CHP Plant Central Controller Development and Testing with RTDS

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Agenda

- Power Systems Research Group overview
- RTDS @TalTech
- CHP Central controller
  - Project overview
  - Stage 1: Design of the Central Controller
  - Stage 2: RTDS Model Development & HIL Setup
  - Stage 3: Commissioning test
- Conclusions

Power Systems Research Group

Team of 12 persons (professor, lecturers, researchers, PhD students)

Group leader prof Jako Kilter

Teaching – BSc, MSc

- Power system basics
- Power system stability
- Relay protection and automation
- Substations
- Power Quality

Research and development

- PMUs and wide-area protection and control
- Power system inertia monitoring
- Power quality in transmission Network
- Relay protection and system automation
- Power generating facility modelling and performance assessment

Cooperation

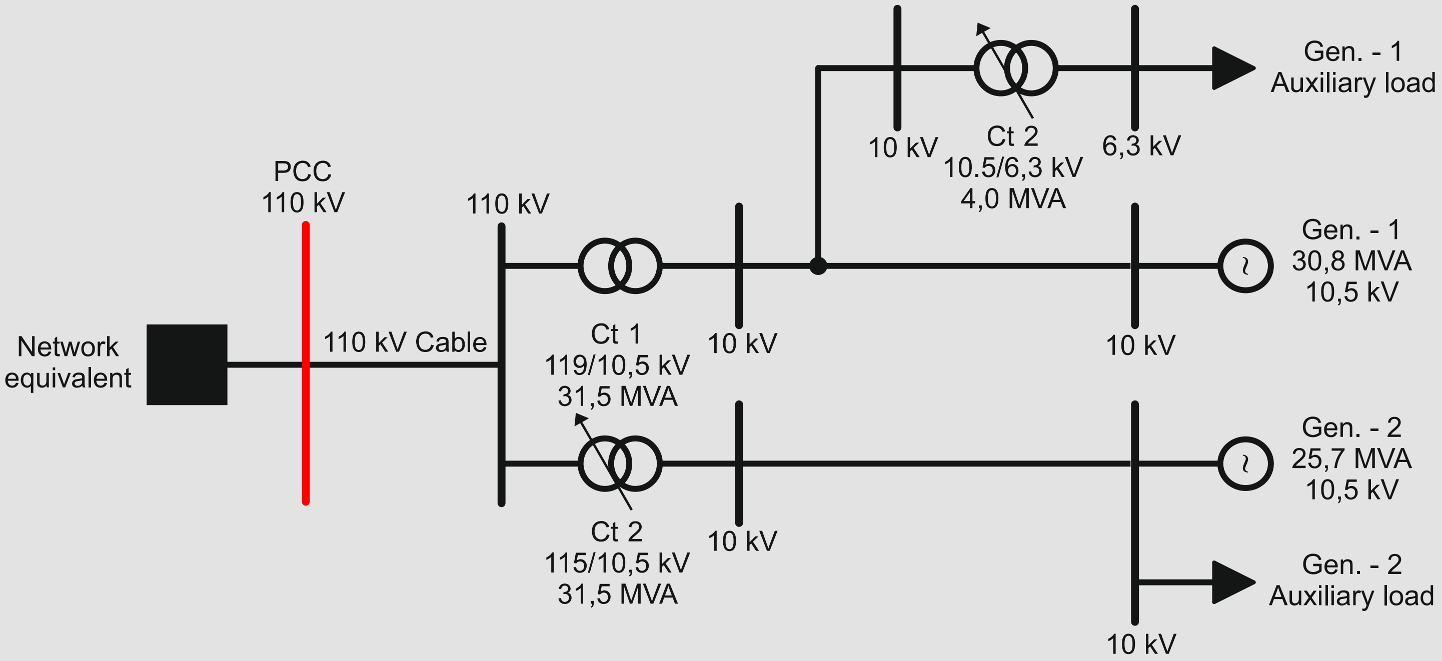
- Universities (TU Berlin, TU Dresden, Uo Manchester, Aalto, TU Delft, NTNU)
- Industrial and utility partners in Estonia
- CIGRE (B4, C3, C4)

RTDS @TalTech

- 2 x Racks
- 8 x PB5 Processor cards
- 1 x GTNETX2
  - PMU
  - IEC-104
  - GSE/Goose
  - SV (Sampled Values)
- 3 x Omicron CMS 356 amplifiers

CHP Central controller: Project overview

Objective: design a common control for Gen 1 and 2 to control them as a single unit at PCC.

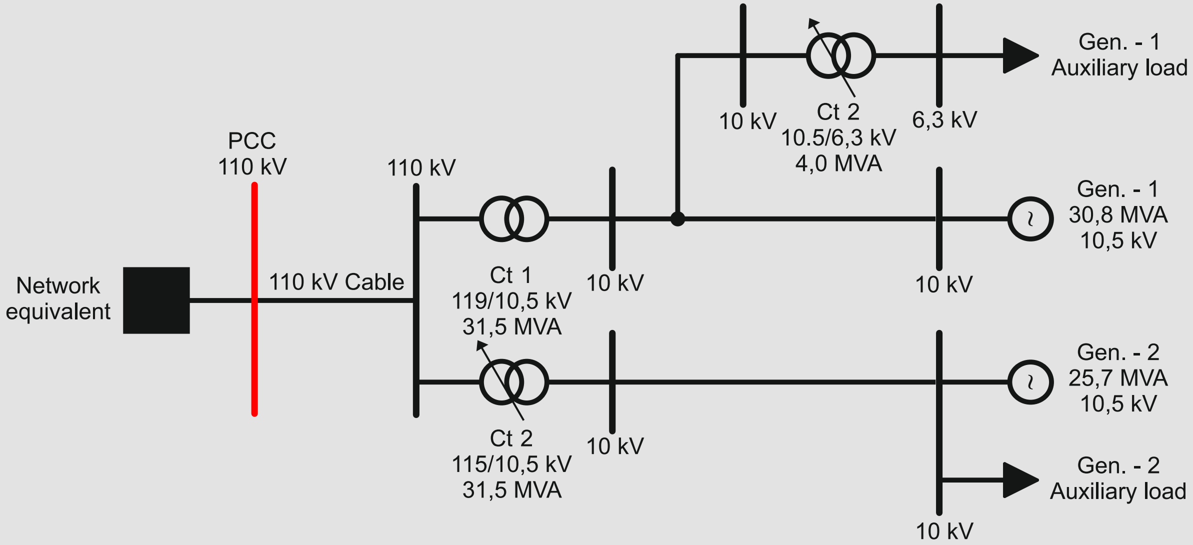


CHP Central controller: Project overview

- Central Control (Plant) controller required by TSO requirements for new generators;
- Technical conditions and timeline → **no off-the-shelf solutions**;
- Tight deadlines:
  - Project **completed in 30 days**.

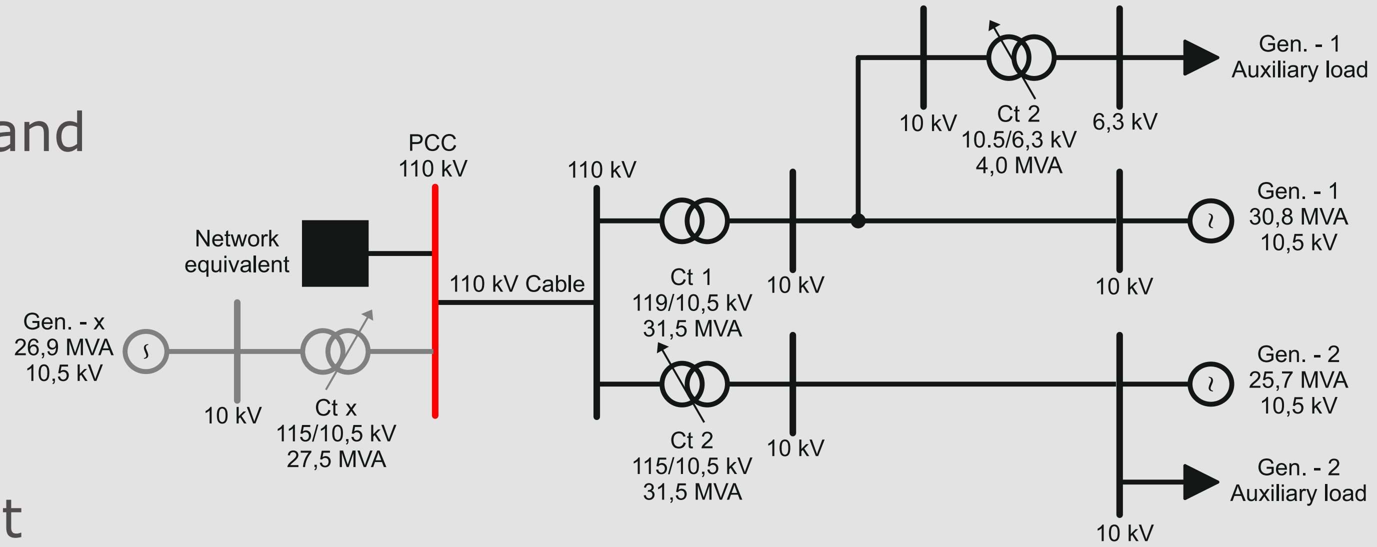
CHP Central controller: Design specifications

- Combined regulation P & Q/U at PCC;
- No measurements from PCC → **control based on estimation**;
- Accuracy requirements by TSO:
  - P: ± **1 MW**
  - Q: ± **1 Mvar**
  - U: ± **1 kV**



CHP Central controller: Technical challenges

- Different generators: significant regulation and capability differences;
- Gen. -1 parameters fixed;
- Additional power plant at PCC.



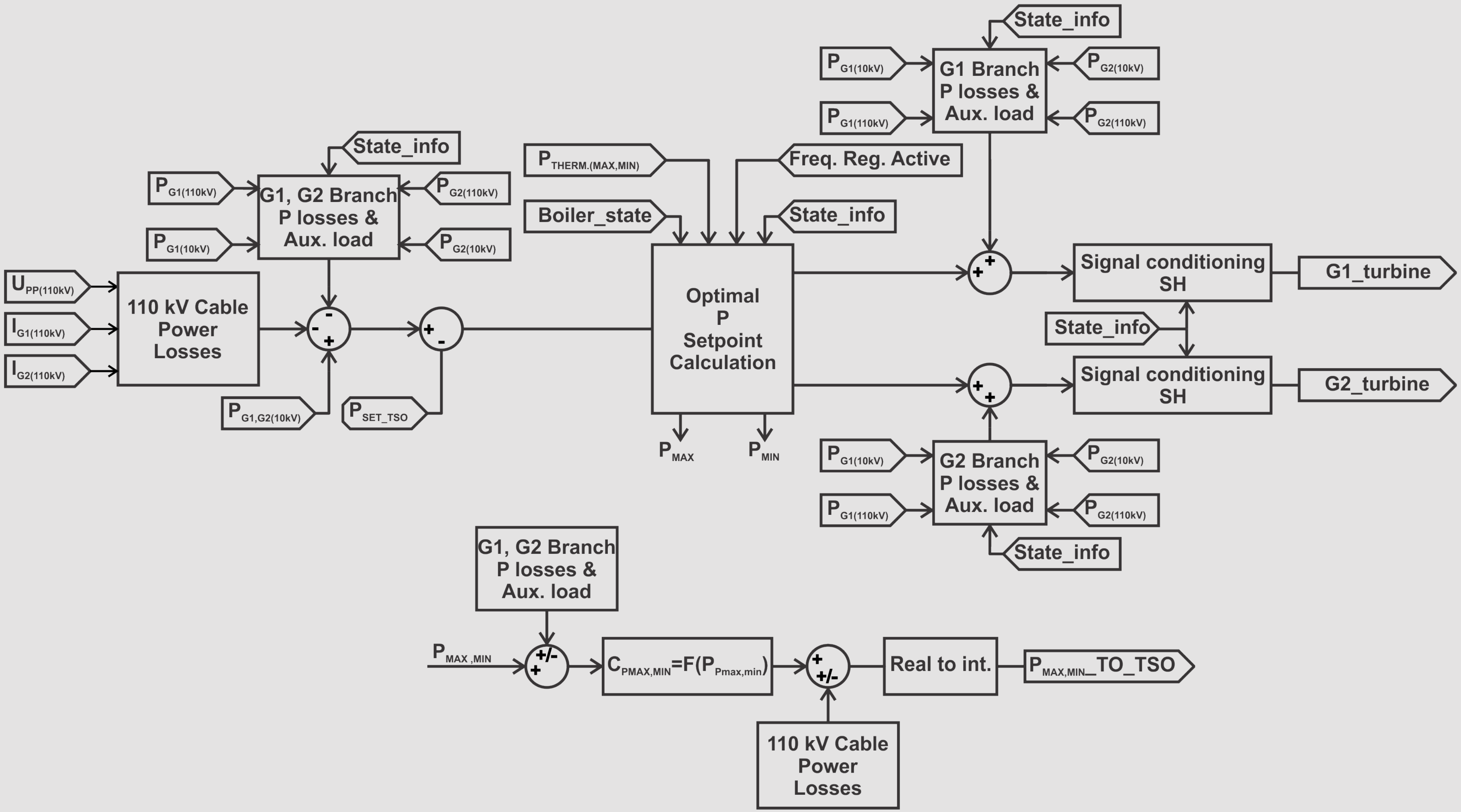
Stage 1: **Design of the Central Controller**

- Control system **design and implementation on PSCAD;**
- Developing contractor requested features;
- Approval from TSO;

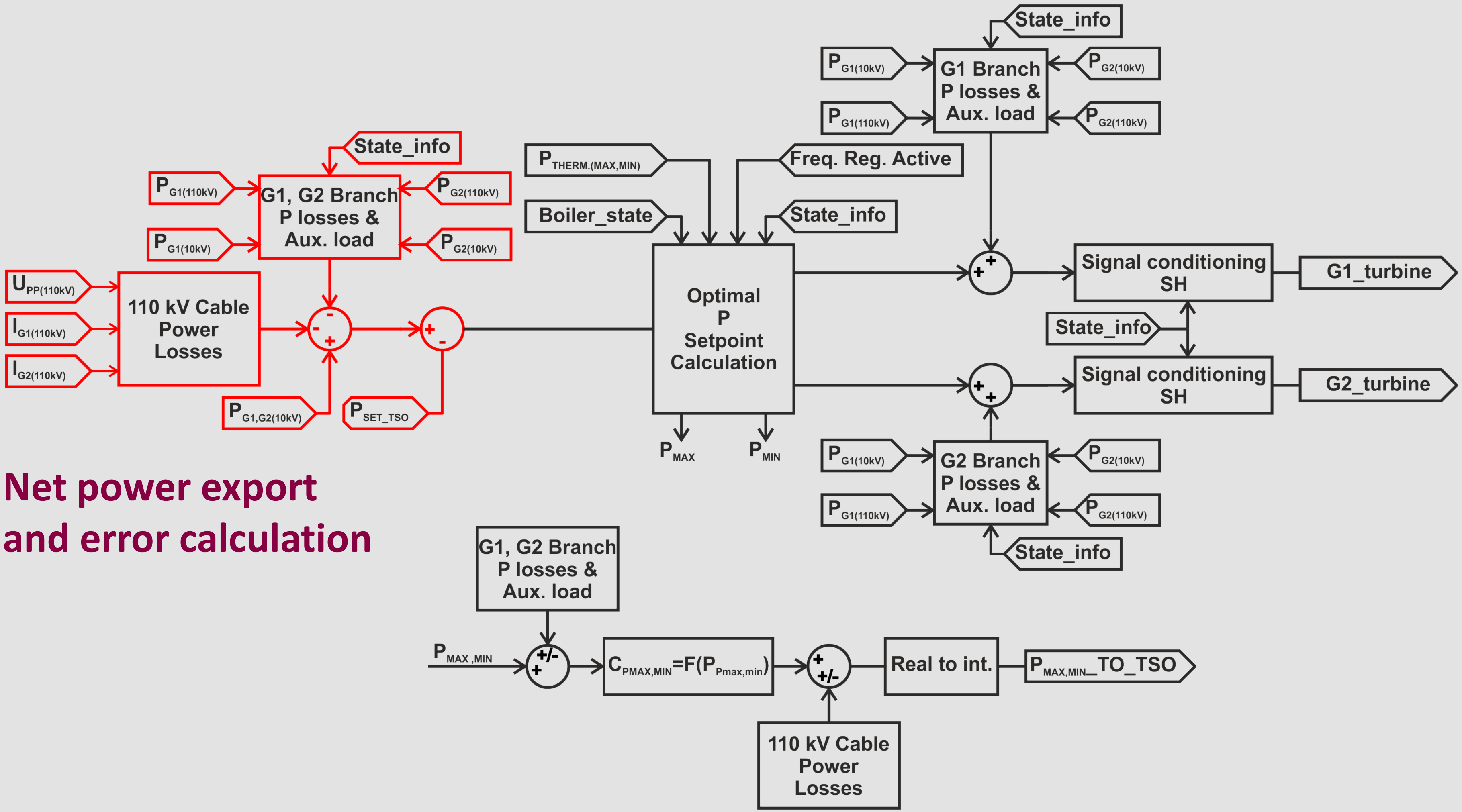
Stage 1: Design of the Central Controller

- Black box PSCAD model of the nearby power plant;
- Cooperation testing requirements:
  - **No significant impact to nearby generator stability** during fault at PCC;
  - **No reactive power hunting** between generators;
  - **No undamped oscillations** due to central control operation.
- Cooperation tests repeated during HIL development.

Central Controller: Active Power Control

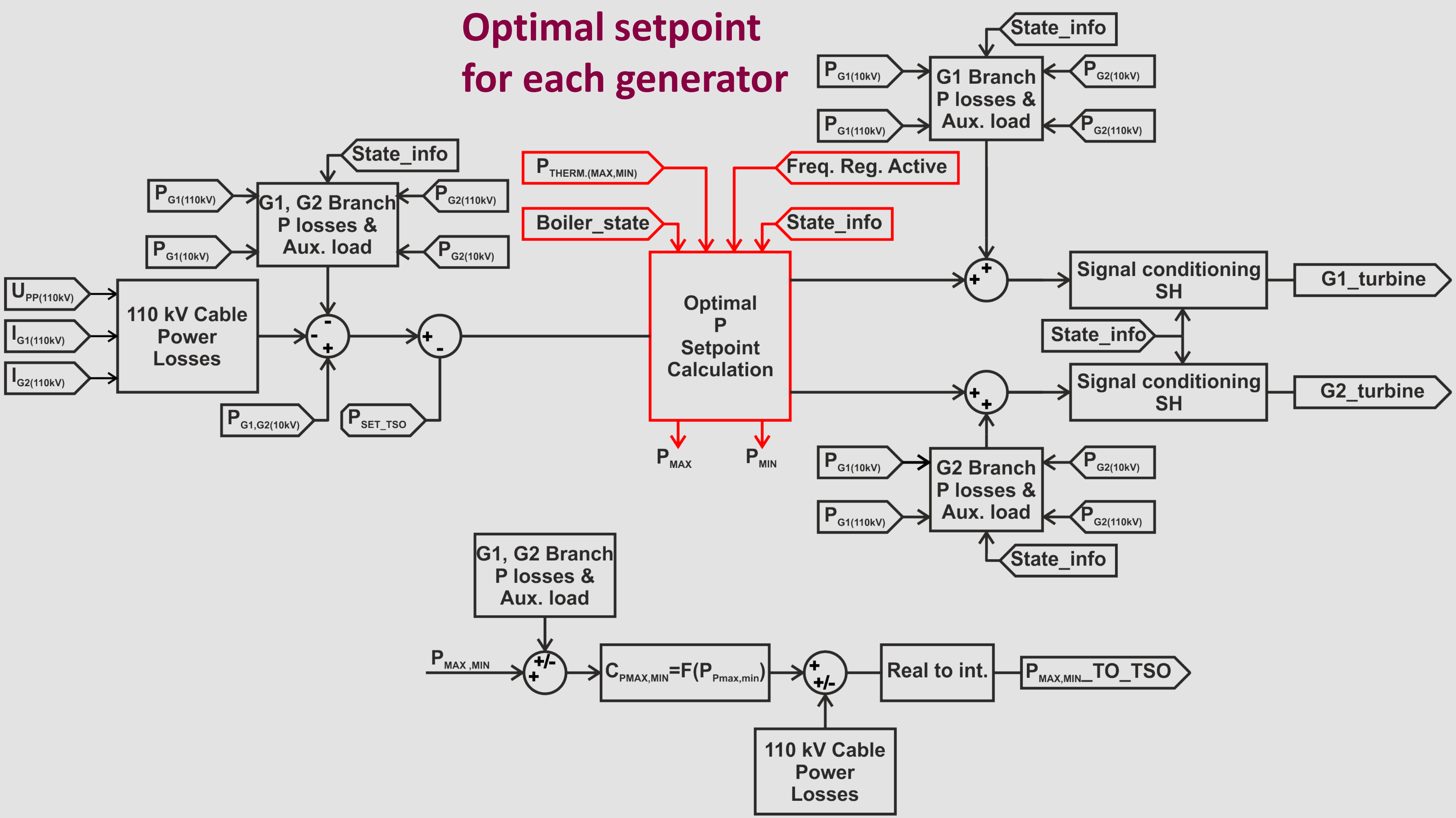


Central Controller: Active Power Control

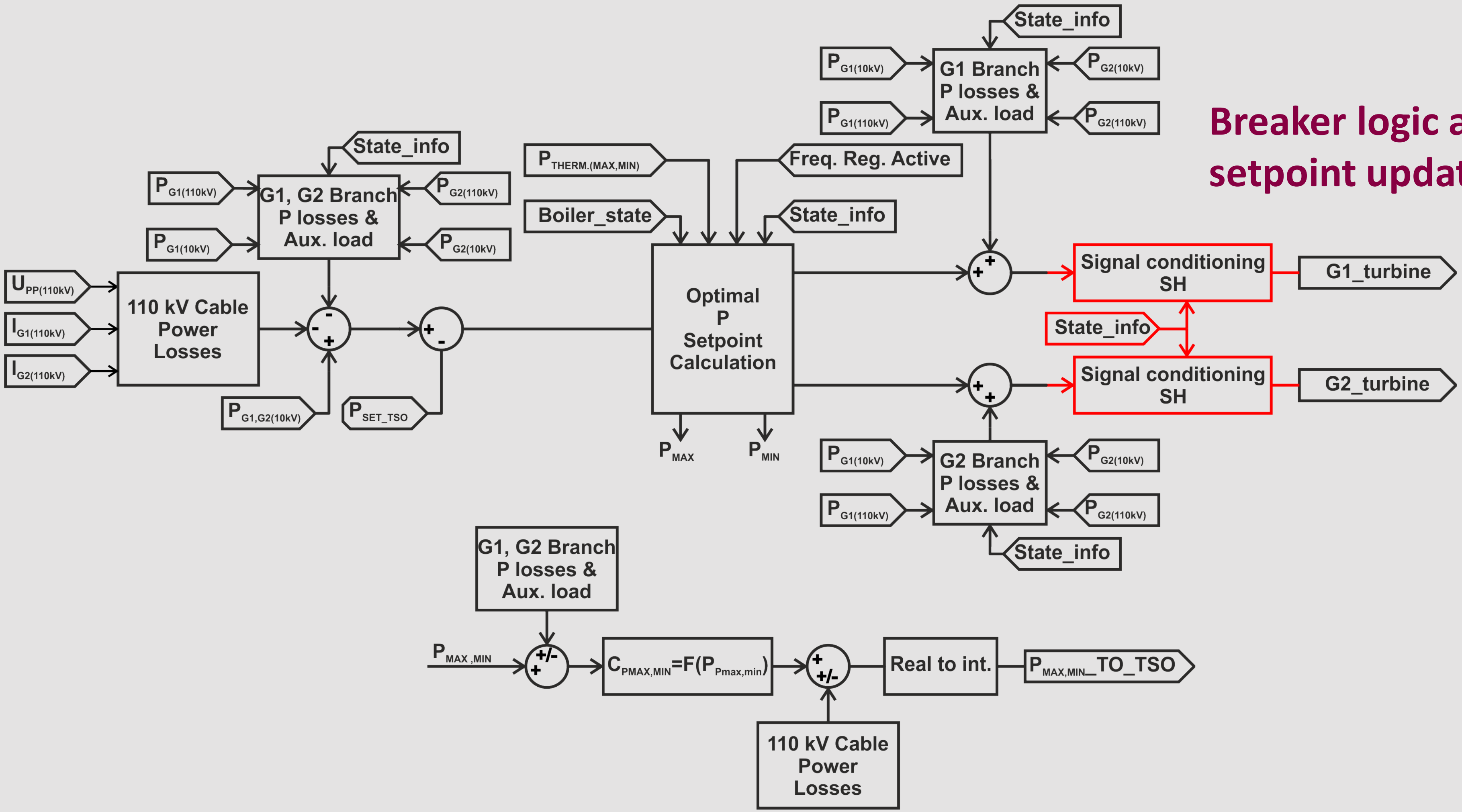


Net power export and error calculation

Central Controller: Active Power Control

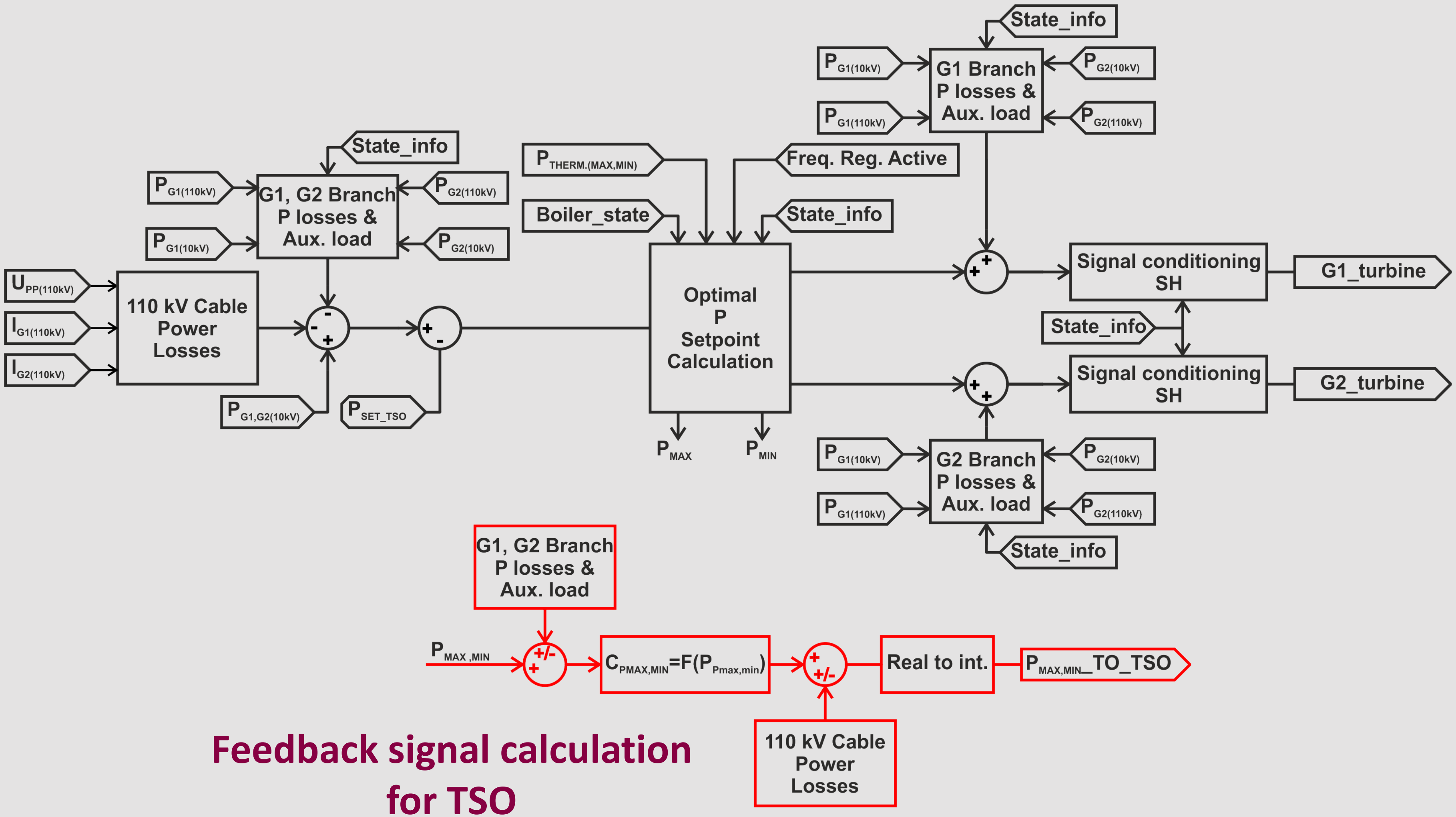


Central Controller: Active Power Control



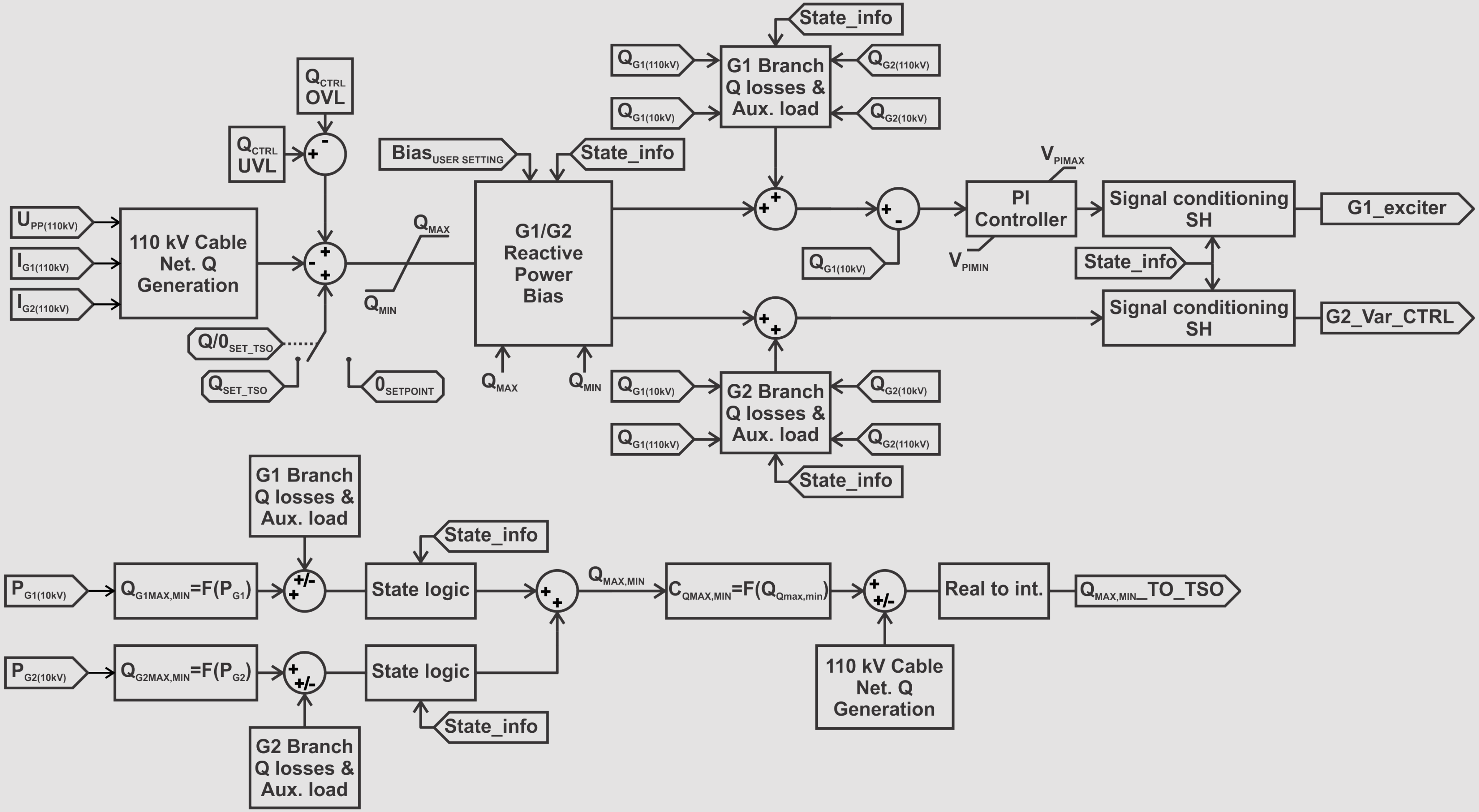
Breaker logic and setpoint update time

Central Controller: Active Power Control



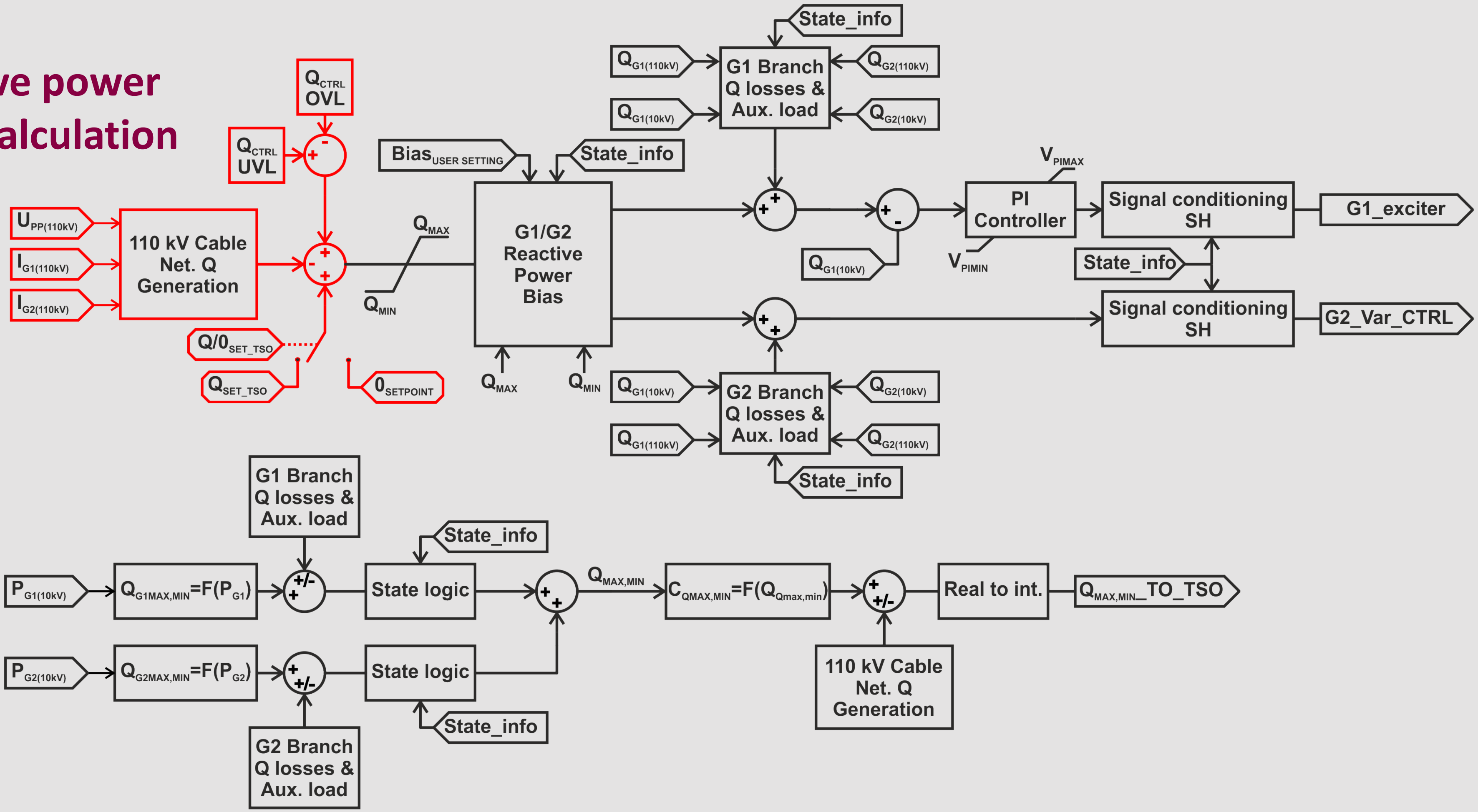
Feedback signal calculation for TSO

Central Controller: Reactive Power Control

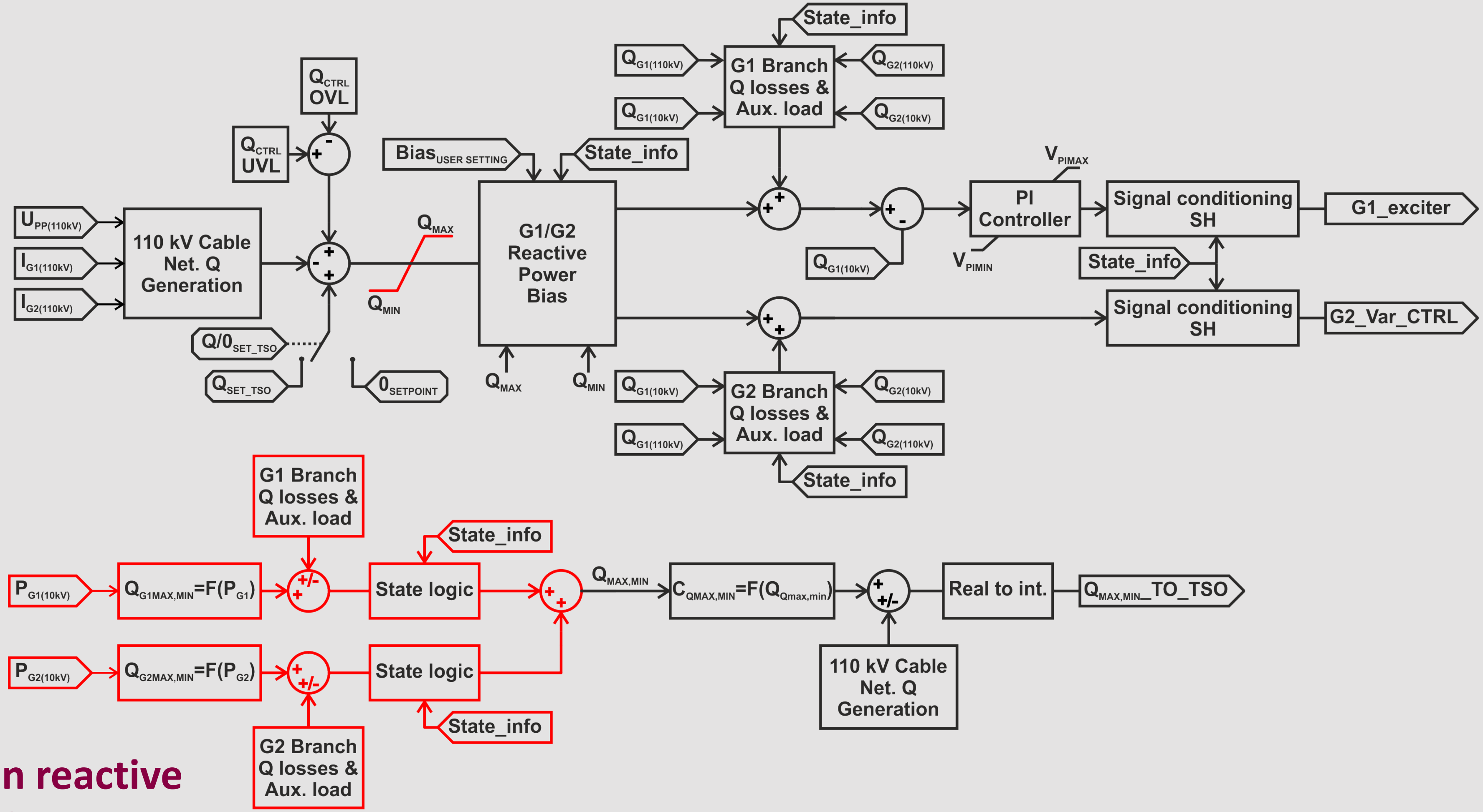


Central Controller: Reactive Power Control

Reactive power error calculation

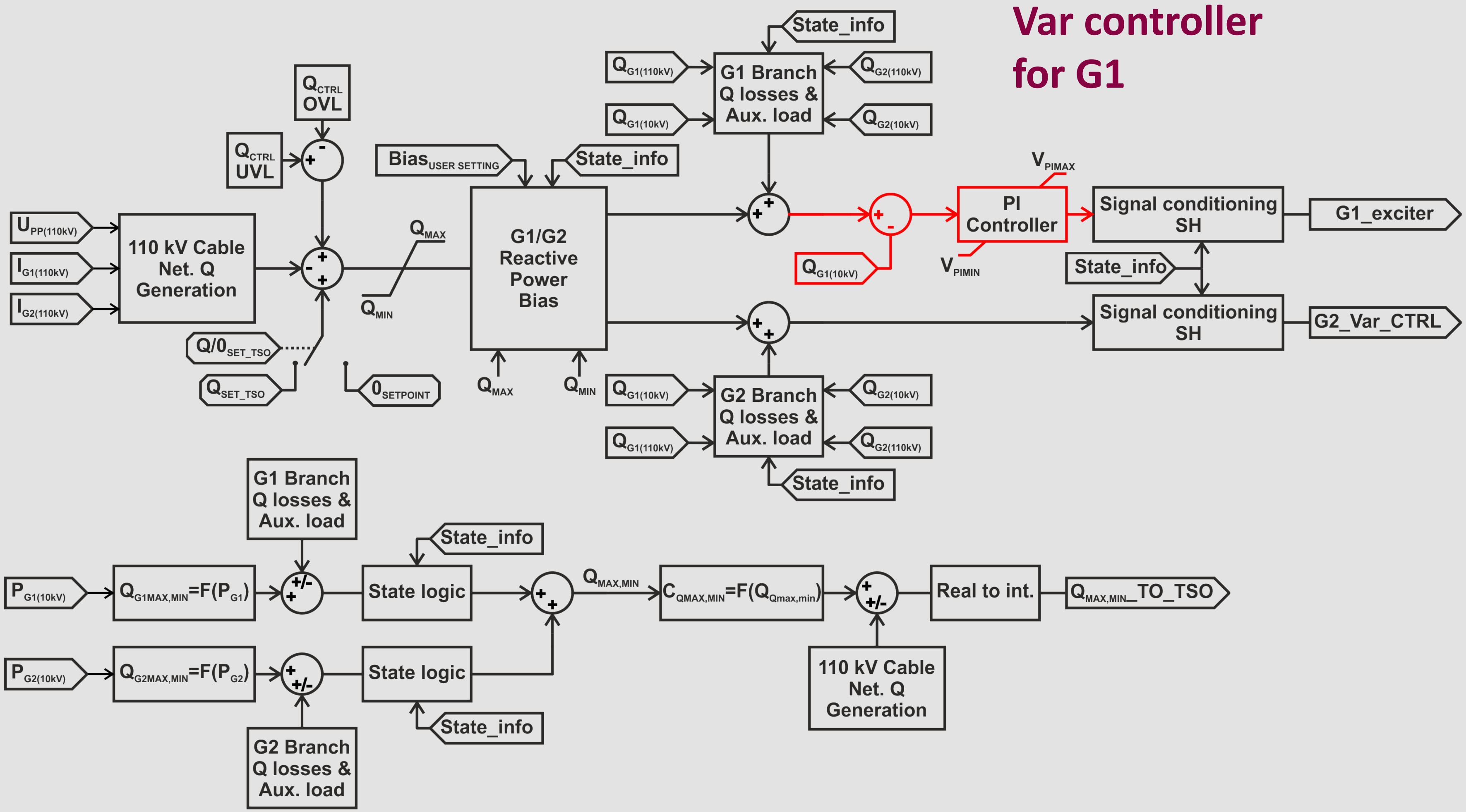


Central Controller: Reactive Power Control

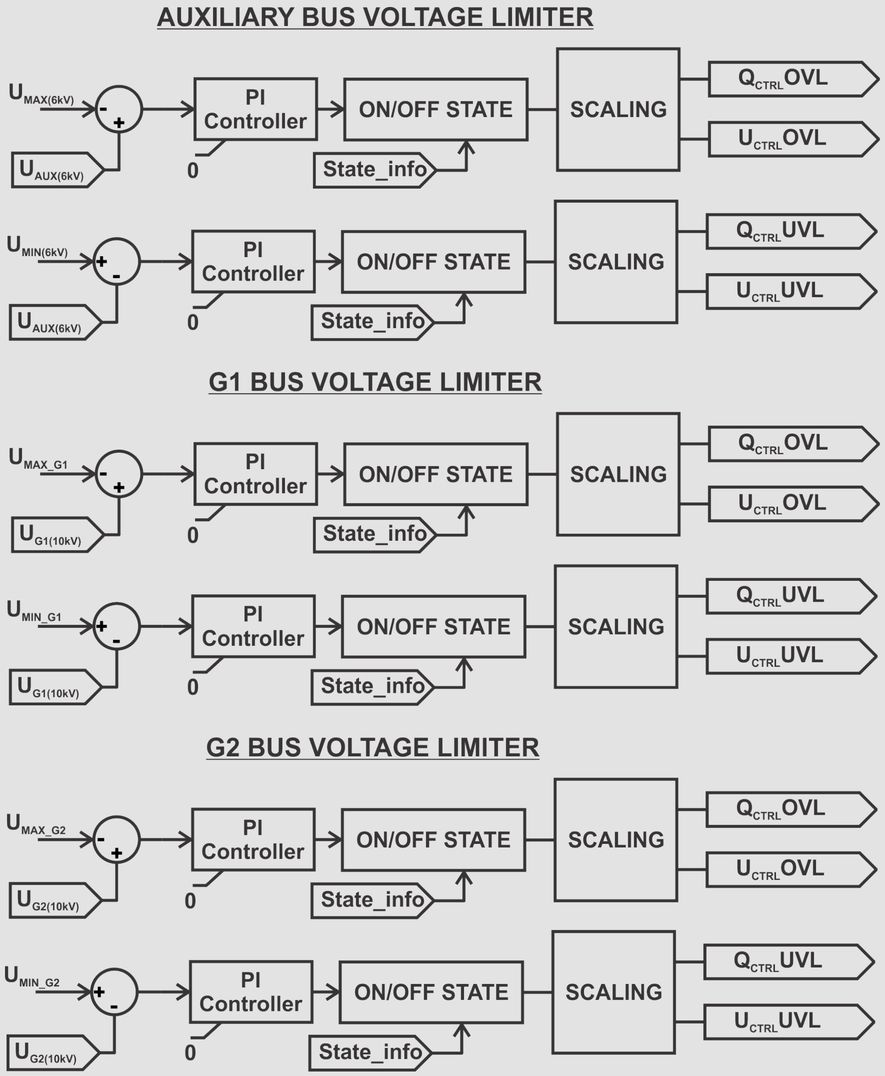


Max and min reactive power calculation

Central Controller: Reactive Power Control



Central Controller: Limiter Functions



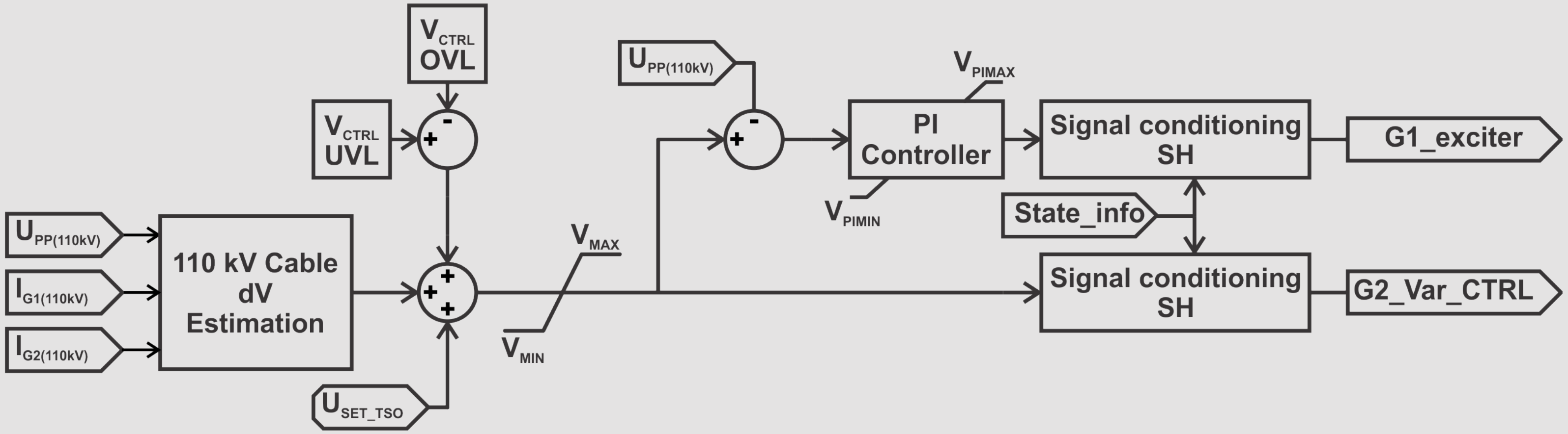
Auxiliary bus voltage limiter

G1 bus voltage limiter

G2 bus voltage limiter

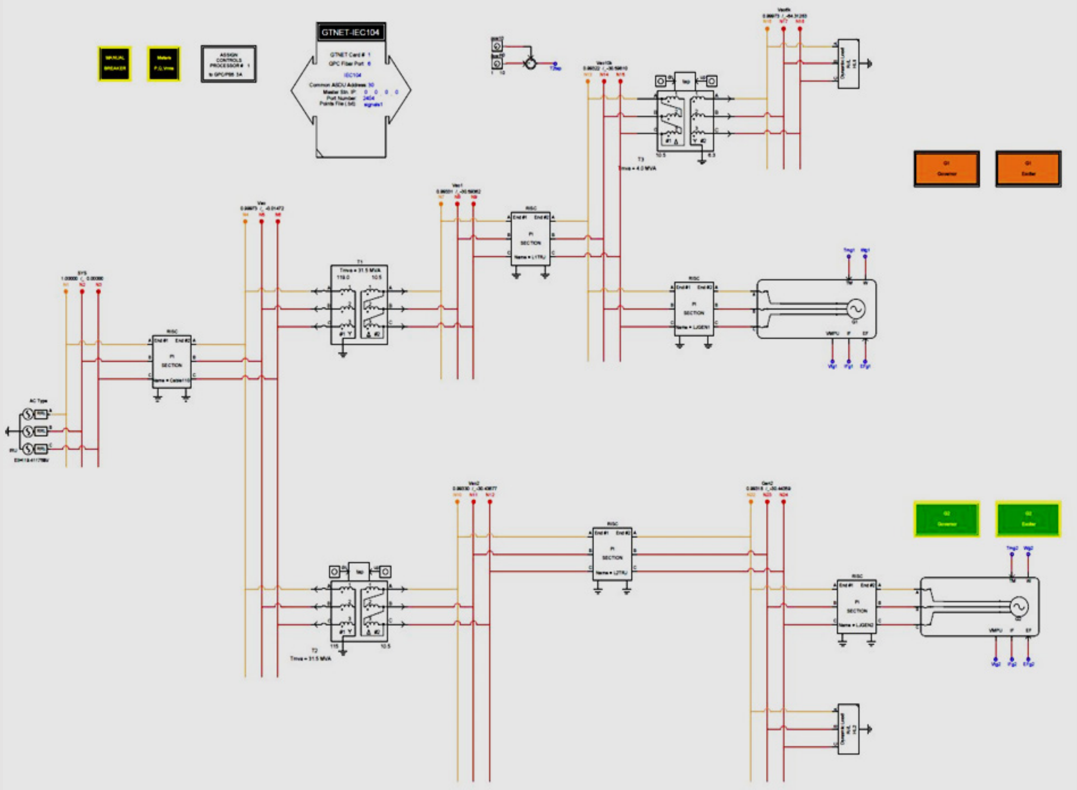
Central Controller: PCC Bus Voltage Control

- Controls power plant 110 kV bus voltage;
- PCC voltage control achieved by **voltage drop compensation**.



Stage 2: RTDS Model Development & HIL Setup

- Developed based on PSCAD model;
- Generator appropriate controls modelled;
- Hardware implementation of central control system developed in parallel with RTDS model.



RTDS Model Verification

- Model verification done **based on the PSCAD model**;
- RTDS model was verified according to:
  - **No-load voltage step response;**
  - Grid connected voltage reference step response;
  - Active power regulation speed;
  - Reactive power regulation speed;
  - **3-phase fault at PCC (0.25 s)**;
  - Sudden network impedance change.

Hardware-in-the-loop: **Setup**

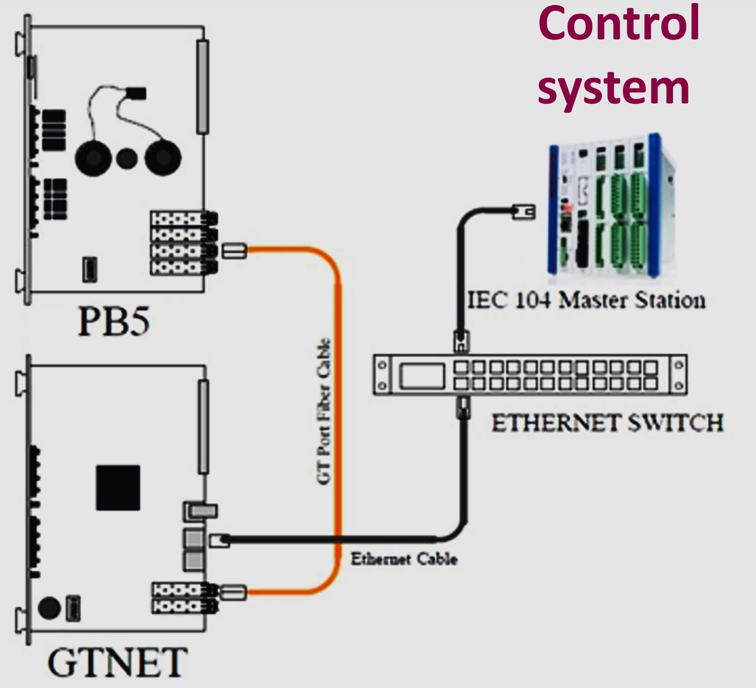
- Modelling of the power plant **IEC-104 communication system**;
- Master station (central control system) is SAE IT-systems Net-line FW-50.

```
# BI: Binary Input Objects 1,2 in DNP Specification
BI: 0   PctrlONSW1      PctrlONSW1       0
BI: 1   UctrlONFB       UctrlONFB        0
BI: 2   QctrlONFB       QctrlONFB        0
BI: 3   PrimONFB        PrimONFB         0
BI: 4   G1primact5      G1primact5       0
BI: 5   G1primact12     G1primact12      0
BI: 6   G1RPF   G1RPF    0
BI: 7   G1RPact G1RPact  0
BI: 8   G1comF  G1comF   0
```

RTDS signal configuration file

Electrical system

Control system



Hardware-in-the-loop: Control System Adjustment

- Control system “converted” from PSCAD to Net-line FW-50;
- Conversion is not 1:1 because of differences in control blocks implementations by the programs:
  - Optimization and workarounds based on HIL simulations.
- **Final tuning of the control systems.**

Hardware-in-the-loop: Challenges

- RTDS does not support double point information:
  - Requires significant redesign of state information.

Point information	Status
11	closed
01	open
00	error

Plant configuration

Point information	Status
1	closed
0	open

RTDS configuration

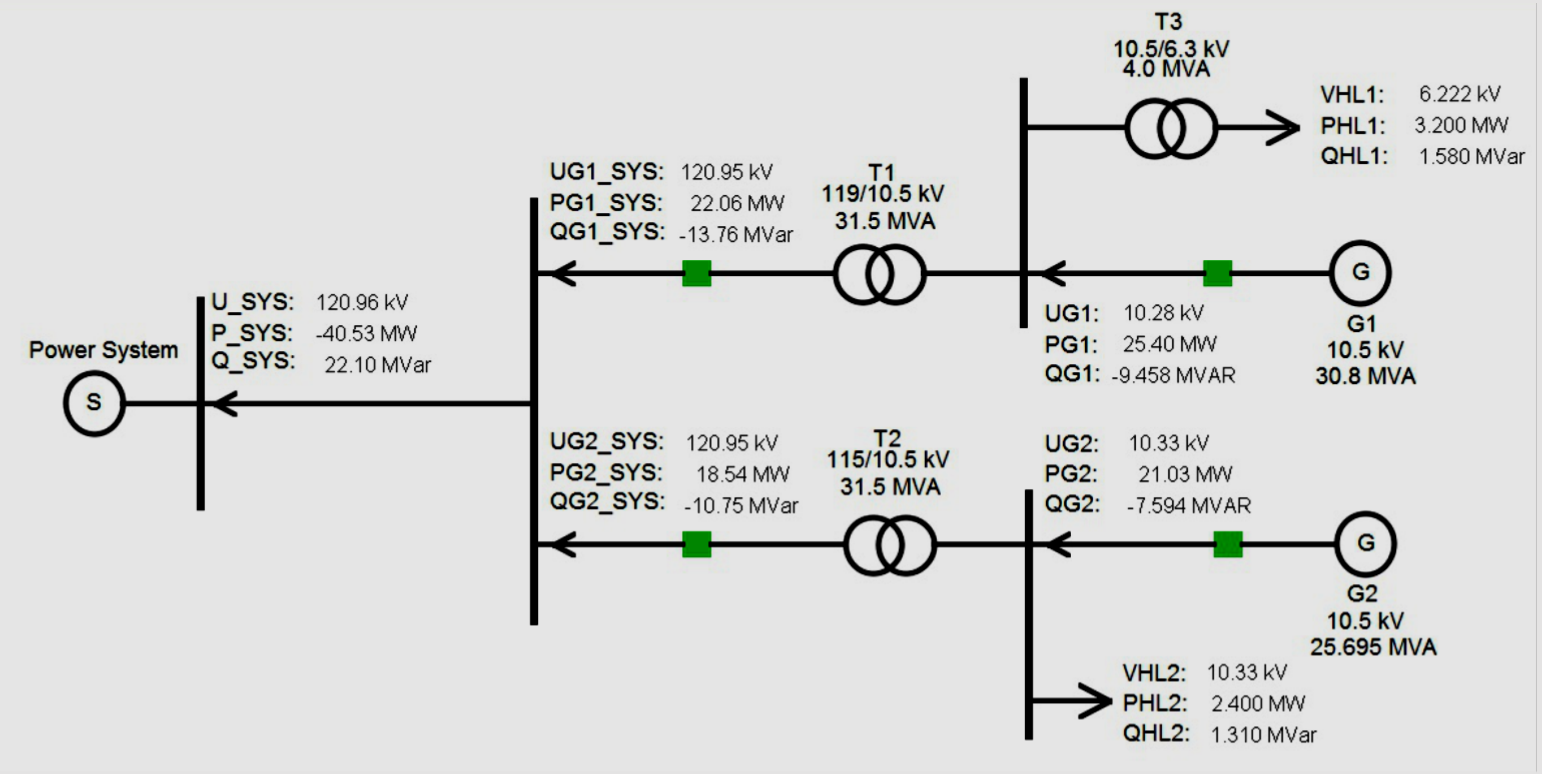
Translation layer

Stage 3: Commissioning Test

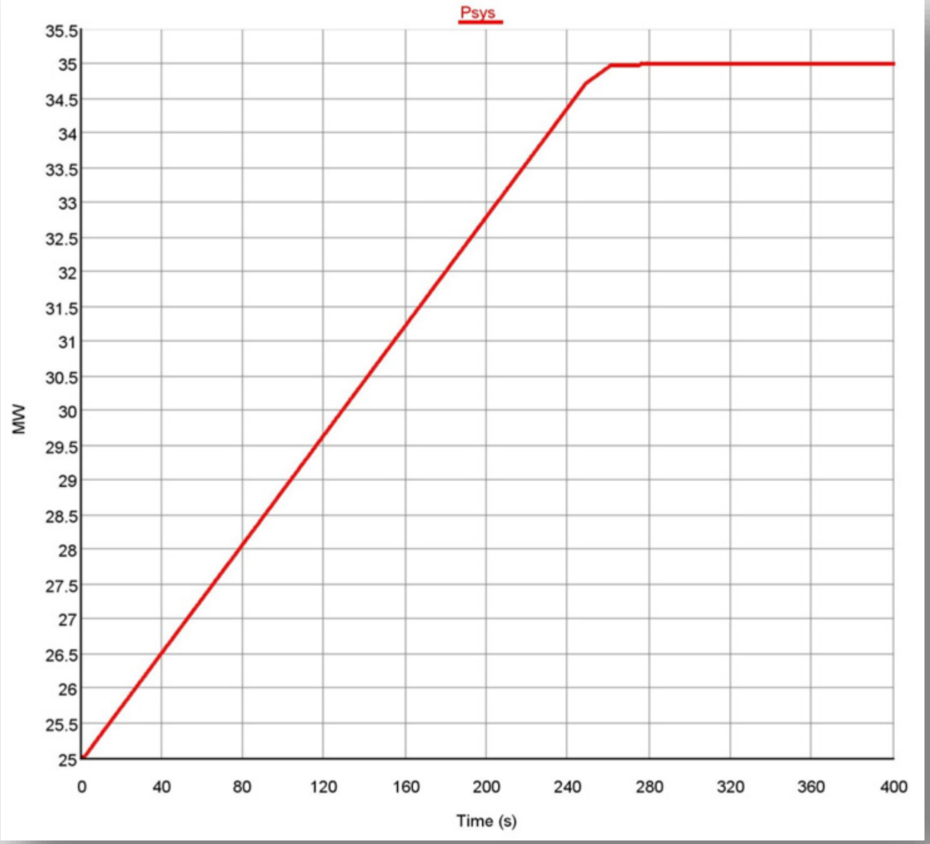
- Tests to demonstrate the control system performance to the Estonian TSO Elering AS;
- 32 test cases divided in 3 groups:
  - Active power control;
  - Reactive power control;
  - Voltage control.

Commissioning Test: Runtime Schematic

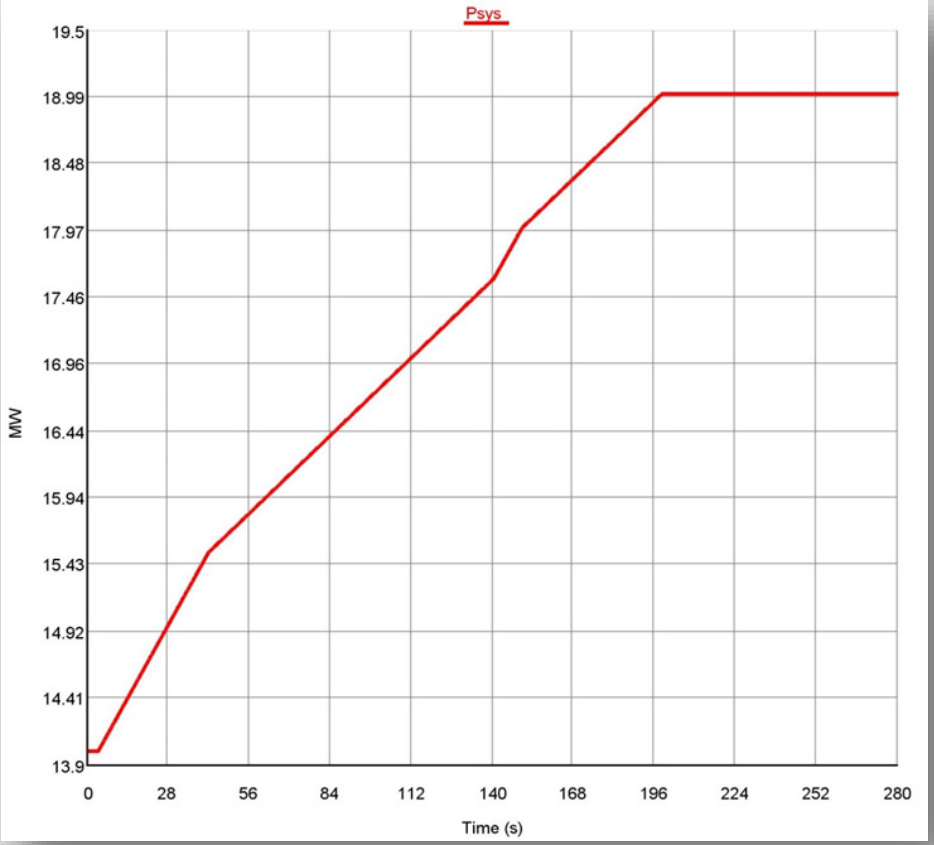
- Schematic for commissioning test: **real-time operation**.



Commissioning Test: P Control

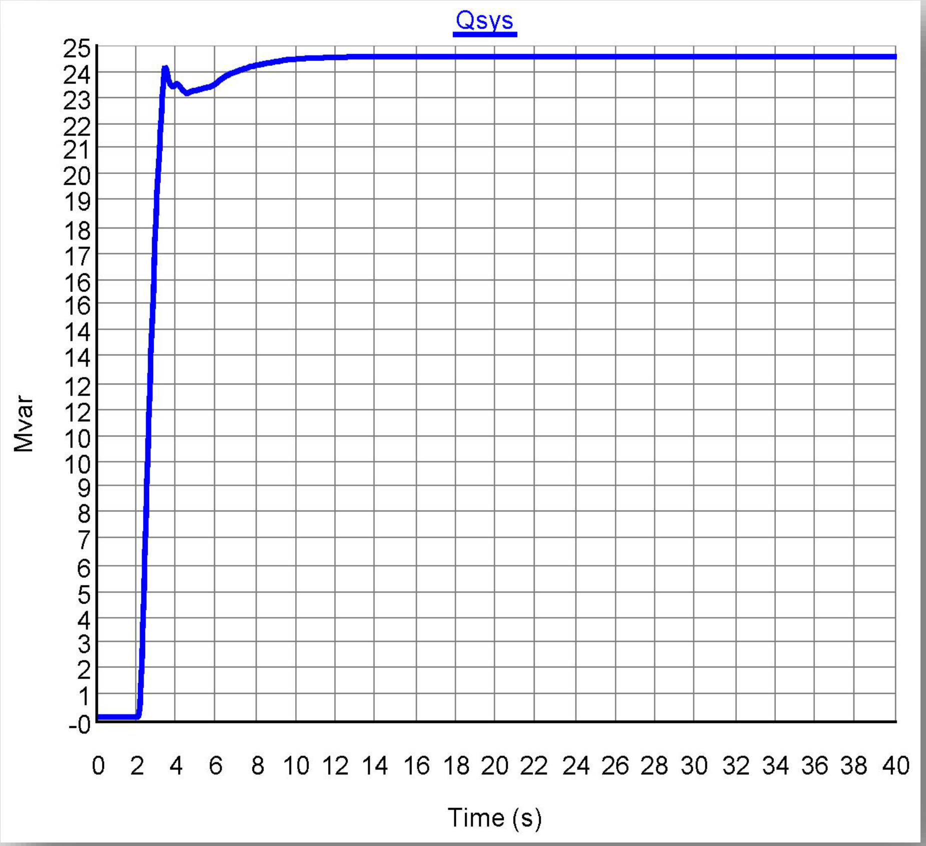


PCC active power step from 25 to 35 MW, without limitations.

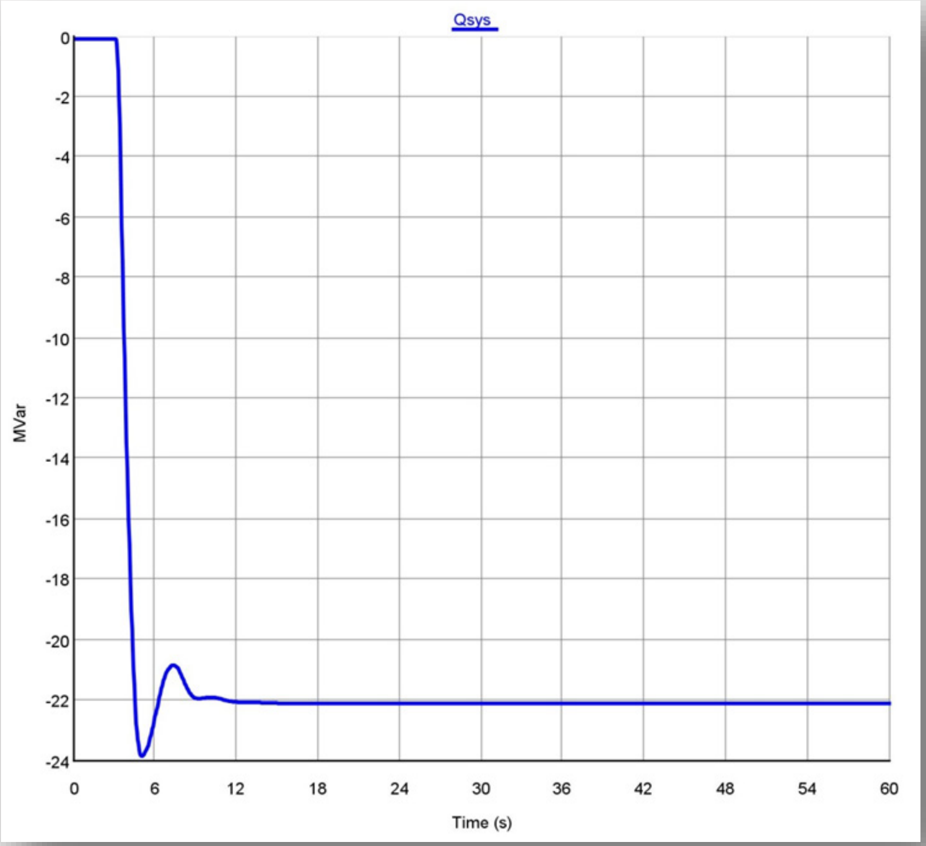


PCC active power step from 14 to 19 MW, with boiler limitations.

Commissioning Test: Q Control

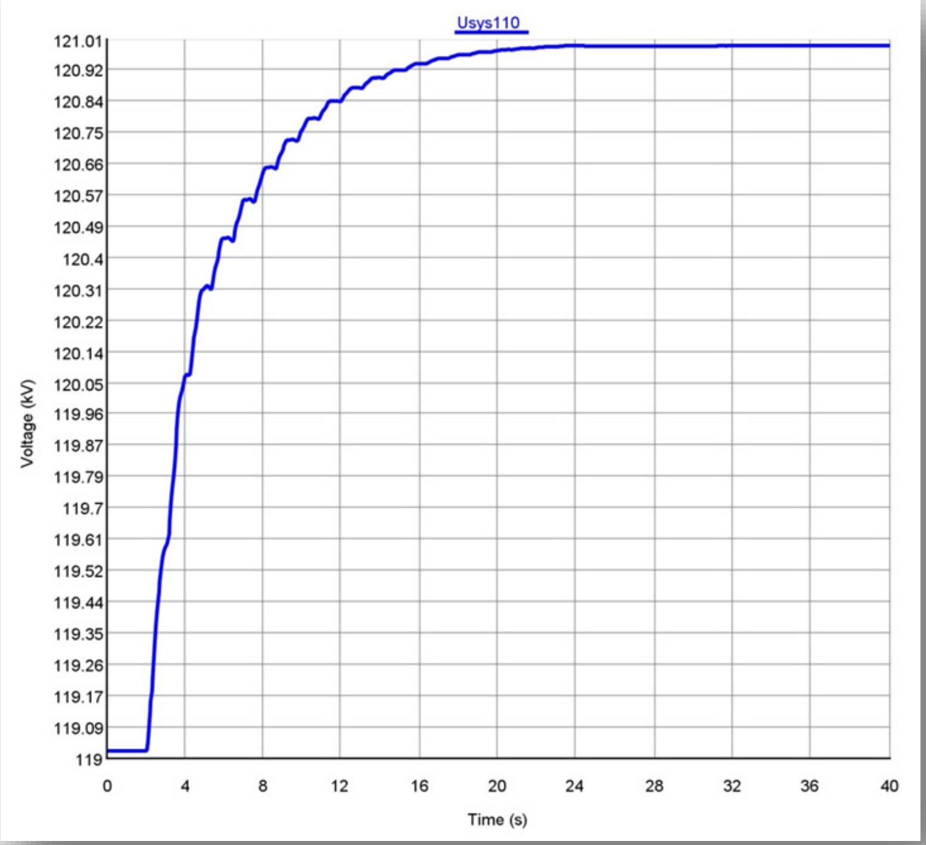


PCC reactive power step from 0 to Qmax.

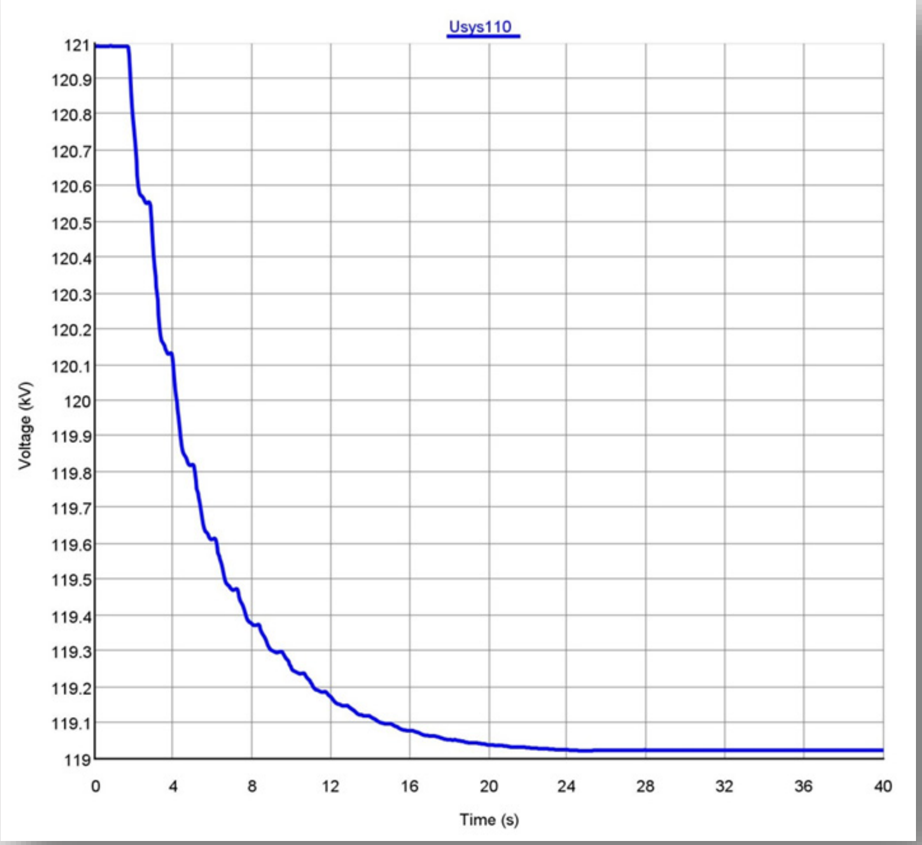


PCC reactive power step from 0 to Qmin.

Commissioning Test: U Control



PCC voltage step from 119 to 121 kV.



PCC voltage step from 121 to 119 kV.

Conclusions

- **Positive outcomes**:
  - After approval by the TSO, the control system was installed as is in the power plant;
  - Control system has been in operation for 2 years without any problems;
  - Significant cost savings for the power plant owner.

Conclusions

- **Challenges faced**:
  - Convincing other parties that real-time simulation is a suitable platform for development and commissioning testing;
  - Missing double point information feature;
  - Simulation reliability of IEC-104 protocol.

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