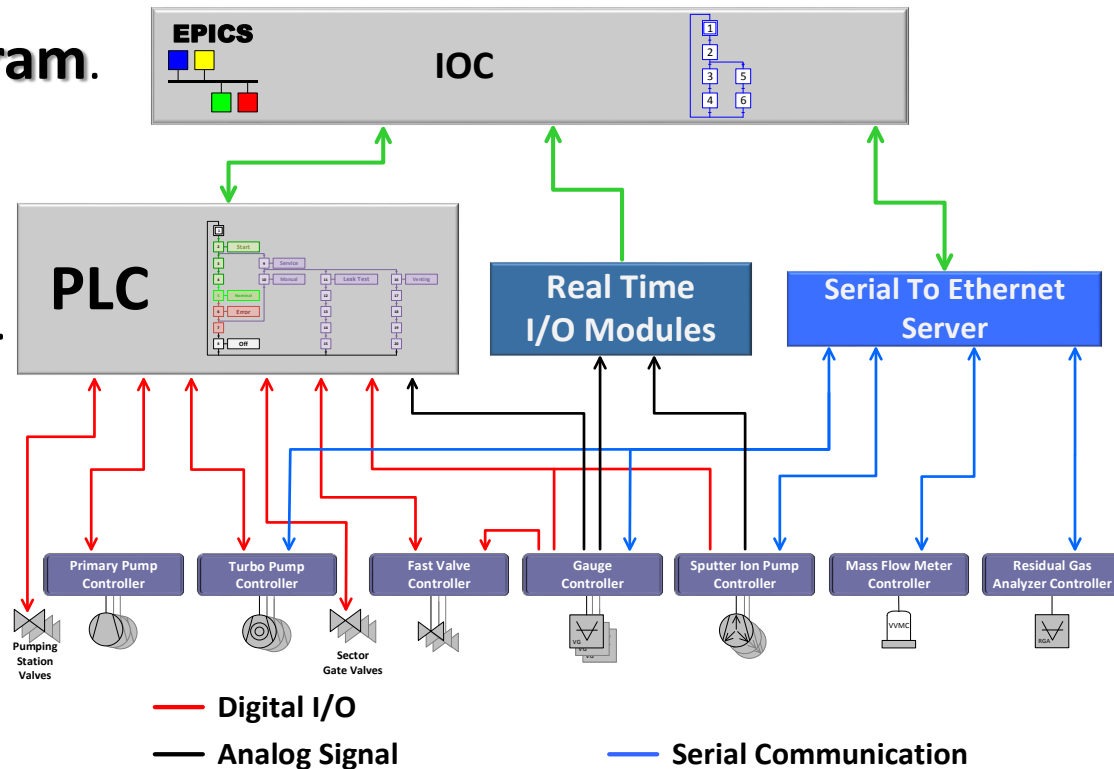
-Control State Machine Diagram.

- Drive controller (I/O Control).
- Local protection.
- Data Acquisition (Process devices).

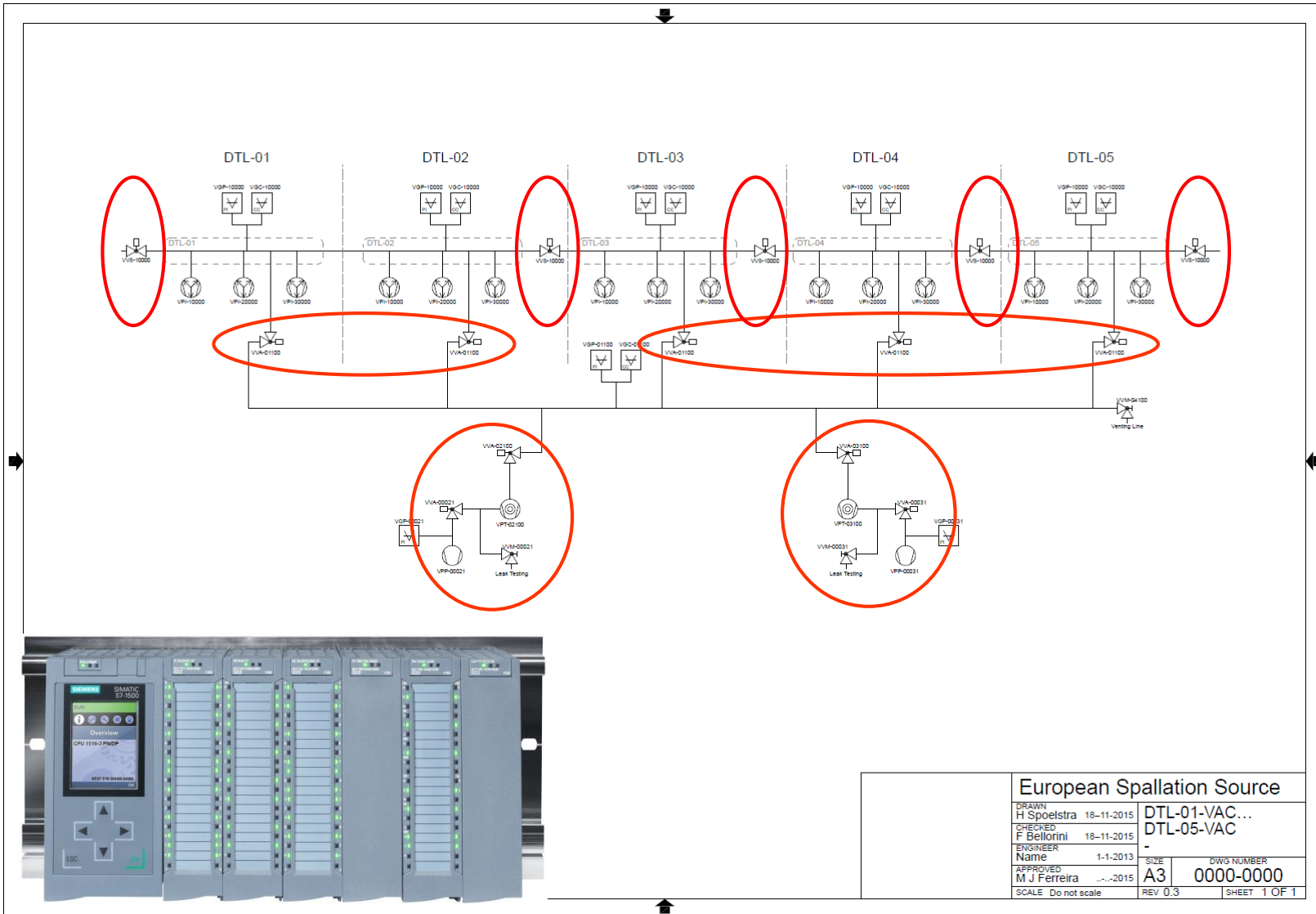
EPICS:

- Control panels, trending.
- Real-time Data Acquisition (Beam devices).
- Data Logging.
- Gateway for PLC to Controllers with serial communication (terminal server).

Vacuum Control Architecture PLC & EPICS



Vacuum Operation PLC Digital I/O Control

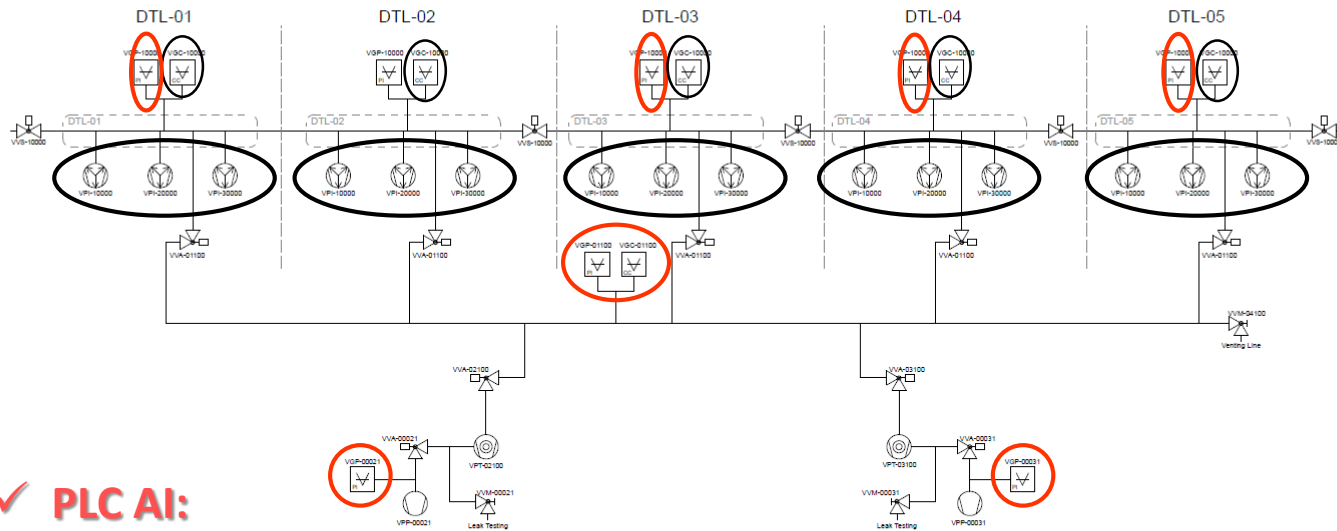


European Spallation Source

| | |
|-----------------------------------|-----------------------------|
| DRAWN H Spoelstra 18-11-2015 | DTL-01-VAC... DTL-05-VAC |
| CHECKED F Bellonni 18-11-2015 | |
| ENGINEER Name 1-1-2013 | |
| APPROVED M J Ferreira ...-2015 | SIZE A3 |
| SCALE Do not scale | DWG NUMBER 0000-0000 |
| | REV 0.3 SHEET 1 OF 1 |

Vacuum Operation

Data Acquisition from Analog values



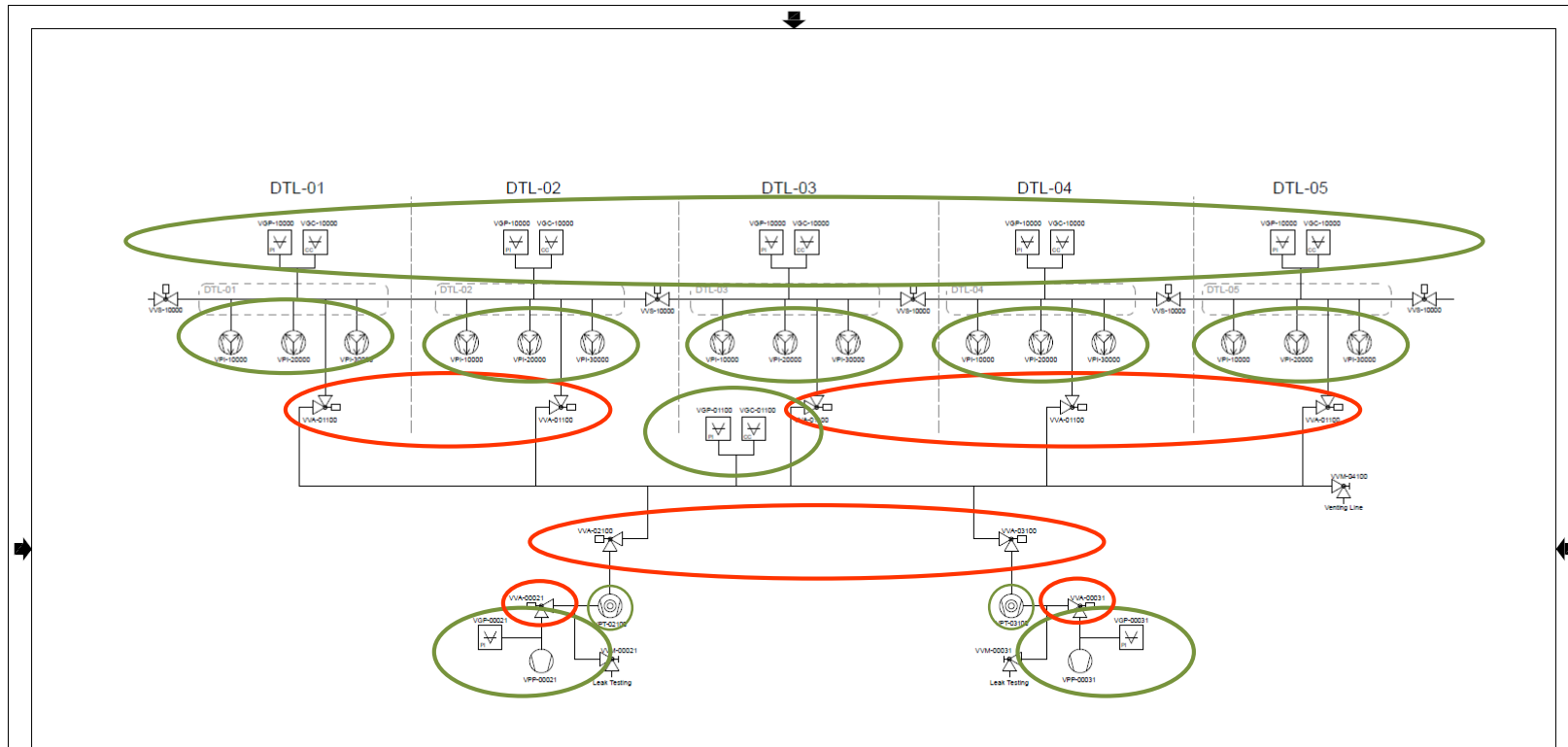
- ✓ **PLC AI:**
- Mechanical pumping process
 - Pirani gages on vacuum sector



- ✓ **Real Time AI:**
- Pressure measurement along the beam line

| | | | |
|-----------------------------------|--------------------|--------------|-------------------------|
| European Spallation Source | | | |
| DRAWN H Spoelstra 18-11-2015 | DTL-01-VAC... | DWG NUMBER | |
| CHECKED F Bellonni 18-11-2015 | DTL-05-VAC | 0000-0000 | |
| ENGINEER Name 1-1-2013 | SCALE Do not scale | SIZE A3 | DWG NUMBER 0000-0000 |
| APPROVED M J Ferreira ...-2015 | REV 0.3 | SHEET 1 OF 1 | |

Vacuum Operation Local Protection



✓ Self-Protected Devices
(by their controllers)

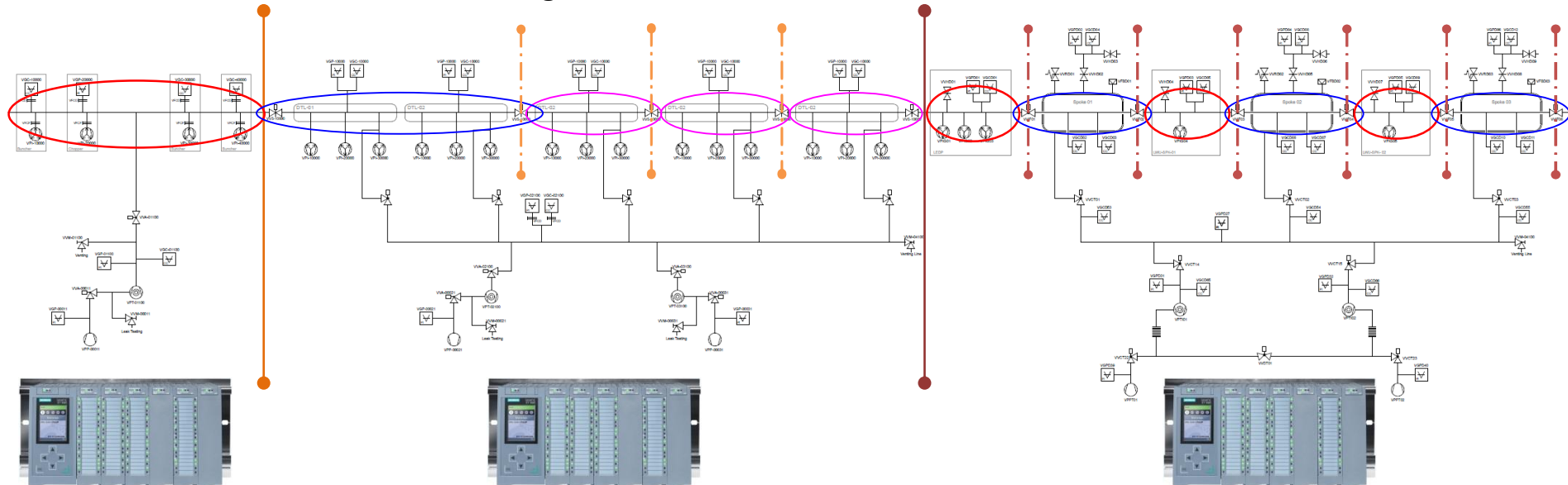
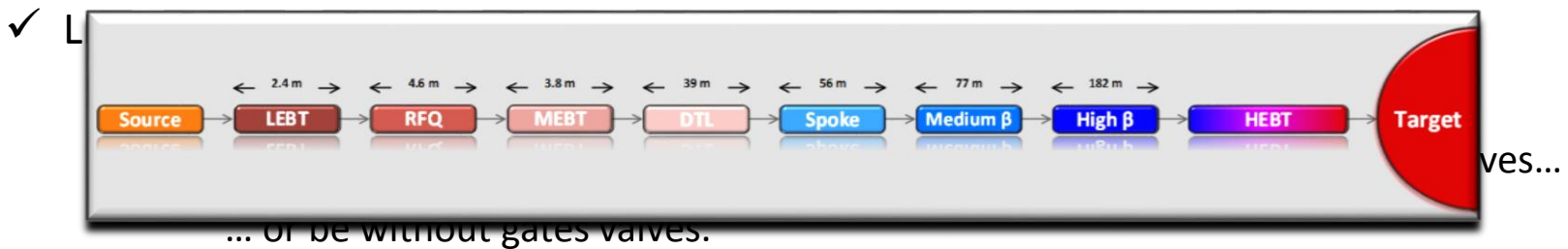
✓ By PLC's Logic



| | | | |
|-----------------------------------|---------------|-----------------------|---------------------------|
| European Spallation Source | | | |
| DRAWN H Spoelstra 18-11-2015 | DTL-01-VAC... | | |
| CHECKED F Bellonni 18-11-2015 | DTL-05-VAC | | |
| ENGINEER Name 1-1-2013 | | SIZE A3 | DWG'S NUMBER 0000-0000 |
| APPROVED M J Ferreira ...-2015 | | SCALE Do not scale | REV 0.3 |
| | | SHEET 1 OF 1 | |

LINAC's Sections & Vacuum Sectors

- ✓ Each section of the LINAC will be control by a dedicated PLC:
 - Flexibility during the installation of the LINAC.
 - Flexibility during the operation (ex: Limit down-time for cryogenic pumping).



Vacuum Sector Valves Interlocks

“Interlocks Trigger”

“Voting plan on Sector”

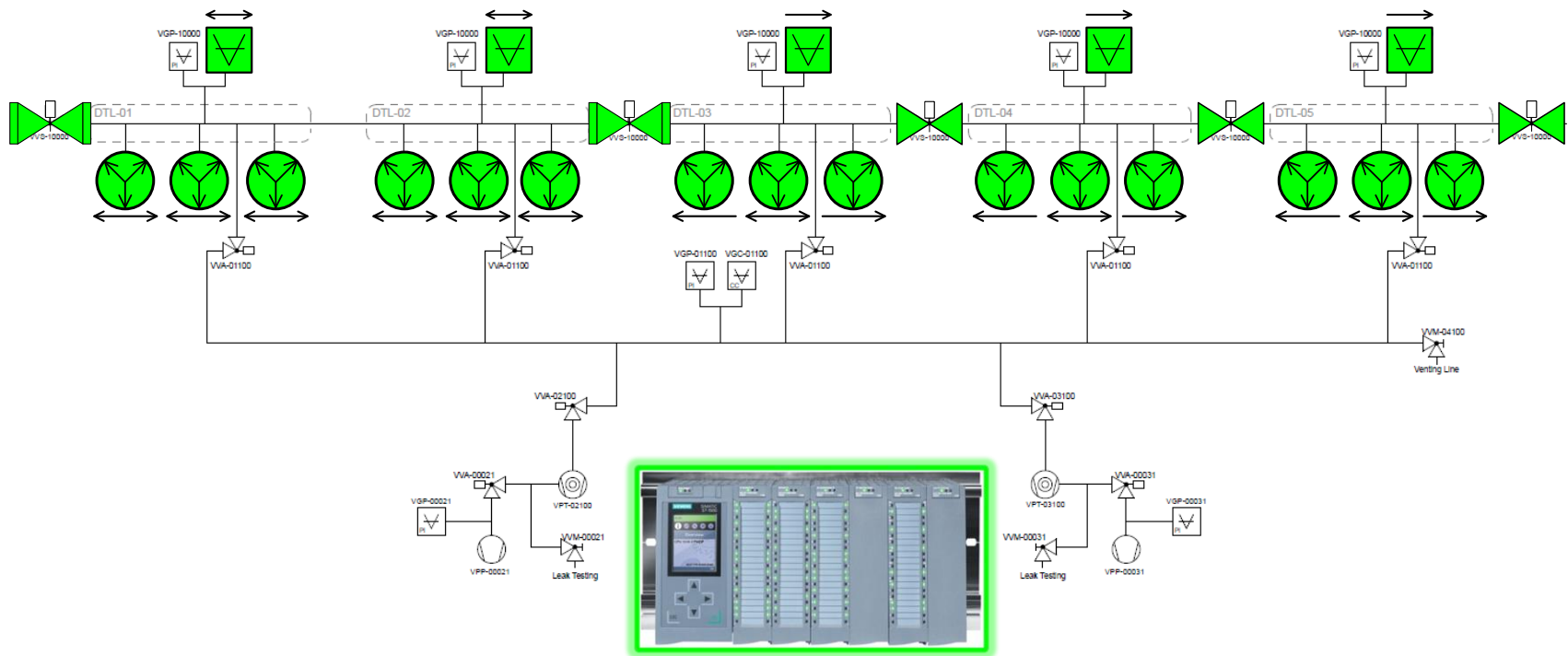
- Pressure “Ok”
& Sector “Nominal”

then valves can be open

“Voting plan on Valve”

- Pressure “Ok”
& Sector “Nominal”

then valves can be open



Vacuum Sector Valves Interlocks

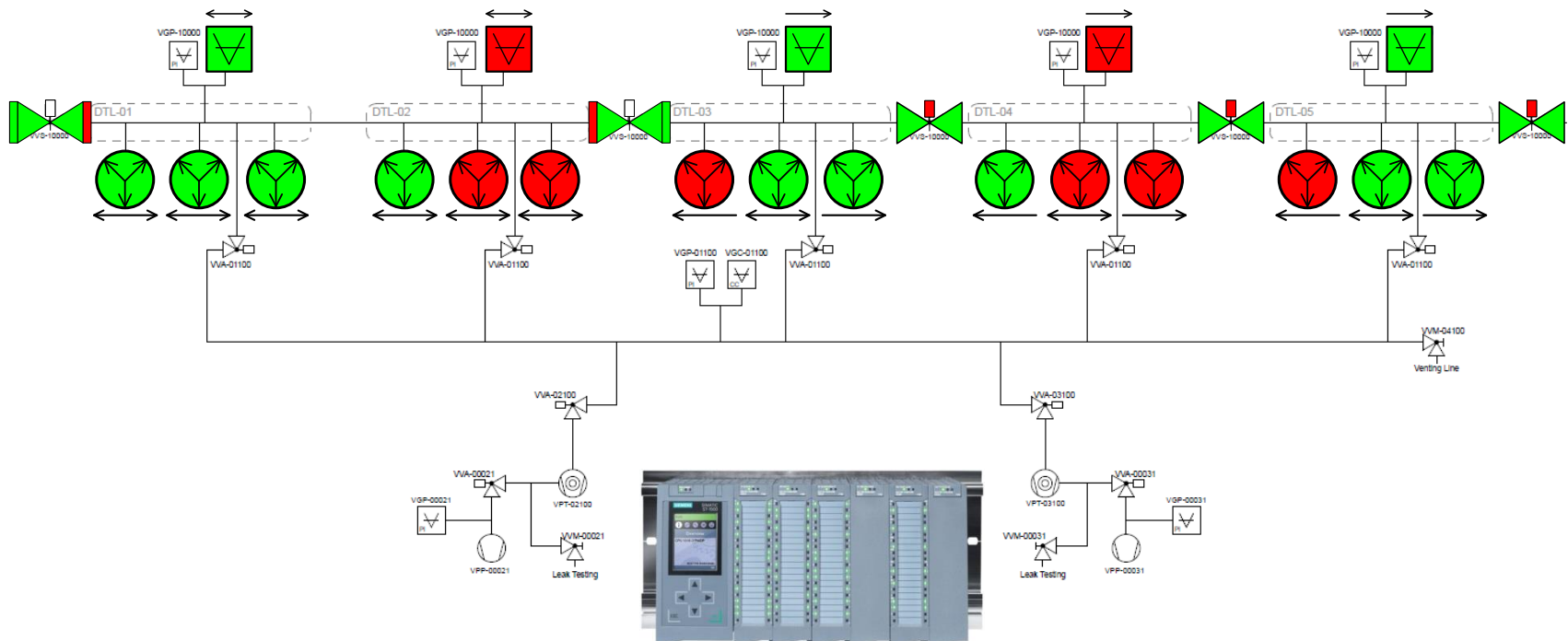
“Interlocks Trigger”

“Voting plan on Sector”

- Pressure “Ok” + Sector “Nominal” -> Valves Open
- If pressure increases, valve interlocks are triggered ...

“Voting plan on Valve”

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Vacuum Sector Valves Interlocks

“Interlocks Trigger”

“Voting plan on Sector”

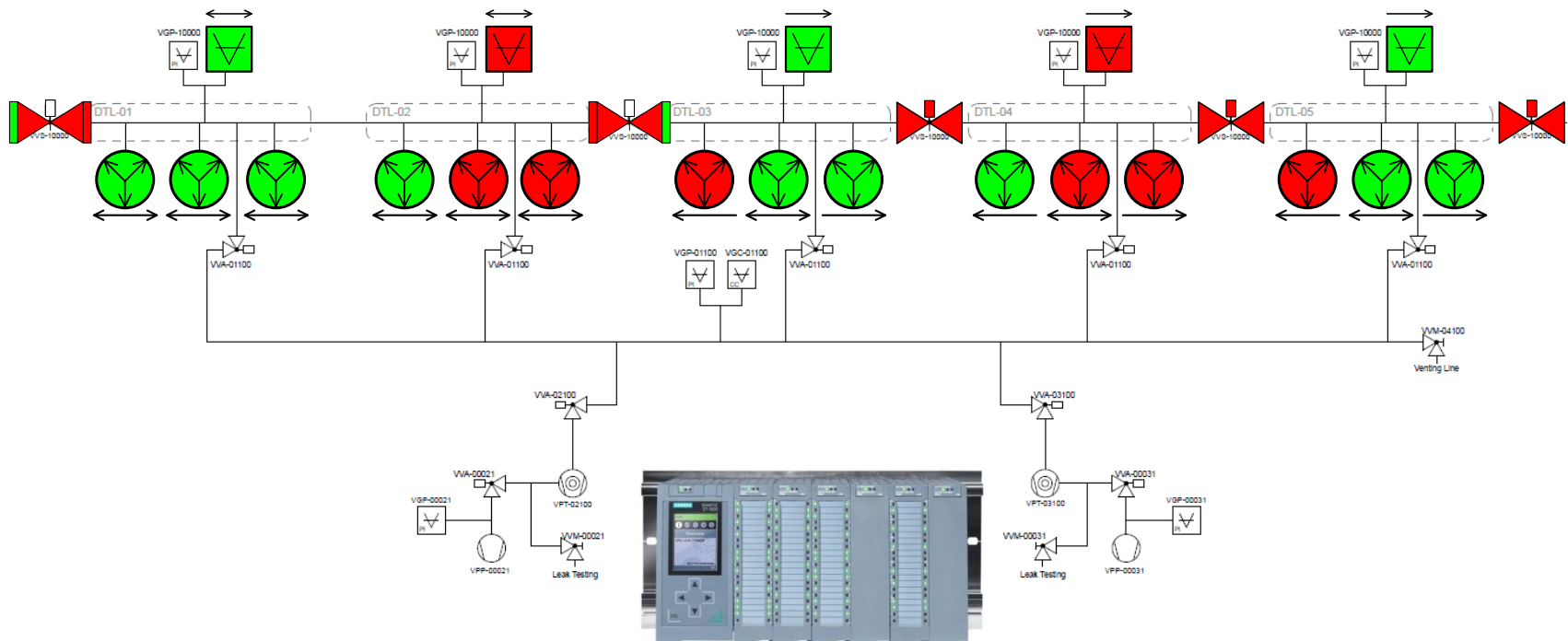
- Pressure “Ok” + Sector “Nominal” -> Valves Open
- If pressure rise up, valve interlocks are triggered ...
- **Valves will close.**

“Voting plan on Valve”

- Pressure “Ok” + Sector “Nominal” -> Valves Open
- If pressure rise up, valve interlocks are triggered ...
- **Valves will close.**

(2 Valves)

(3 valves)



Vacuum Sector Valves Interlocks “Controllers”

- Valves closure by interlocks can be achieved using several systems:

- ✓ Home-made electronic crates

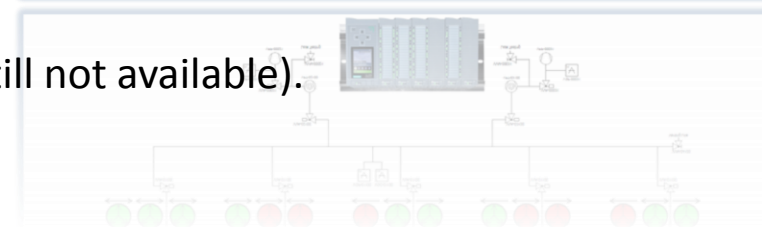
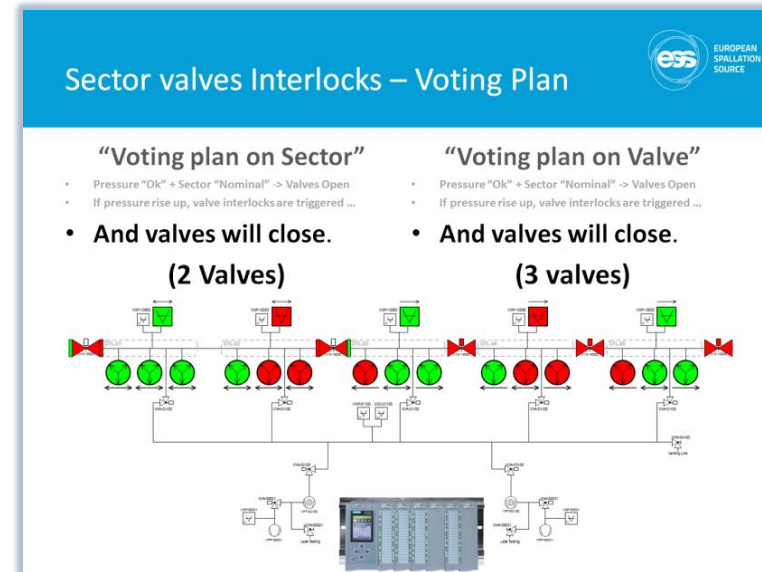
- ☹ Non flexible voting plan, require lot of cabling.
- ☹ Need development & fabrication.
- Never been foreseen...

- ✓ FM PLC (FPGA based)

- ☺ Flexible voting plan, very fast.
- ☹ Require lot of cabling.
- ☹ Require lot of devices (And the new series is still not available).

- ✓ Standard PLC (LINAC's sections PLC)

- ☺ Flexible voting plan (within LINAC's sections).
- ☺ Quiet fast reaction time (Analog value calculation).
- ☹ Require communication between PLC (Operation & Maintenance/Service)



Vacuum Sector Valves Interlocks “Controllers”

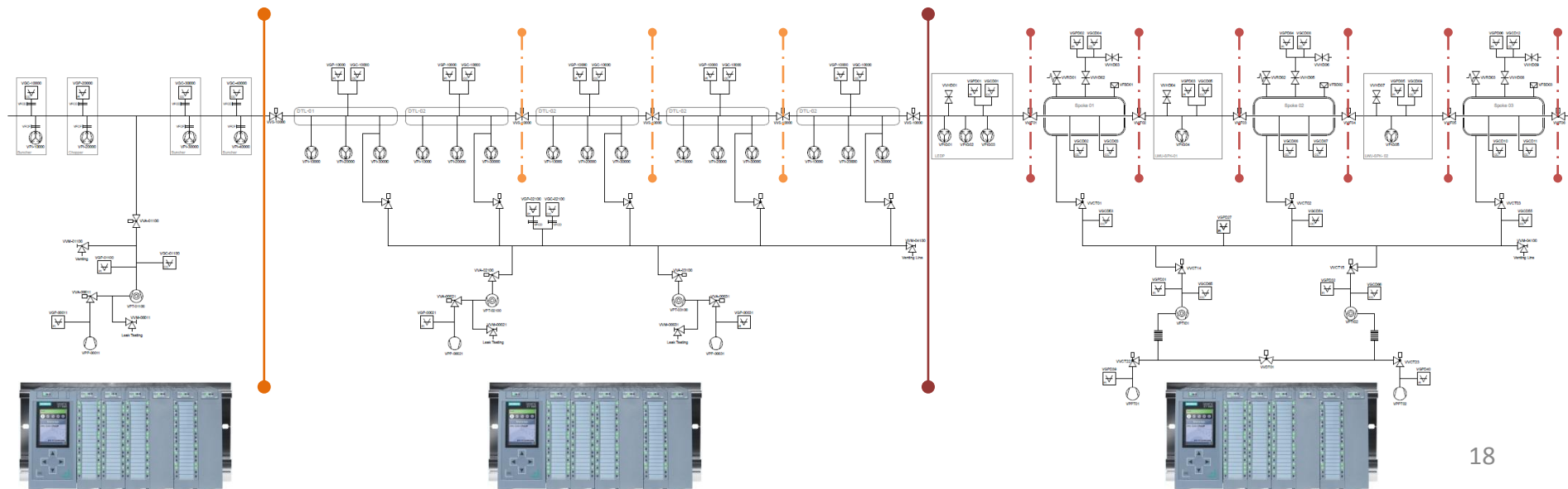
... Each section of the LINAC will be control by a dedicated PLC...

... Depending on the mechanical design vacuum sector can control one, two or not any gate valve...

... Despite voting plans haven't been chosen yet ...

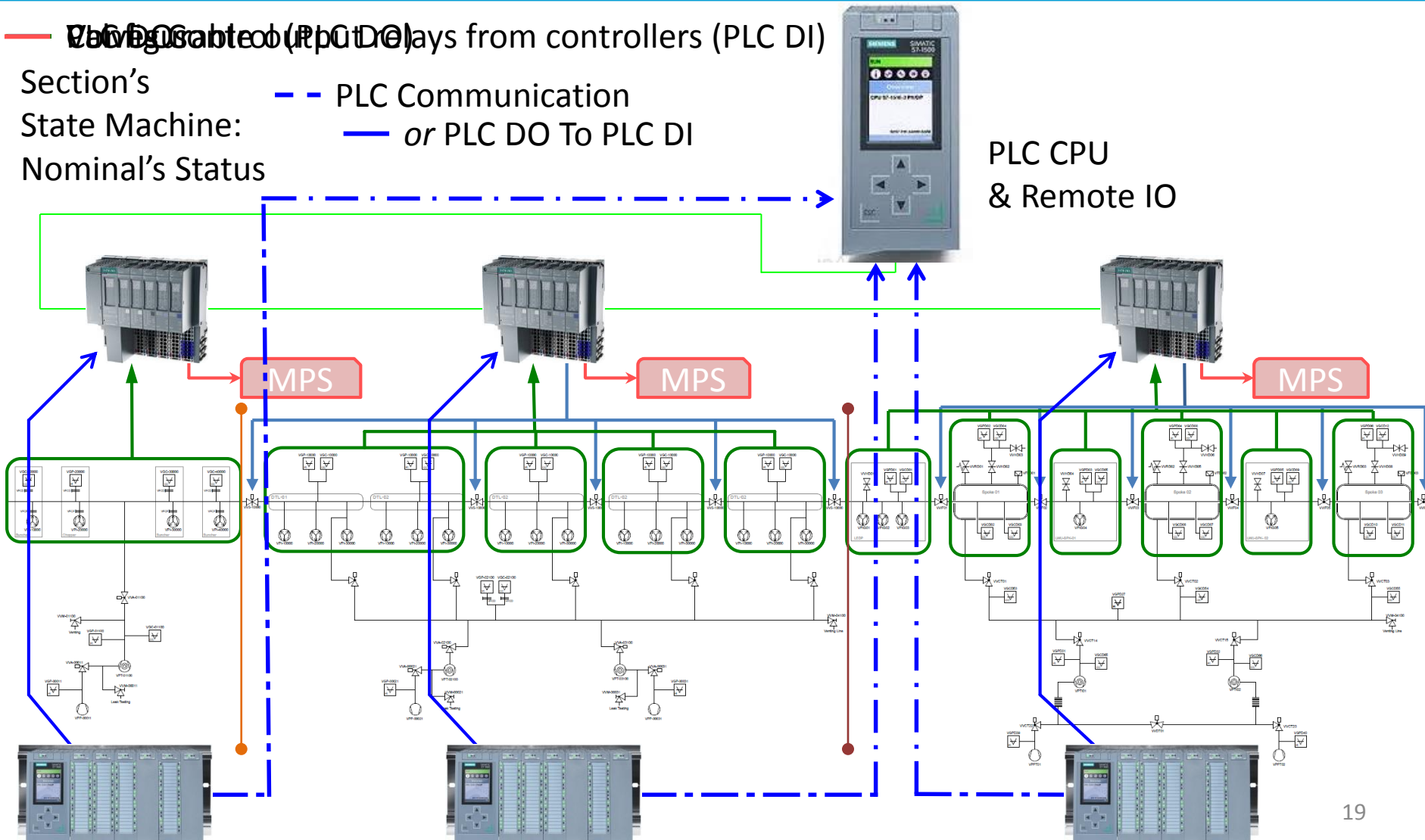
... Many Solutions are possible...

So ...



Vacuum Sector Valves Interlocks

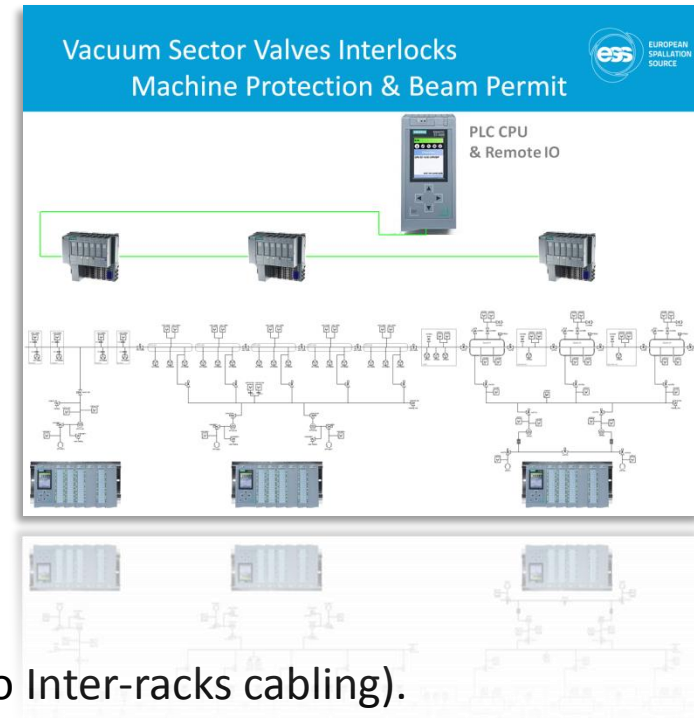
Machine Protection & Beam Permit



Vacuum Sector Valves Interlocks Machine Protection & Beam Permit

- **PLC & Remote IO:**

- Allow the centralization of the interlocks signals.
- Flexibility on :
 - Selection of the Interlock's trigger.
 - “Voting Plan” can be done case by case.
 - Valve(s) to be closed in case of interlocks.
 - Evolution & Modification.
- Reduce cabling work (No Inter-section cabling = No Inter-racks cabling).
- Segregation between Control Process & Local Protection and Vacuum Interlocks & Machine Protection.

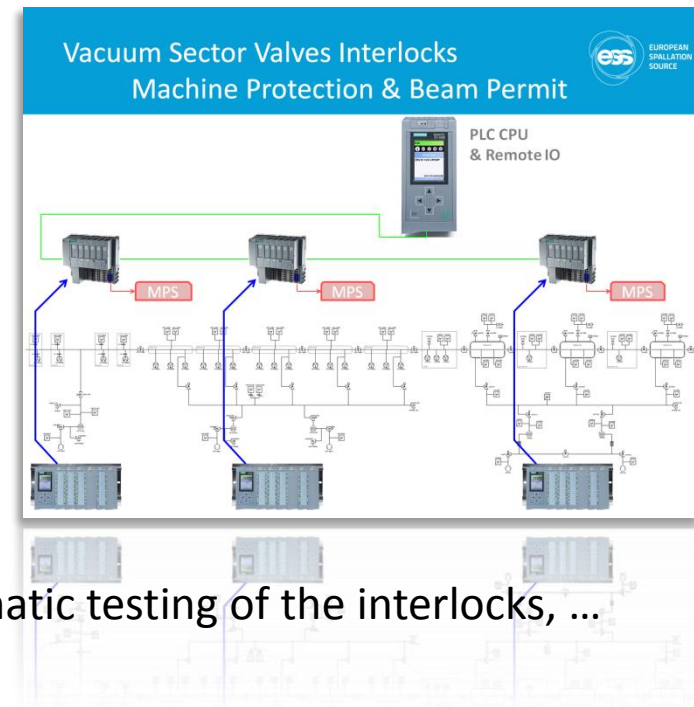


Vacuum Sector Valves Interlocks Machine Protection & Beam Permit

- **Beam permit &**

- **Machine Protection:**

- Beam Permit from Vacuum will take account of:
 - Sector gates valves position.
 - Current status from LINAC's sections.
 - Specific operations: interlocks bypassed, automatic testing of the interlocks, ...
 - ...
- Beam Permit will be used by Vacuum:
 - Inhibition of manual closure of sector valves while beam is on.
 - Cryo-modules containment in case of access.
 - ...



Vacuum Control for the LINAC at ESS and In-kind Contributions.



- **Main challenges:**
 - Keep consistency between in house code and in kind code.
 - Be sure that we will really obtain what we want.
- **Possible Solutions:**
 - Create boundary and “Guide Lines” using ESS’s tools:
 - **EEE** (ESS EPICS Environment) & **IOC Factory** (EPICS Input Output Controllers) on **EPICS** side.
 - Control Configuration Data Base (**CCDB**) & **TIA Portal** Import tool
 - “**ICS Handbook**” and “**Vacuum Control Handbook**” from Integrated Control System division of ESS.
 - Usage of **PLC** code **library**.
 - Any suggestion ??

**Prototyping of this control system using
ESS development tools will start soon.**

**Thank you for your
attention.**