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Power plants & power systems control
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Session on
Control concepts for conventional and non-conventional power plants

Black-startup simulation of a repowered thermoelectric unit

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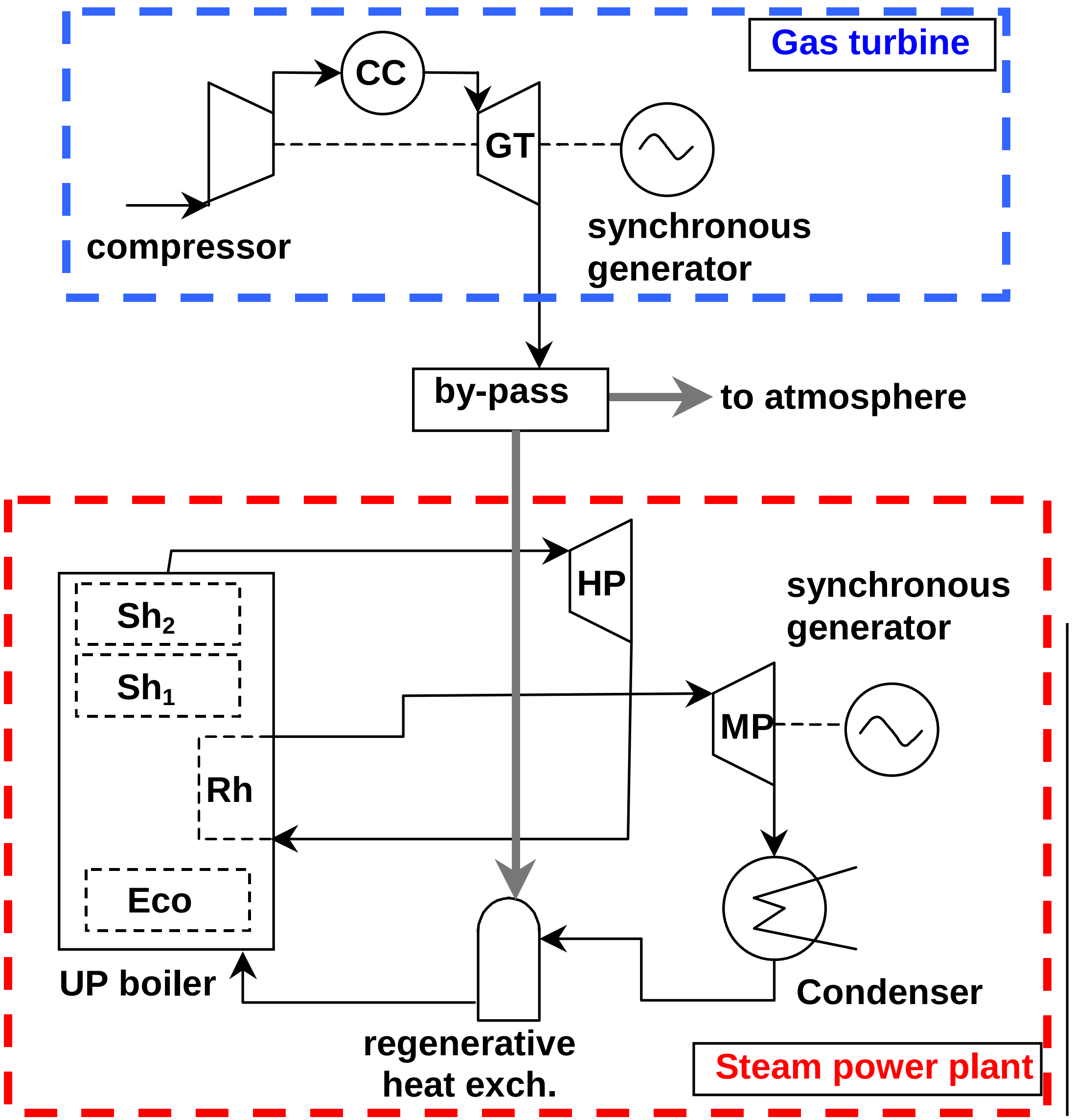
A typical ENEL repowering project



120 MW gas turbine

320 MW
once through UP boiler

The problem to be studied

- Possibility to use a local repowering TG to perform a black start operation on a UP-steam unit without feeding auxiliaries from the network. This could:

1. Spare precious time if load rejection on SPP fails

2. Avoid SPP auxiliaries feeding from network, complex operation involving personnel on large geographical areas.

3. Allows to the group TG/SPP to feed at last other power stations, helping to restore the network as fast as possible

The simulation environment

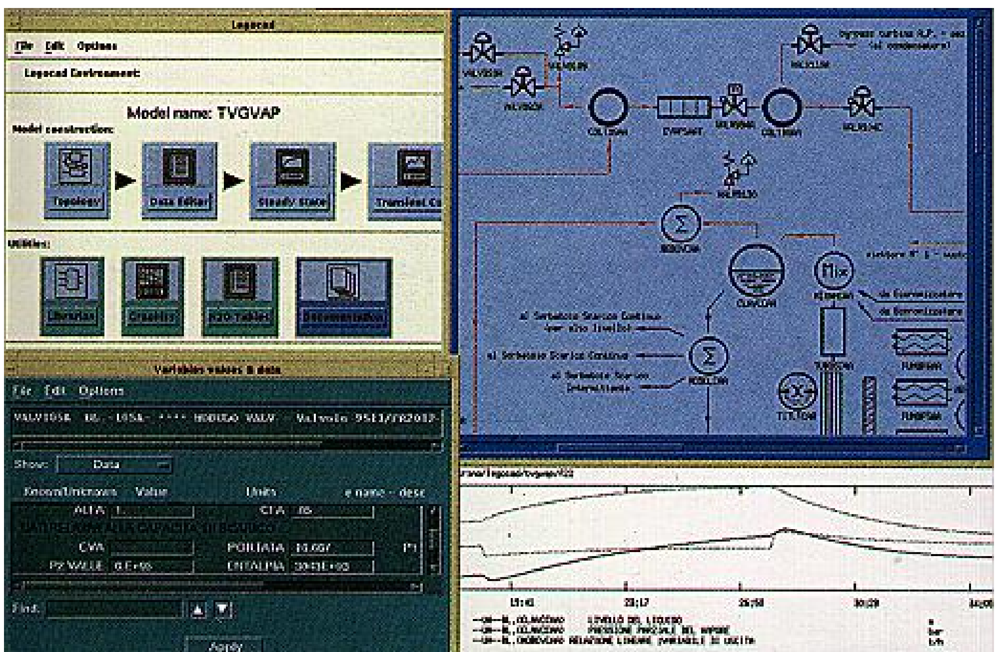
The simulator

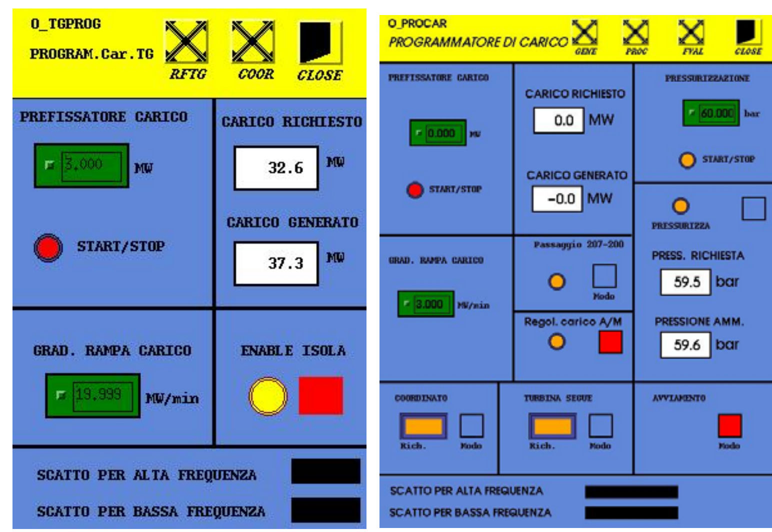
CESI has developed a real time **simulation environment**, named ALTERLEGO.

Its core consists of:

- an **efficient and reliable implicit solver** of large sets of algebraic-differential equations,
- **CAD-like user-friendly tools** for building and managing models
- a **large library of mathematical models** in the field of energy production processes.

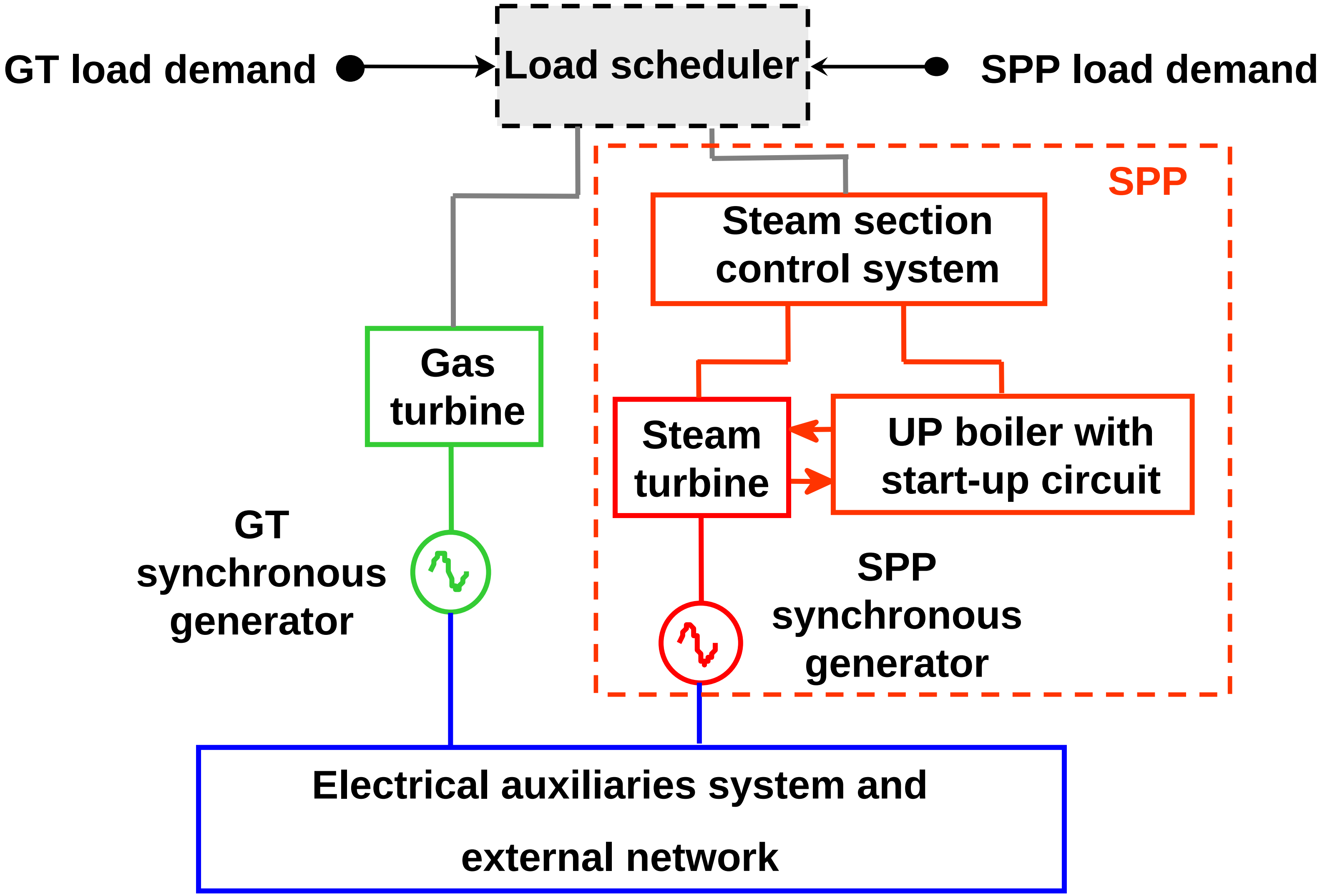
A **run-time executive** enables to run together the various parts and the MMI.





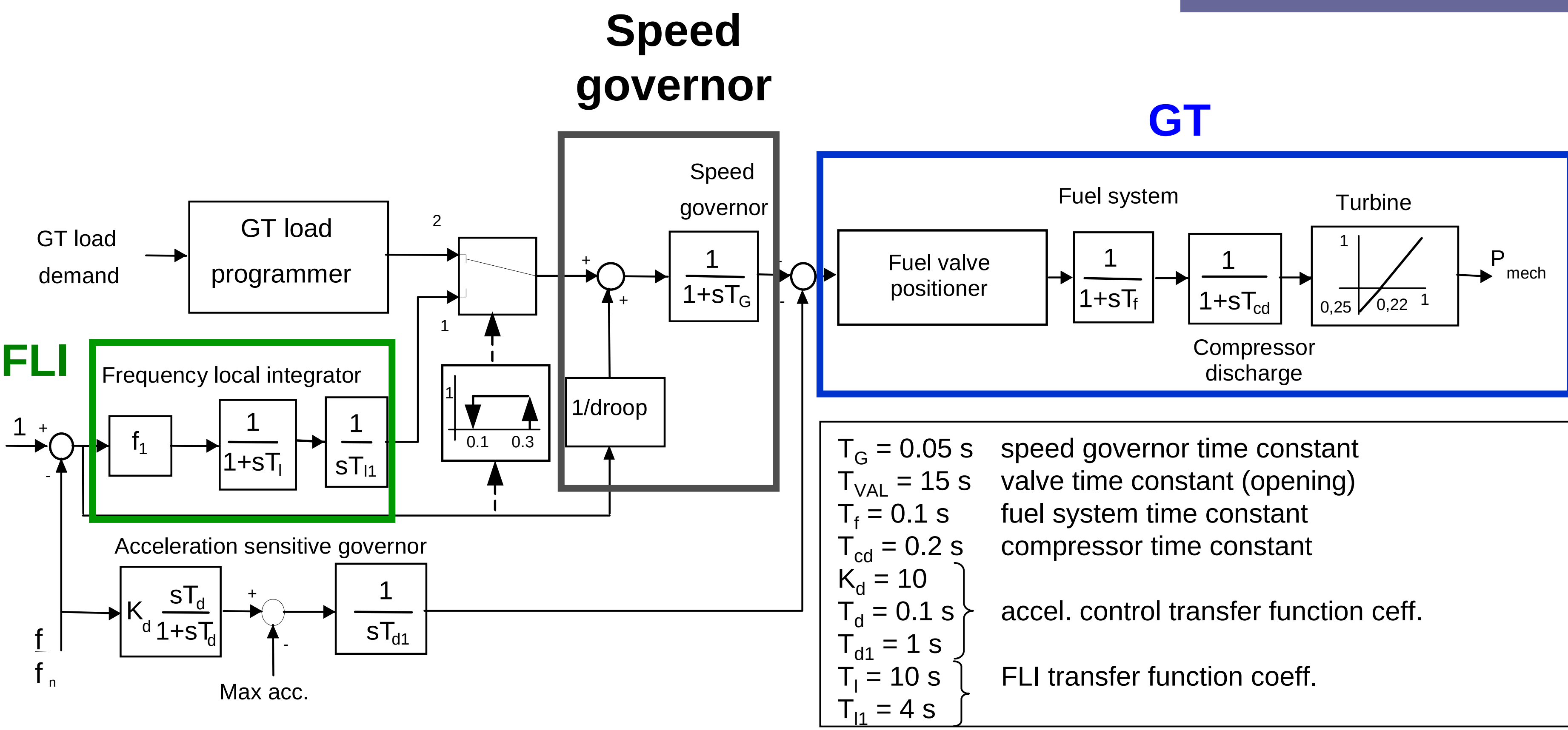
ALTERLEGO man machine interface

Simulator structure



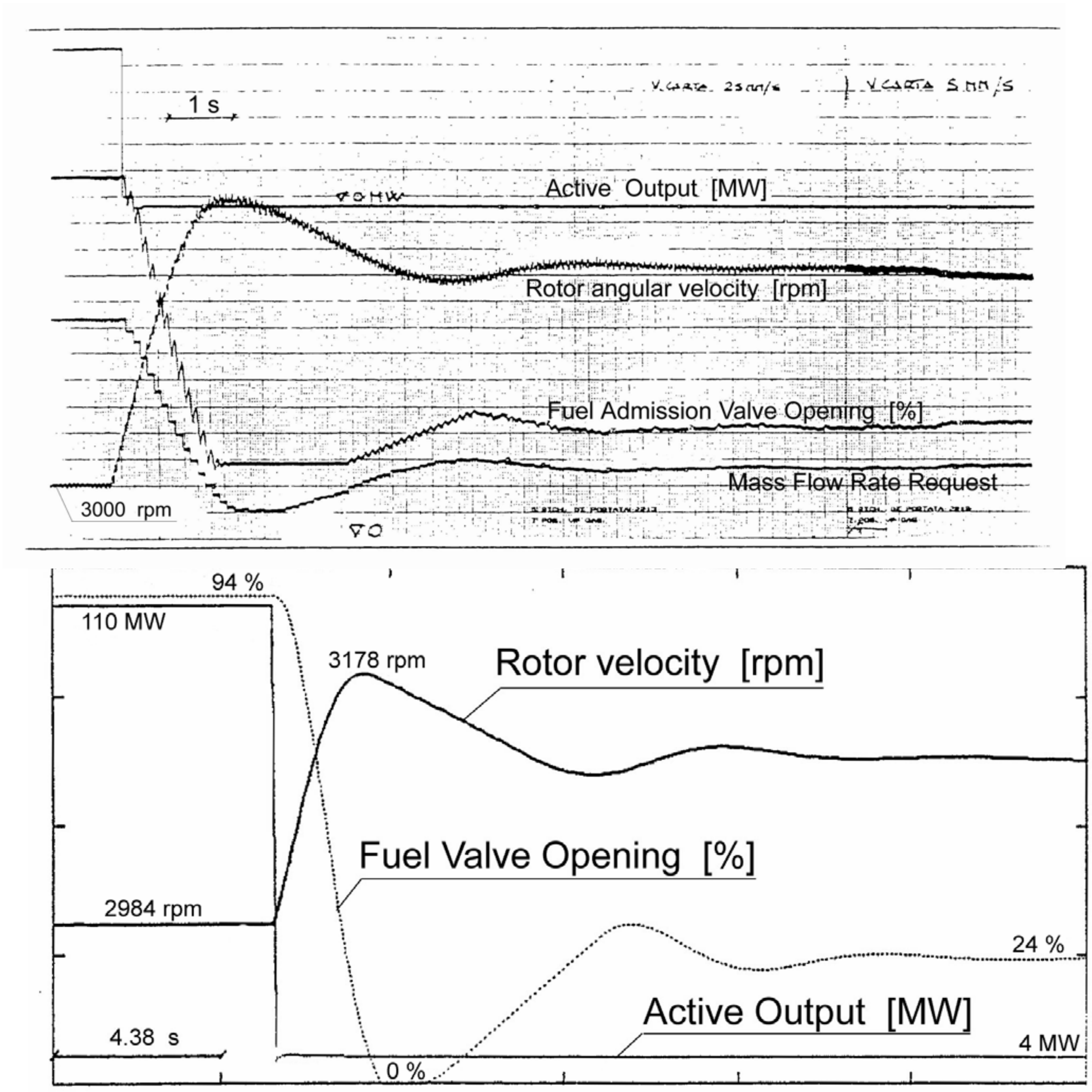
Gas turbine and its control

The simulator



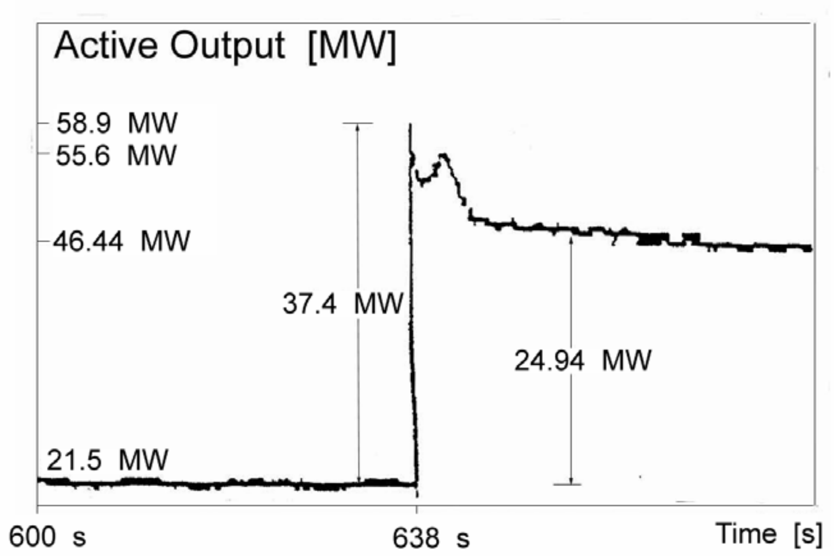
- The temperature control is not represented and it is approximated by reducing the maximum fuel limit.
- The fuel valve positioner has two different actuation speed.
- Valve position 22% ⇨ balance between gas turbine and compressor power

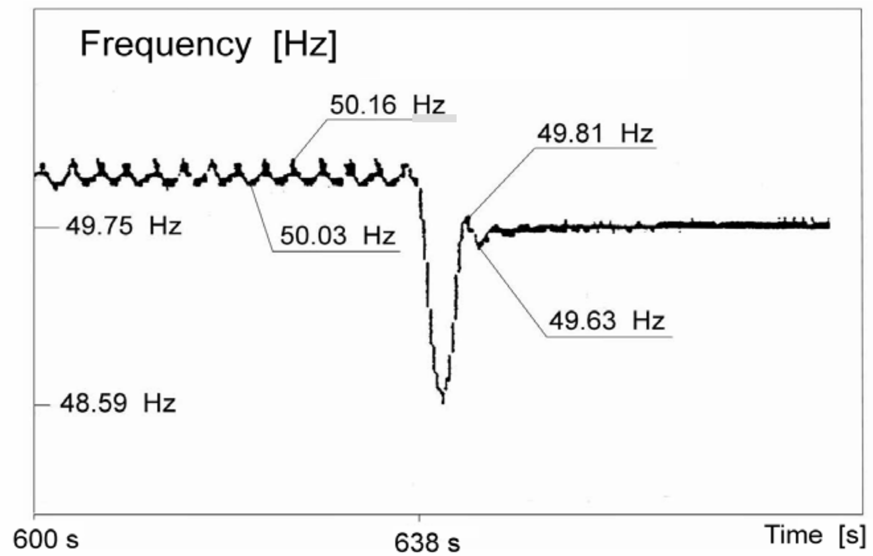
GT model validation

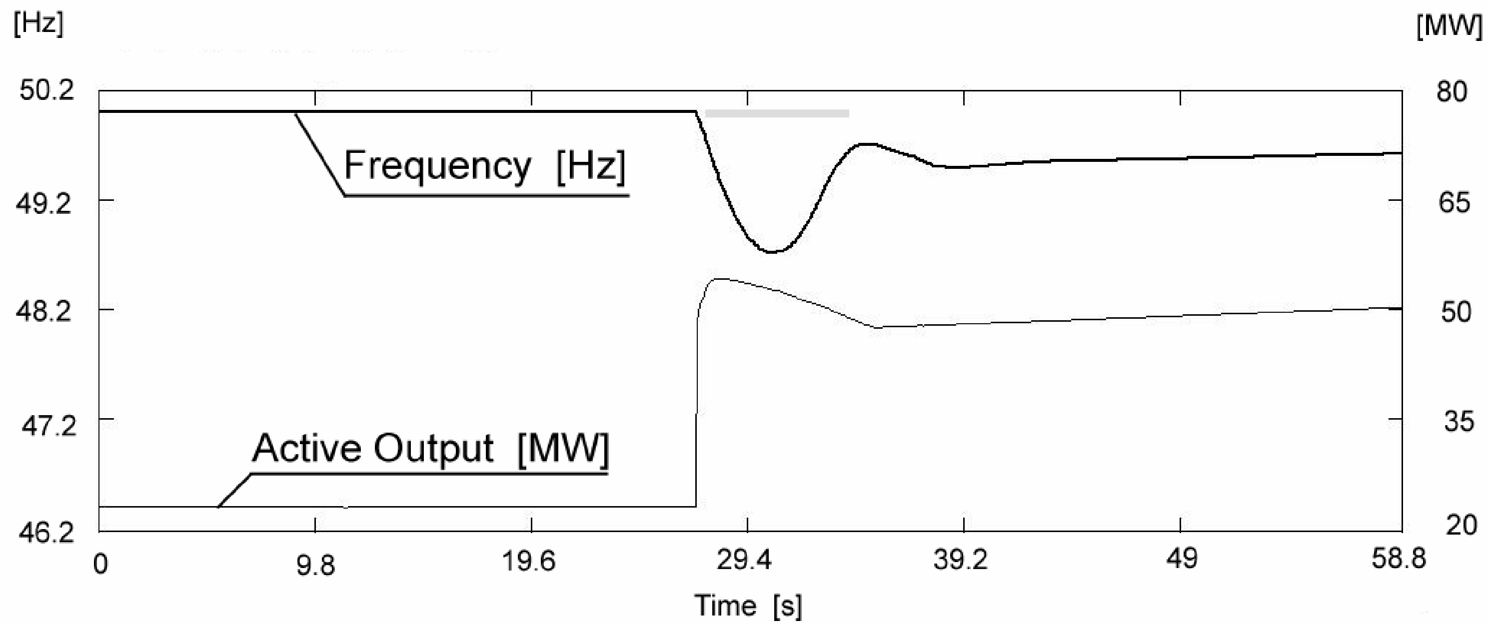


The simulator

GT model validation



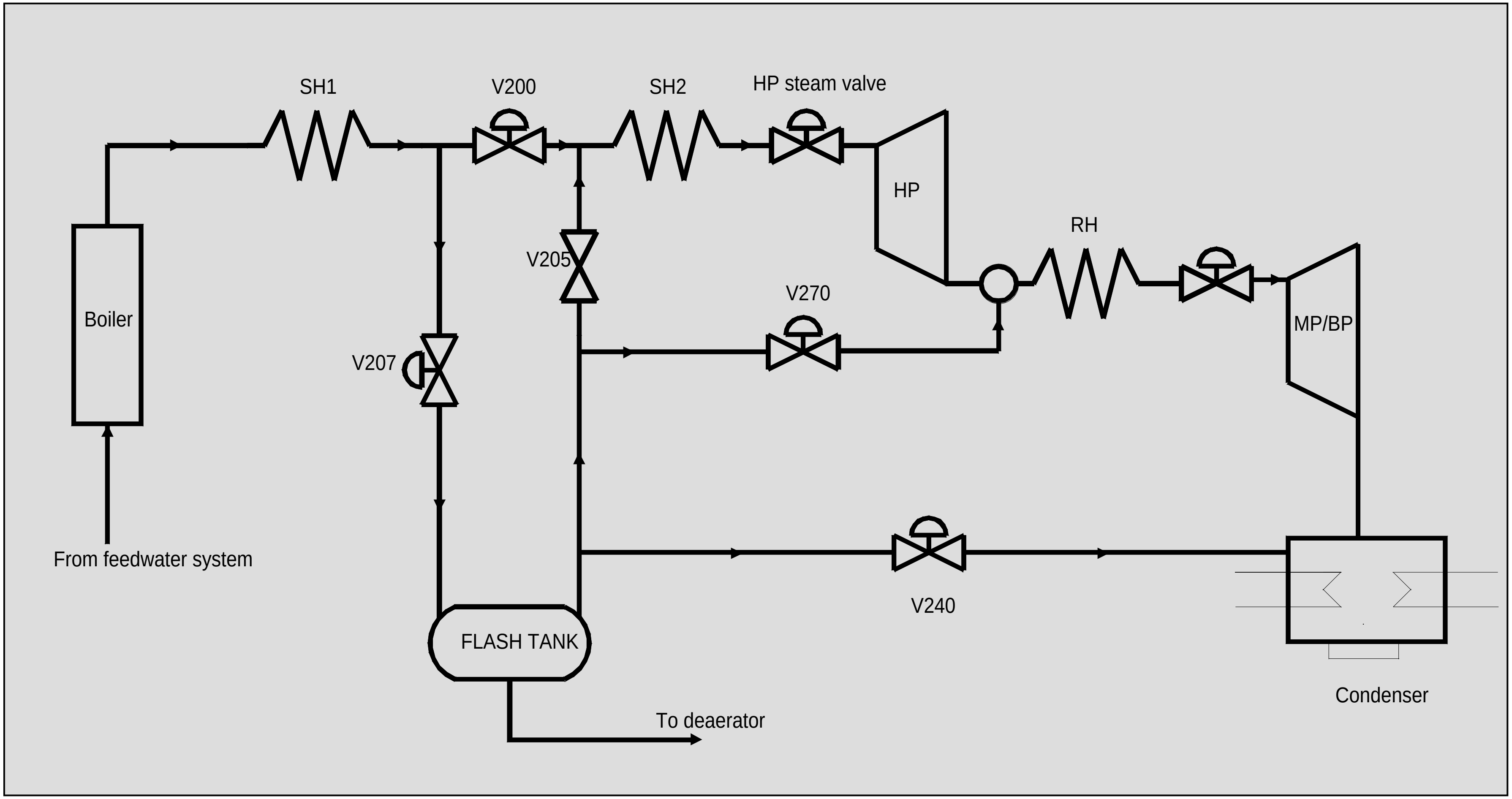




UP Boiler: main assumptions

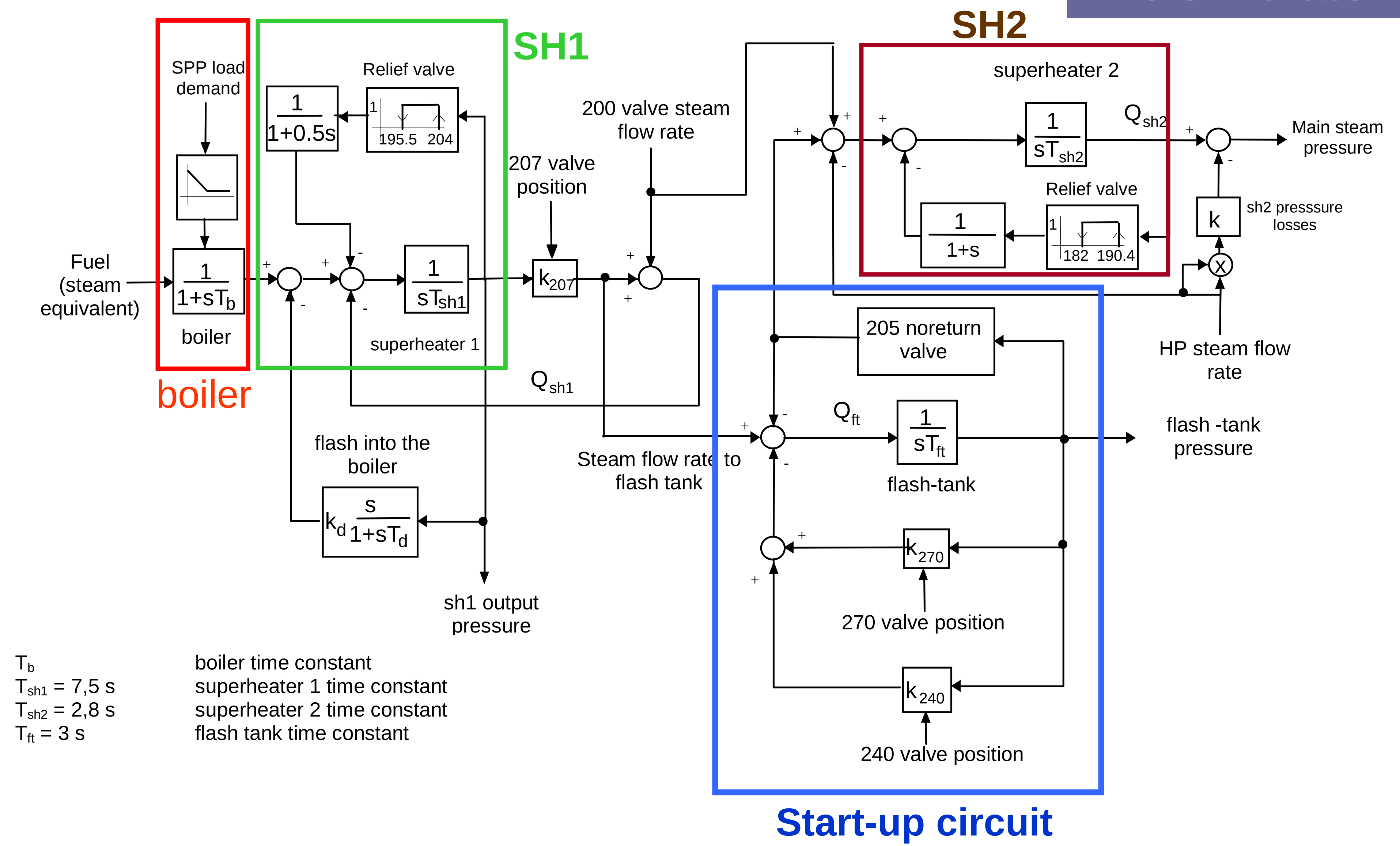
- Thermal balance equations are not represented: load connections generate ΔT_{max}=5-10 C
- Feedwater flow rate proportional to fuel flow rate at each load
- Steam production proportional to feedwater flow rate; time constant greater at diminishing loads
- Neglected F.T. drainings (but oil was increased by program at low load)
- Mass accumulation has been considered in: SH1, FT, SH2

UP Boiler


SH1
V200
SH2
HP steam valve
HP
RH
V205
V270
MP/BP
Boiler
V207
From feedwater system
V240
FLASH TANK
Condenser
To deaerator

UP Boiler

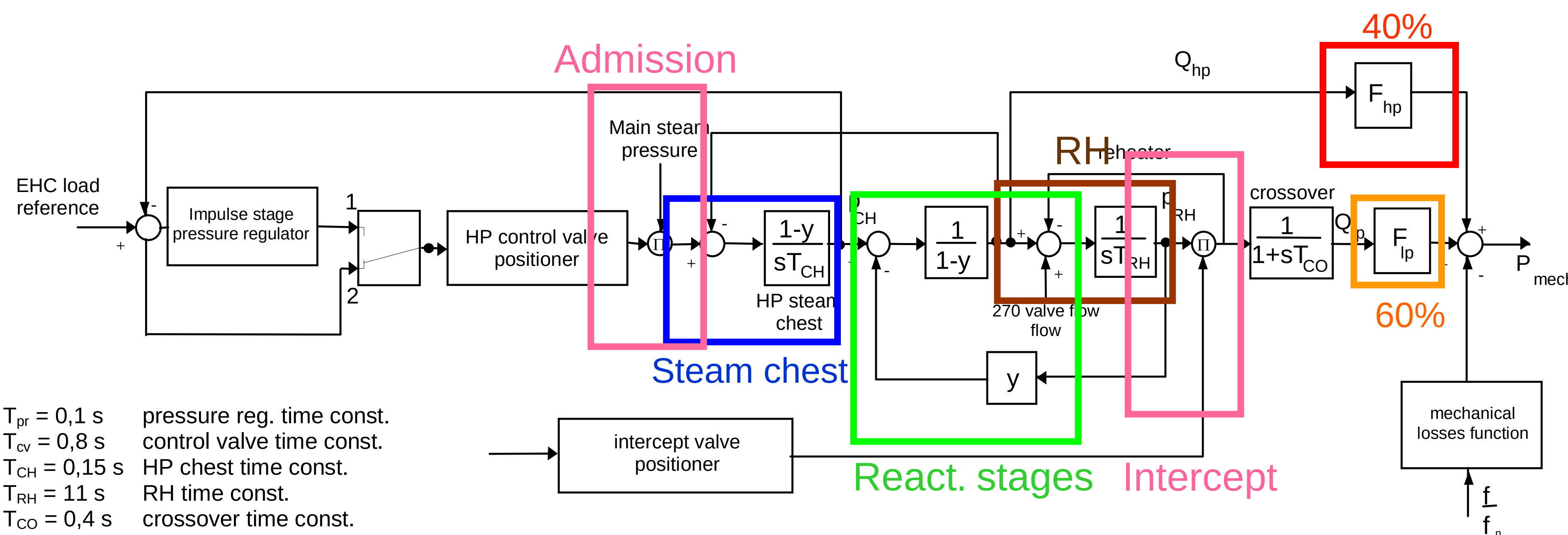
The simulator



T_b boiler time constant
T_{sh1} = 7,5 s superheater 1 time constant
T_{sh2} = 2,8 s superheater 2 time constant
T_{ft} = 3 s flash tank time constant

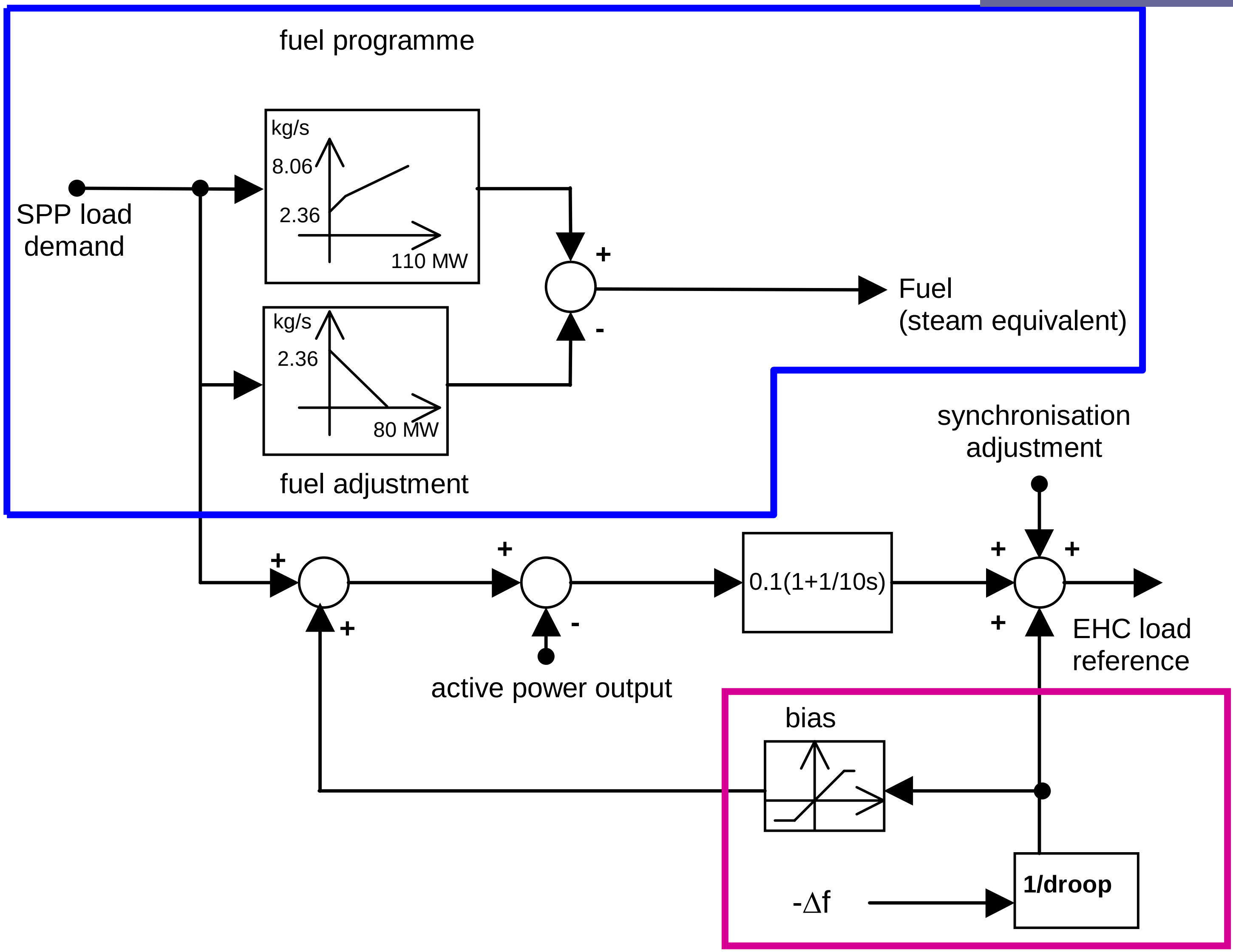
Steam turbine and electrohydraulic control

The simulator

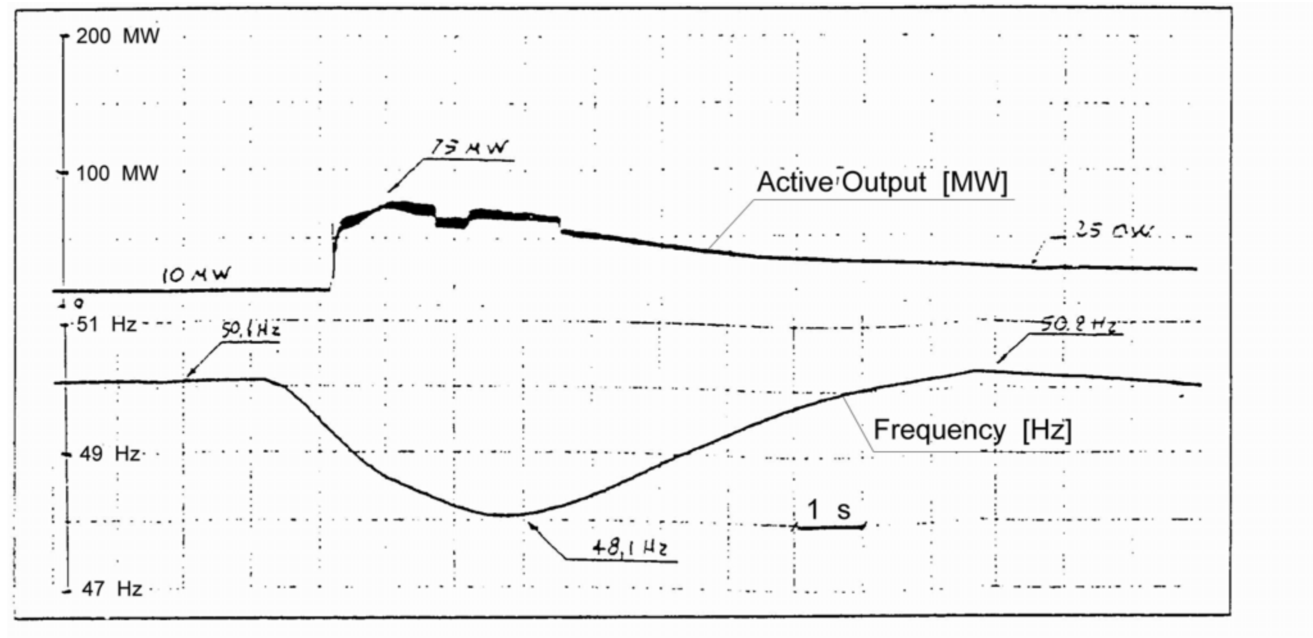


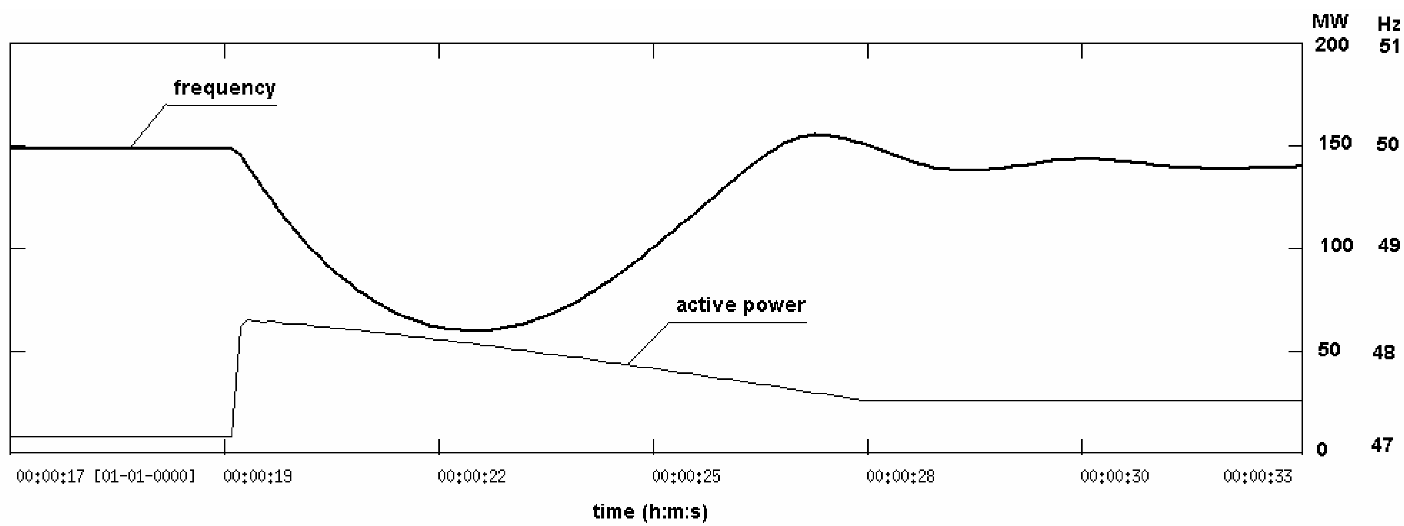
T_{pr} = 0,1 s pressure reg. time const.
T_{cv} = 0,8 s control valve time const.
T_{CH} = 0,15 s HP chest time const.
T_{RH} = 11 s RH time const.
T_{CO} = 0,4 s crossover time const.
y constant ($p_{rh,nom}$/$p_{ch,nom}$)
F_{hp} = 0,4 } fraction of total power generated
F_{lp} = 0,6 } by HP and LP sections

Start-up control mode



SPP model validation





Additional control system during restoration

TG: greater time constant between fuel and power

The power is immediately available

SPP smaller time contant between θamm and power

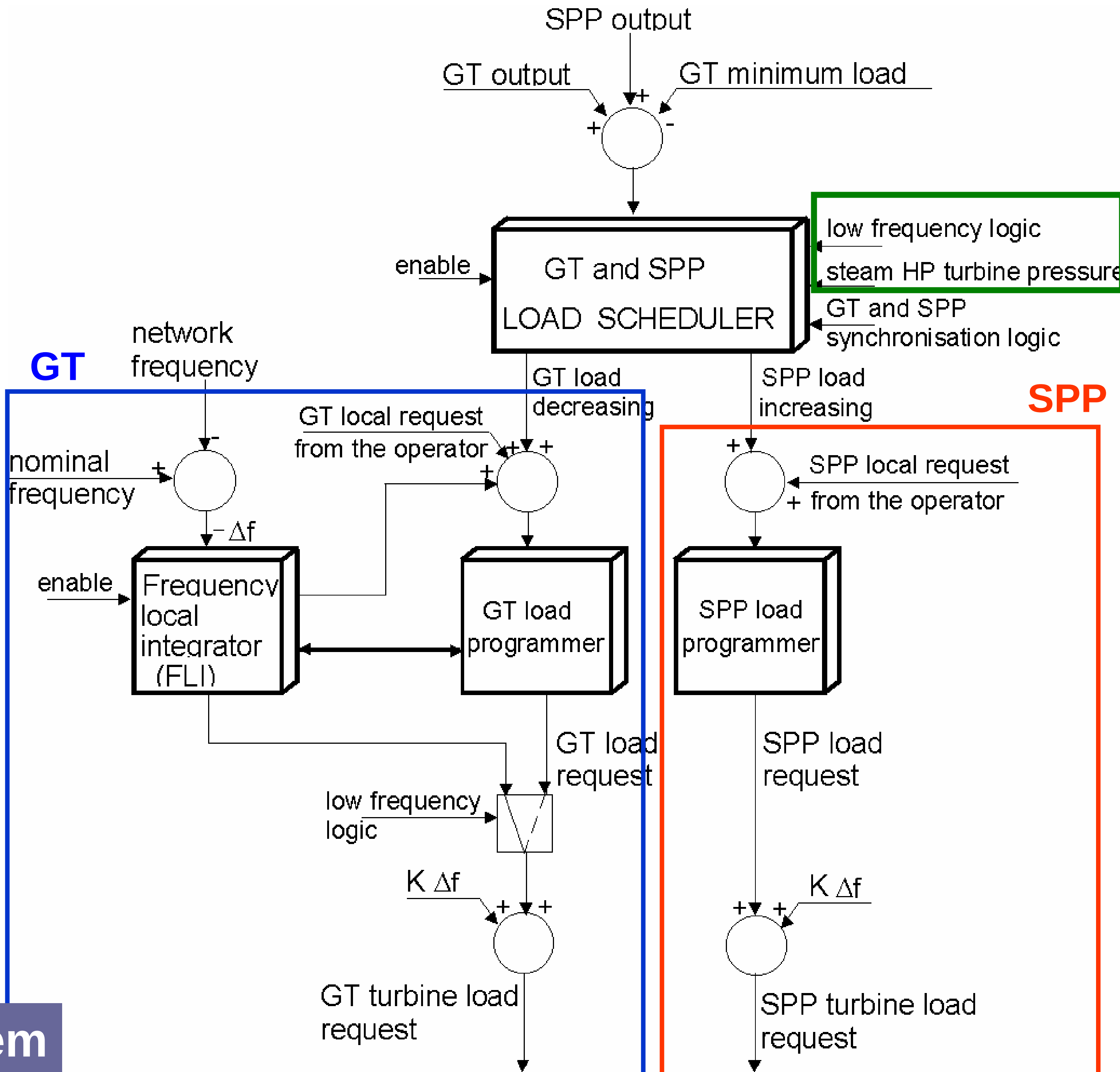
Great “inertia” between fuel and steam production

↓

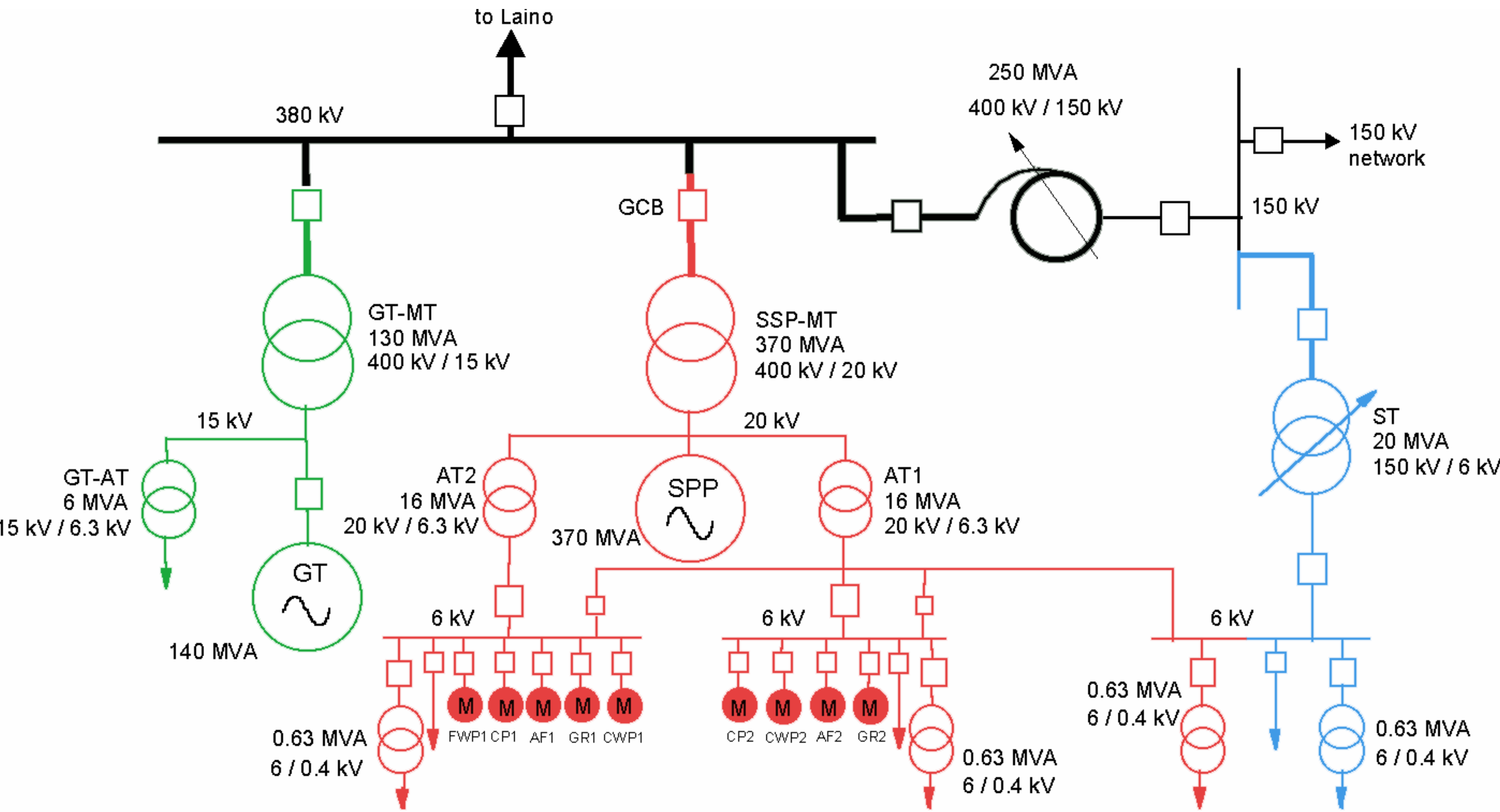
Using TG to take load rapidly and bring to zero the frequency error (FLI)

When frequency and boiler pressure are correct, unload TG in favor of SPP so that TG preserves enough margin for subsequent load connections

Additional control system during restoration



Auxiliaries' electrical system



Models of the auxiliaries

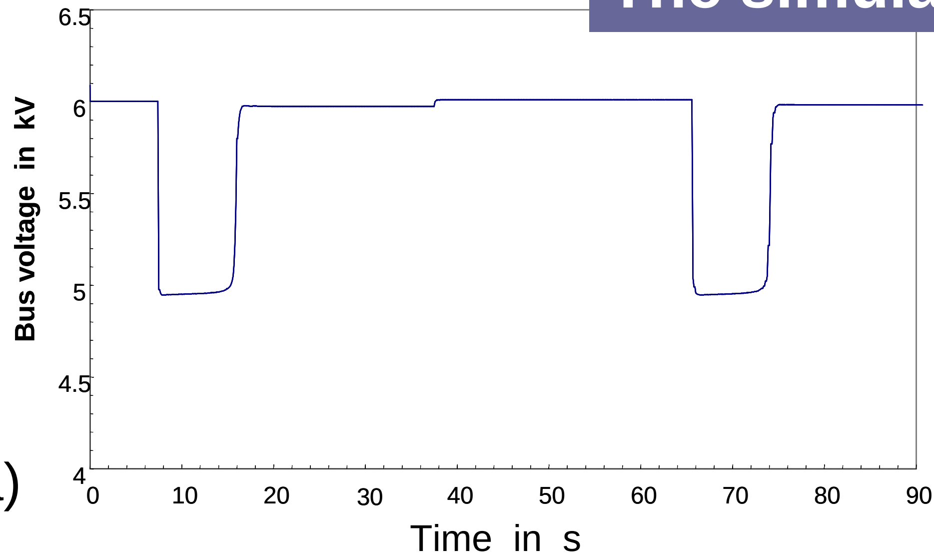
The simulator

Motors: 3 order model

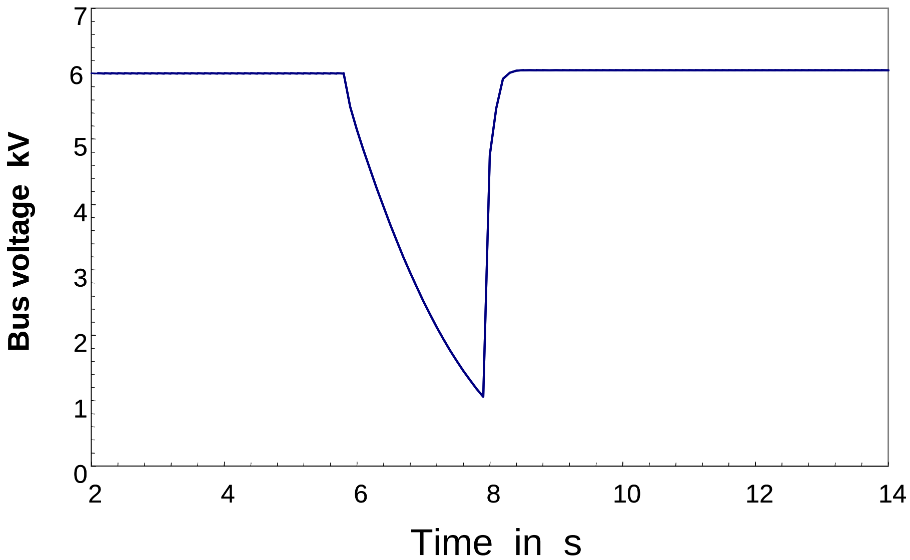
LV auxiliaries: static model

a) Start-up of 2 FW pumps

b) Residual voltage bus transfer

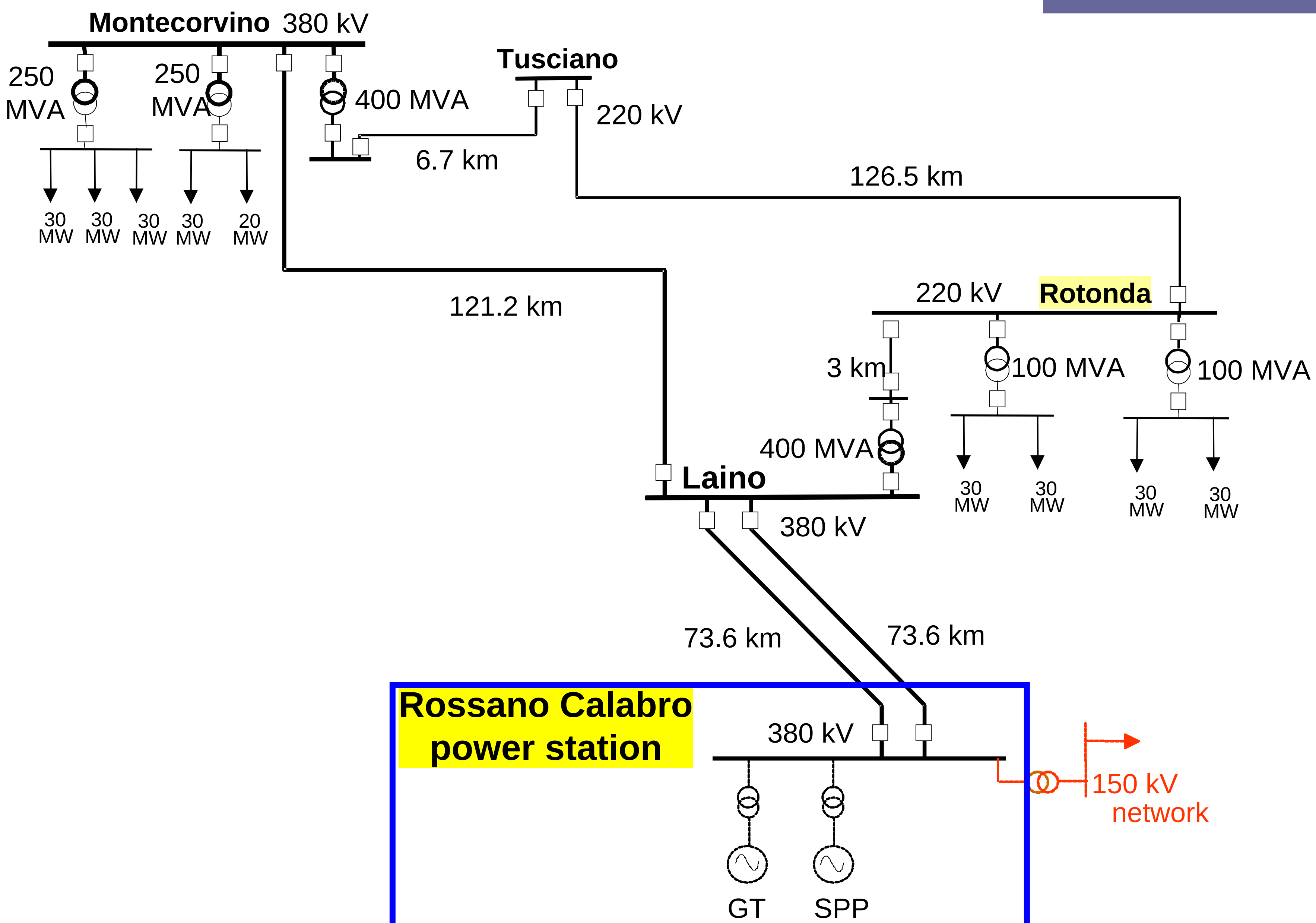


a)

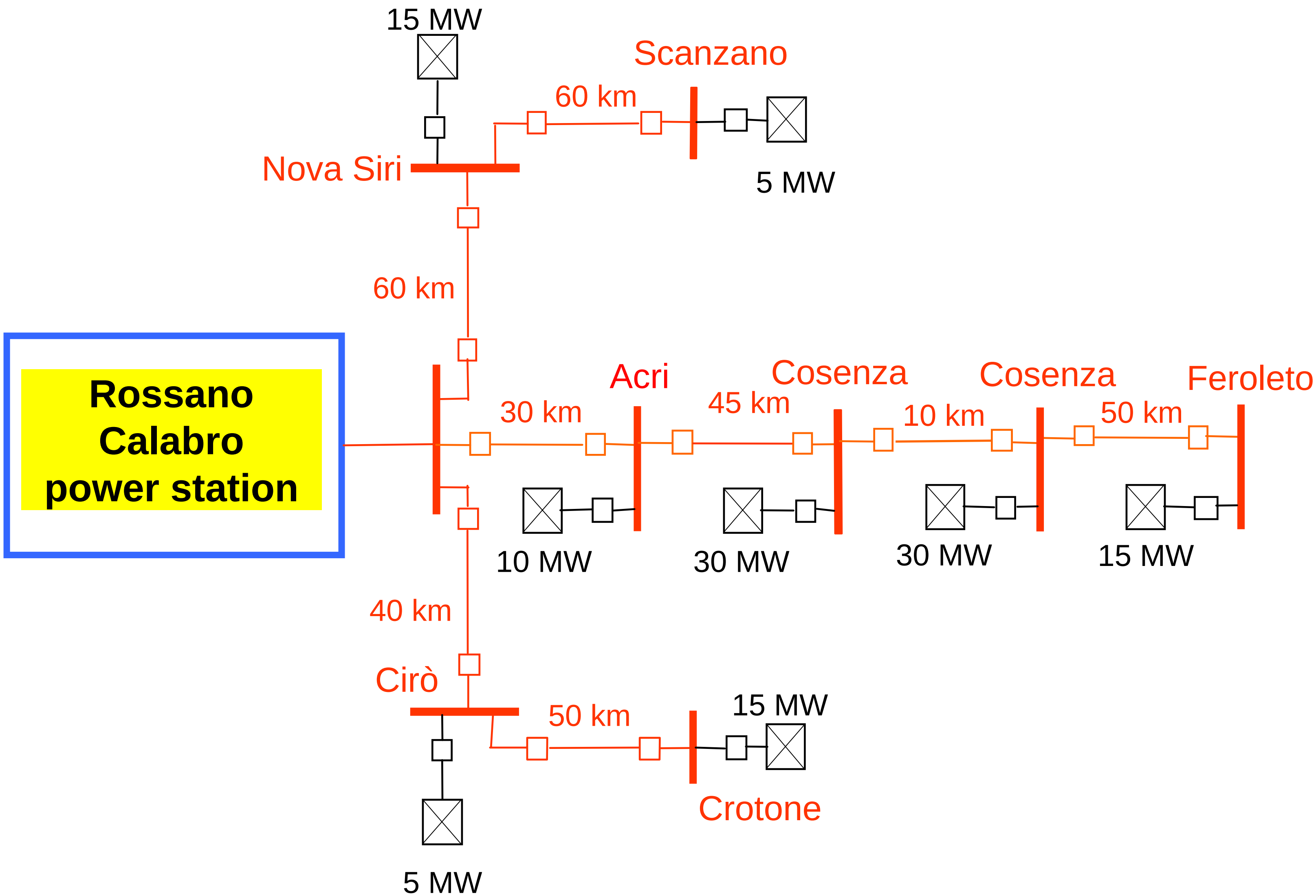


b)

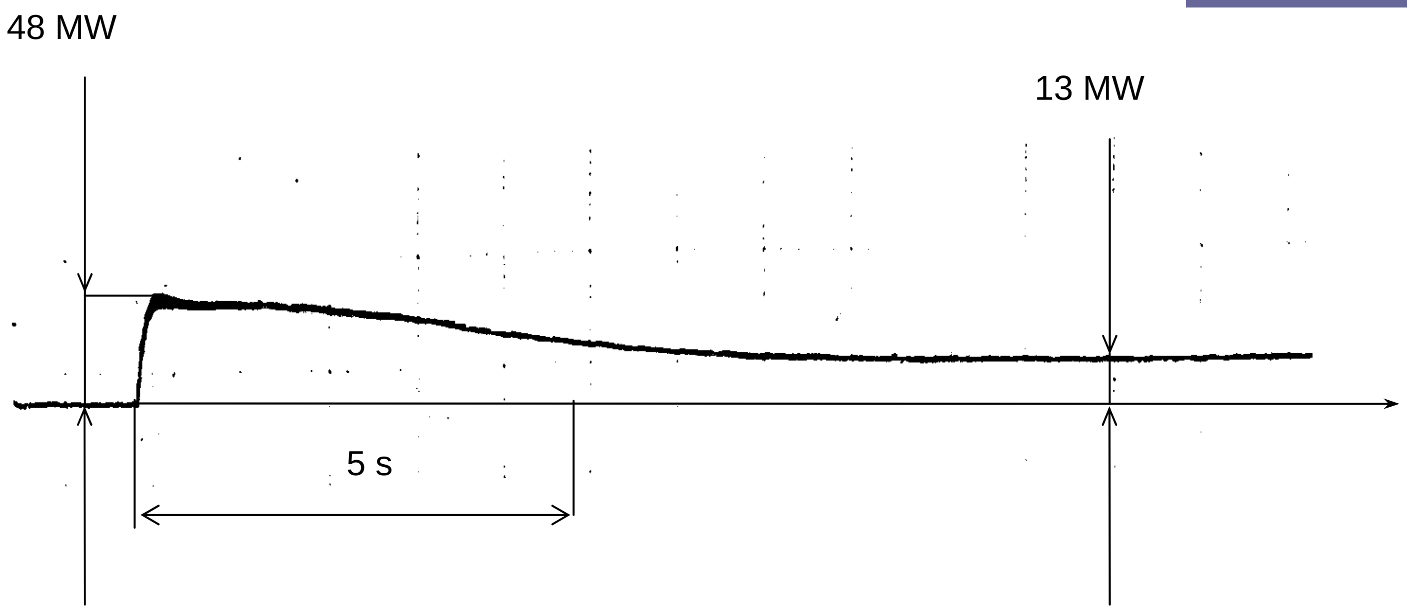
380/220 kV network near the power plant

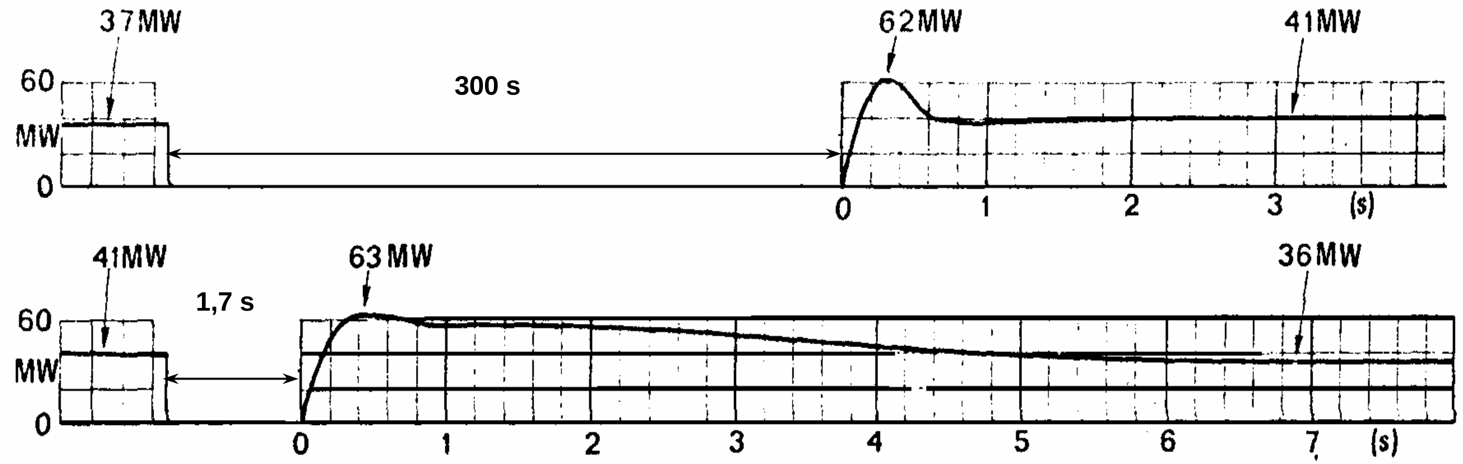


150 kV network near the power plant



Ballast load



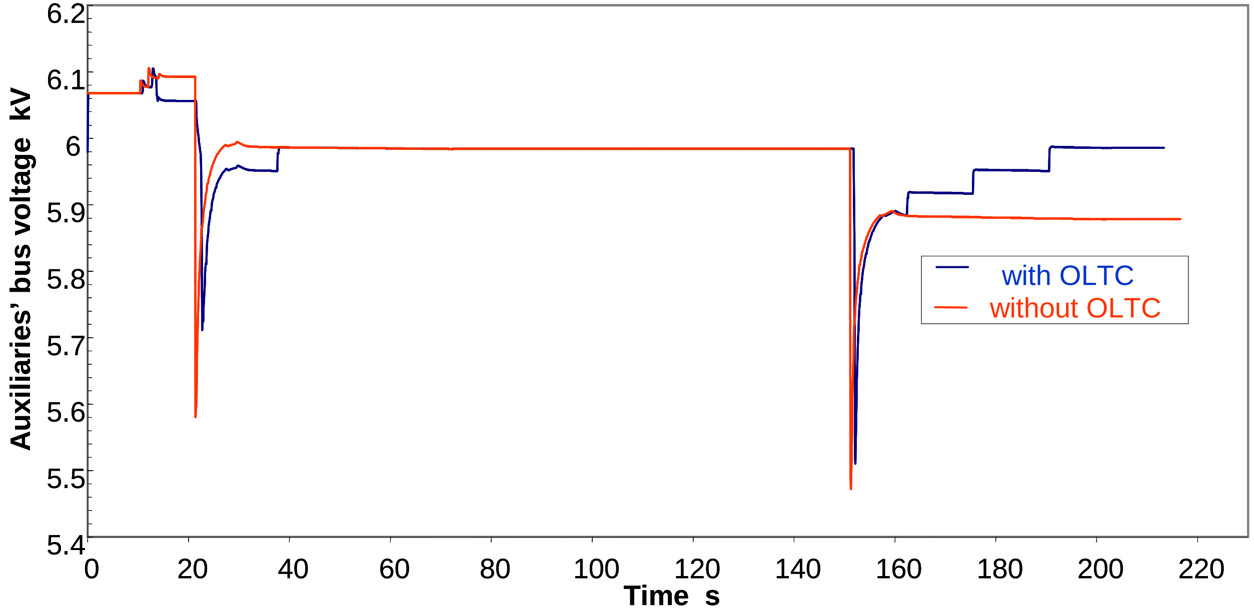


OLTC model

Discrete

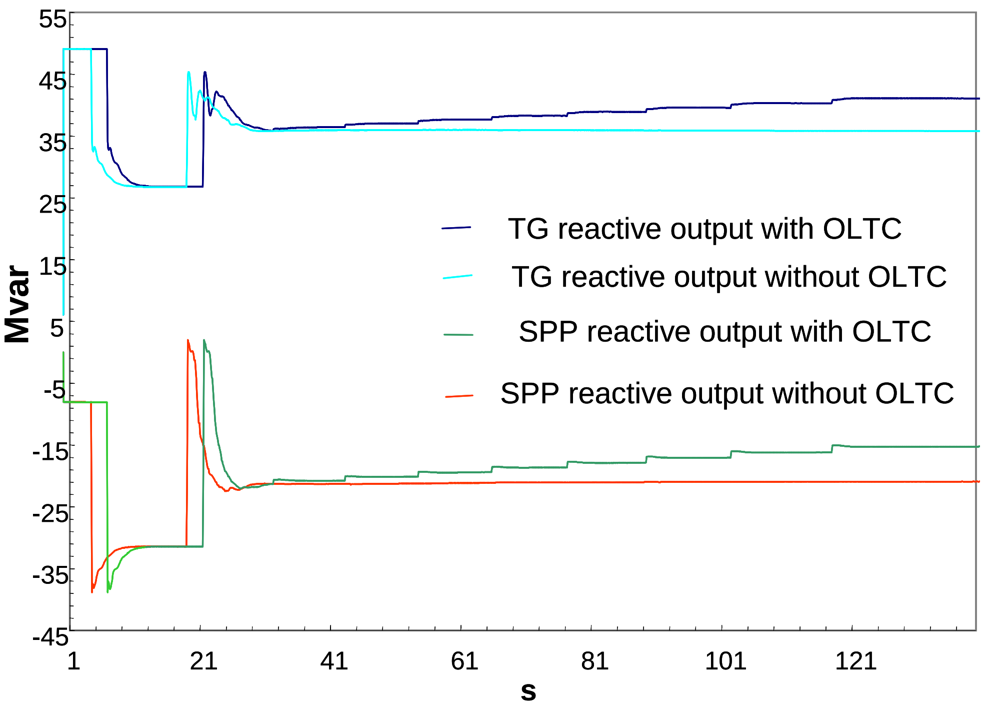
Inverse-time delay

a)



a) OLTC of the start-up transformer (±16; 0.625%)

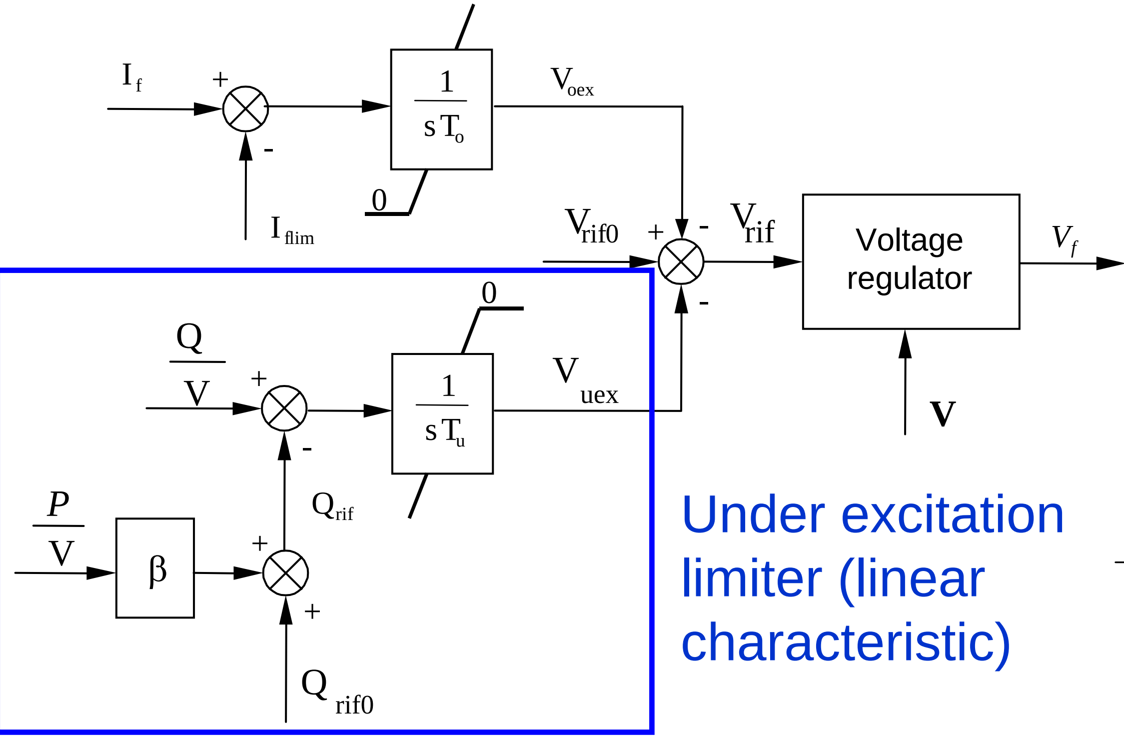
b) OLTC of Rotonda transformer (±8; 1.9%)

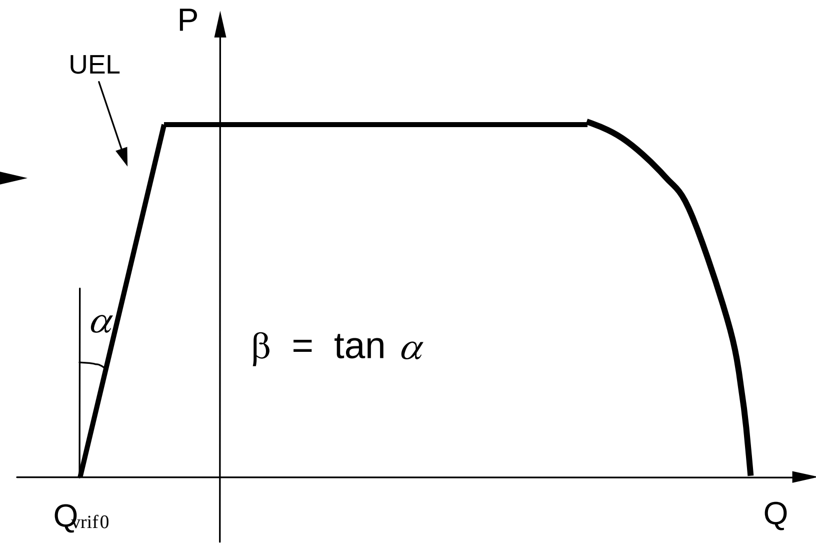


b)

The simulator

Model of the excitation limiters





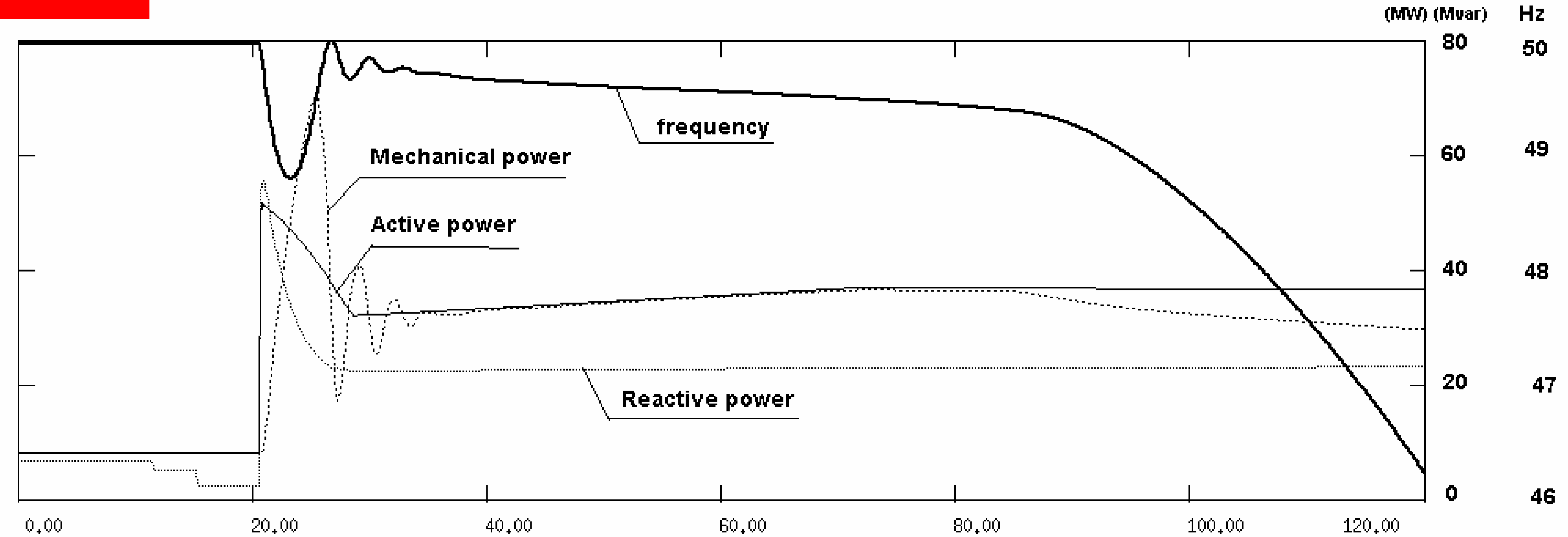
- Generators and power plant auxiliary system **protections**

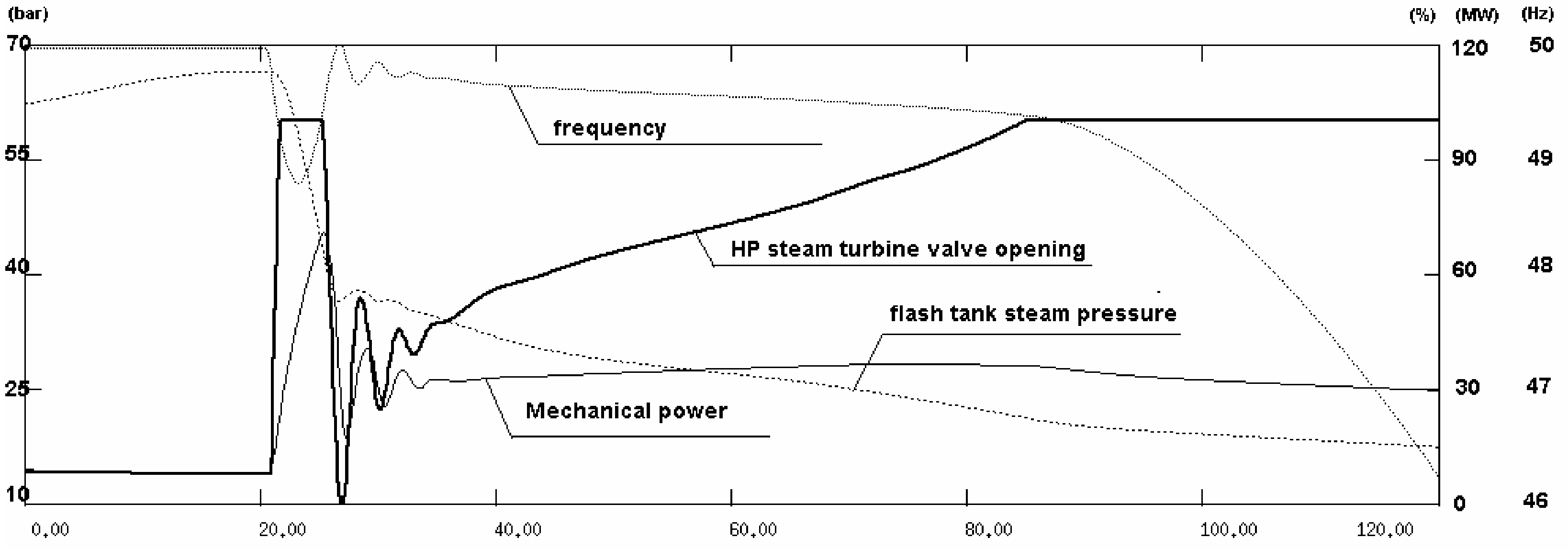
abnormal voltages and frequencies
loss of excitation
inadvertent energisation

Pick-up of a 30 MW load

simulations

SPP alone

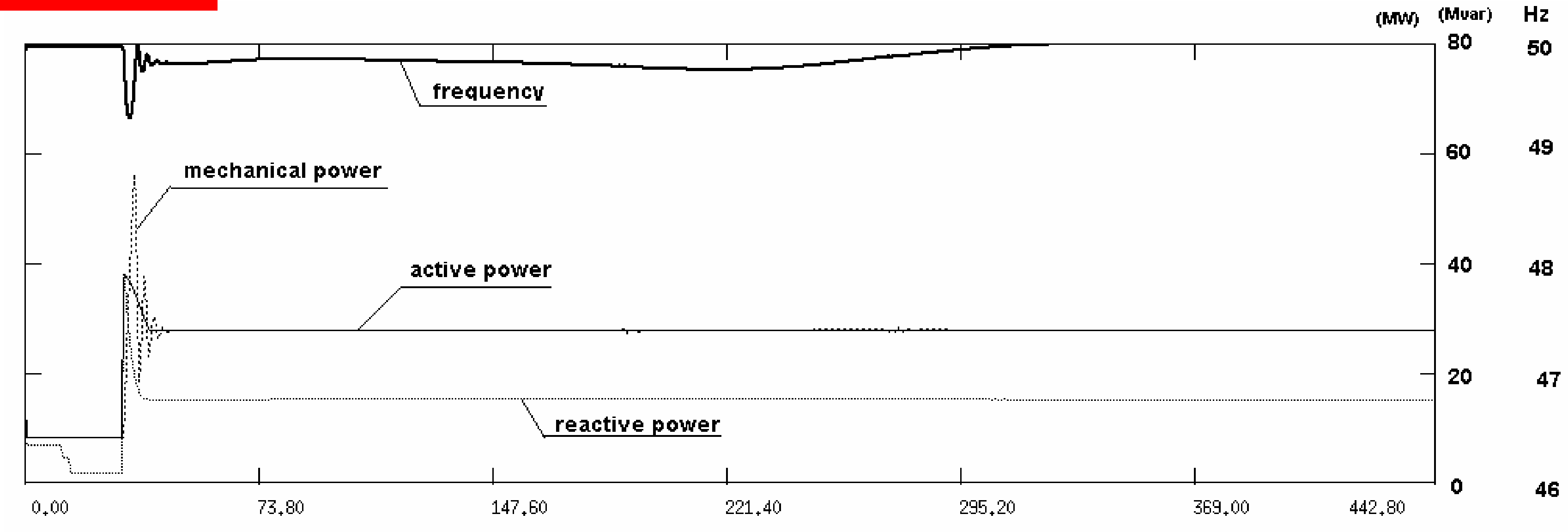


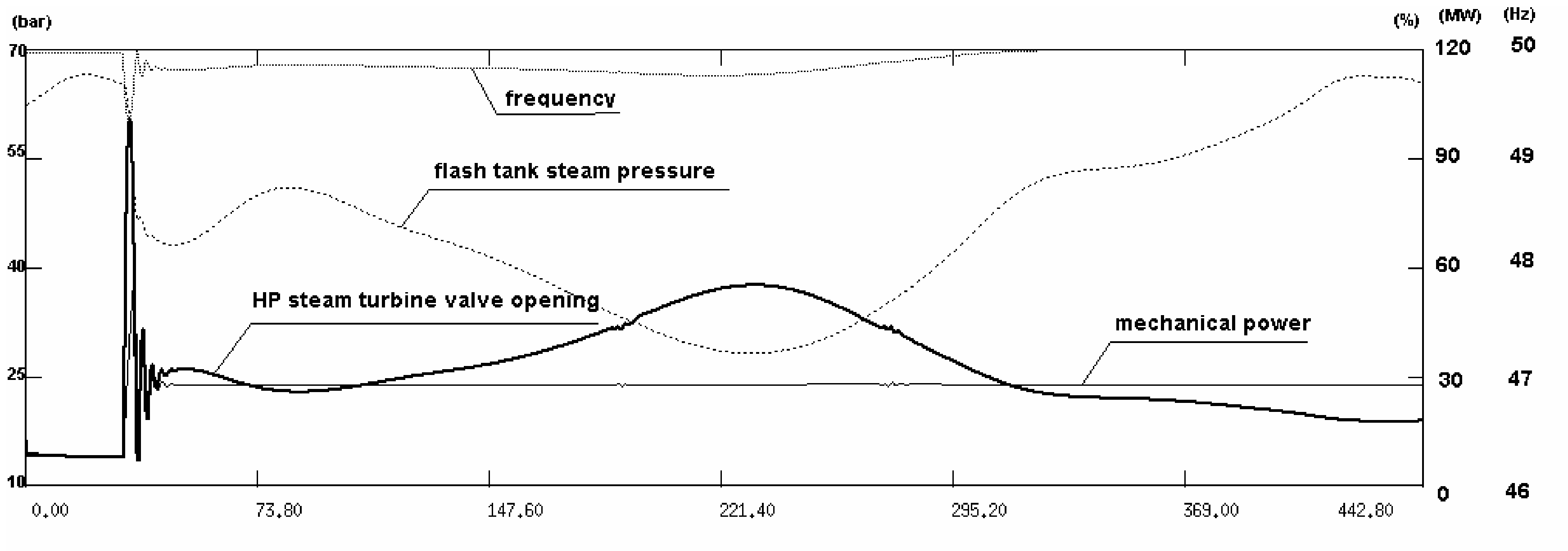


Pick-up of a 18 MW load

simulations

SPP alone



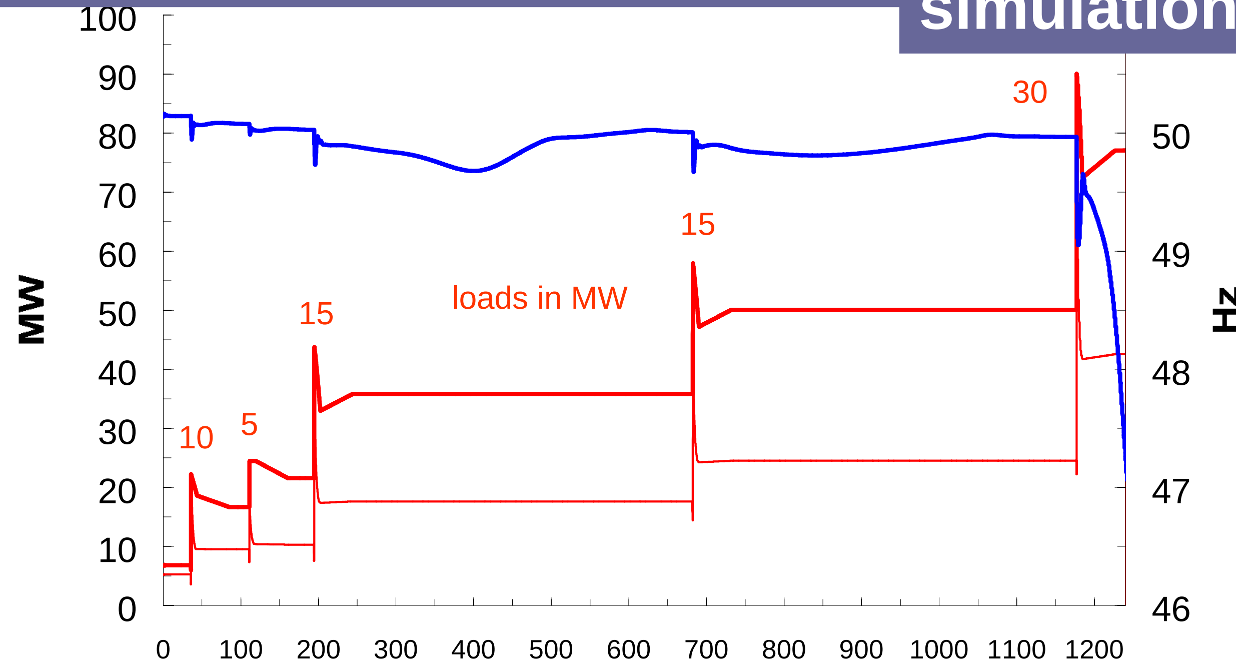


Pick-up of a 30 MW load
(after other four loads)

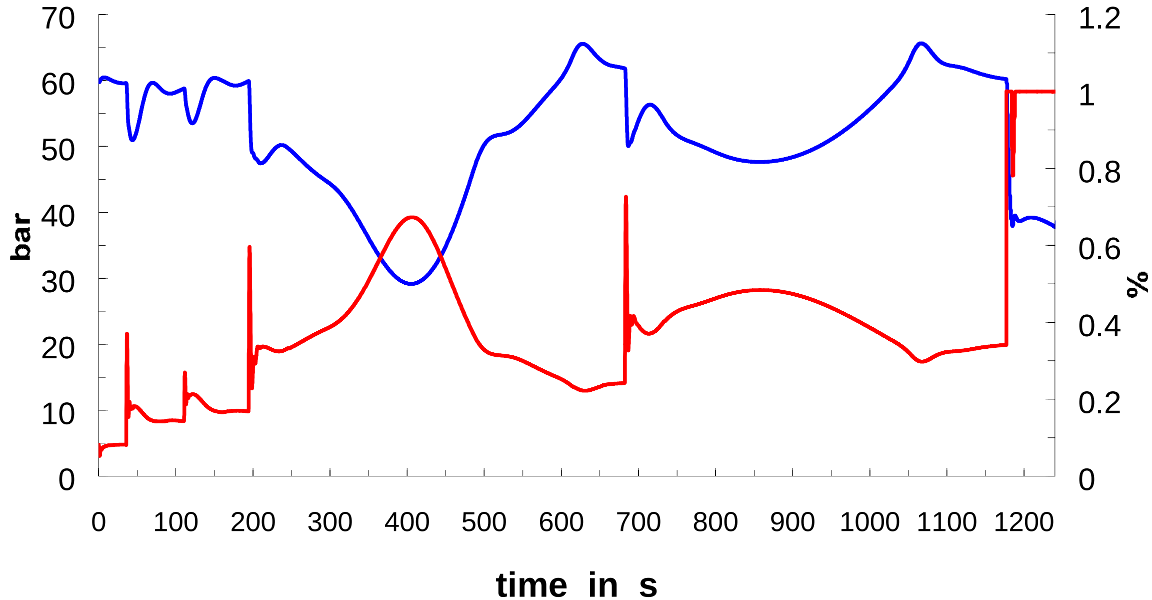
simulations

SPP alone

Frequency
and
SPP outputs



Control valve position
and
FT pressure

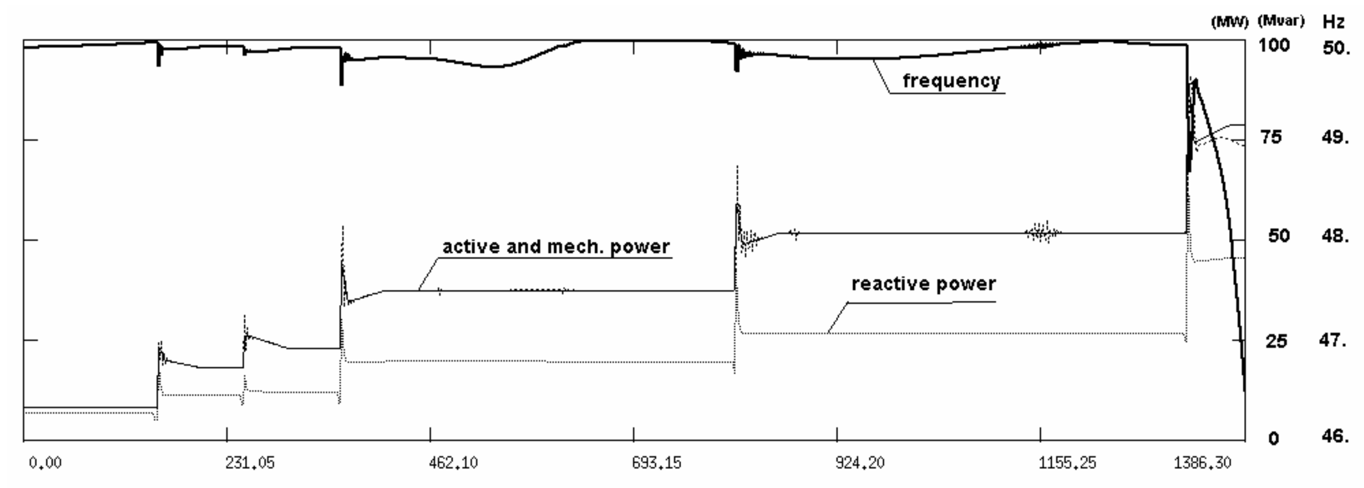


Pick-up of a 30 MW load
(after other four loads)

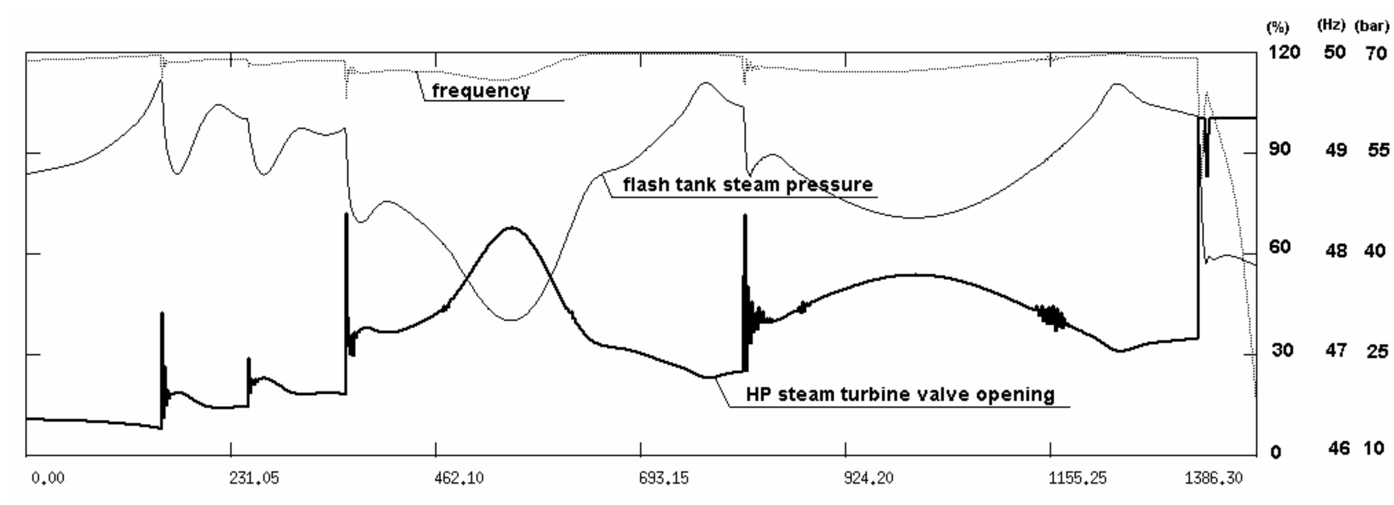
simulations

SPP alone

Frequency
and
SPP outputs



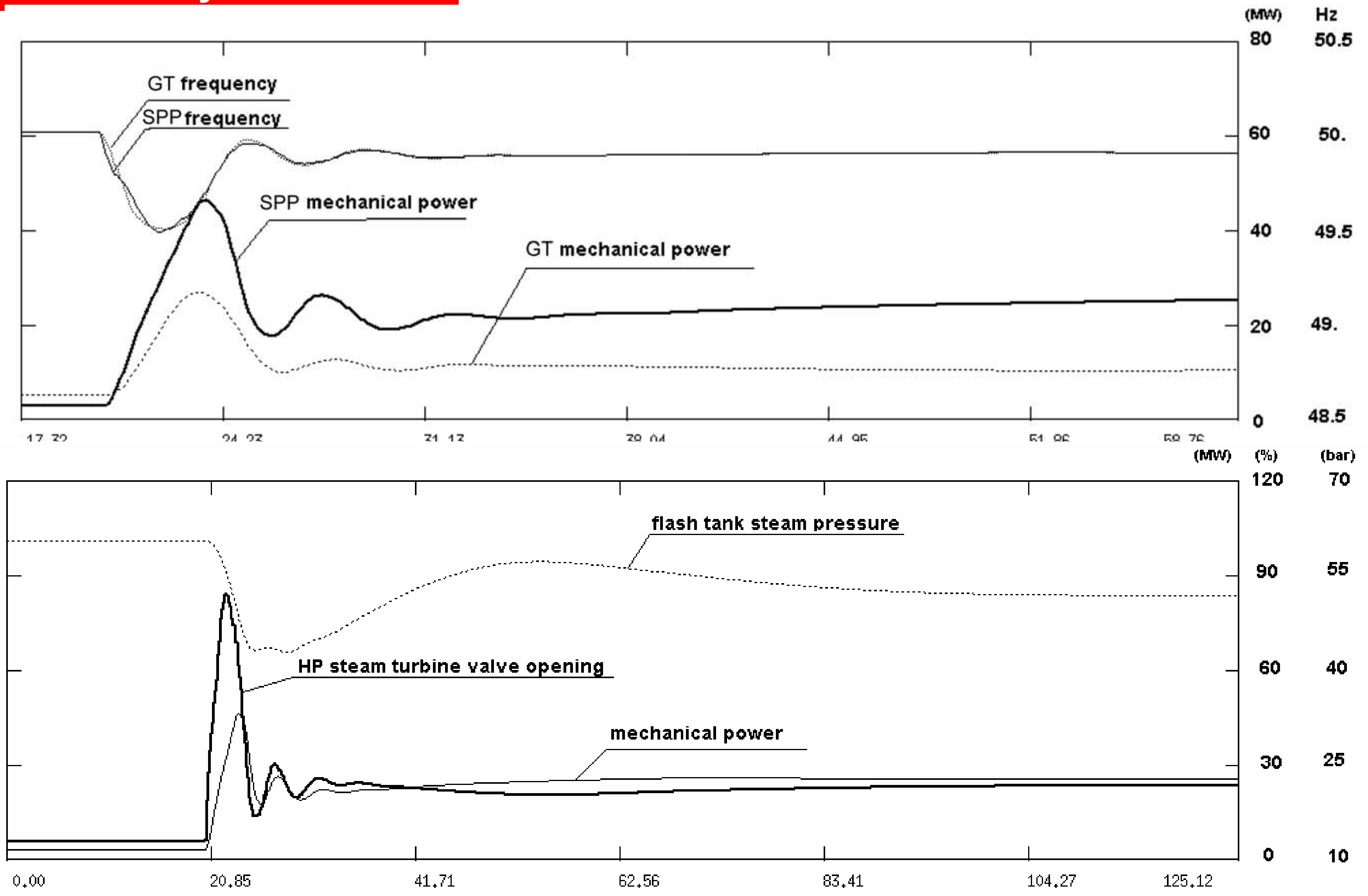
Control valve
position
and
FT pressure



Pick-up of a 30 MW load

simulations

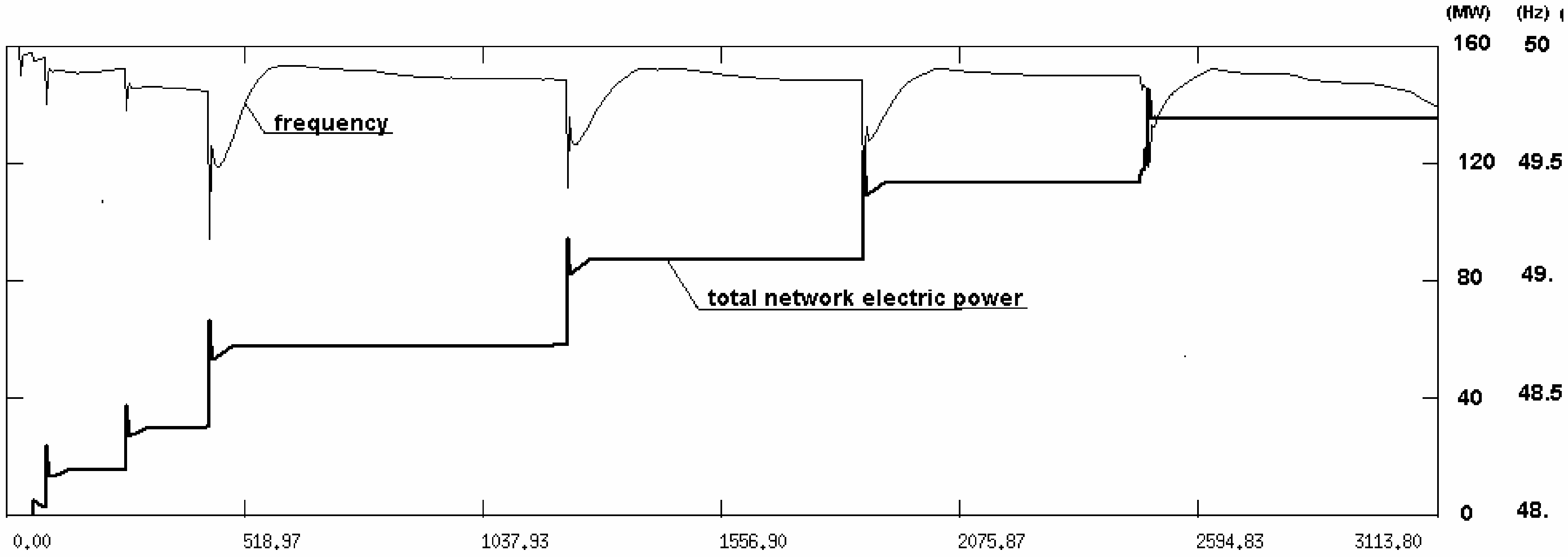
SPP and GT synchronized



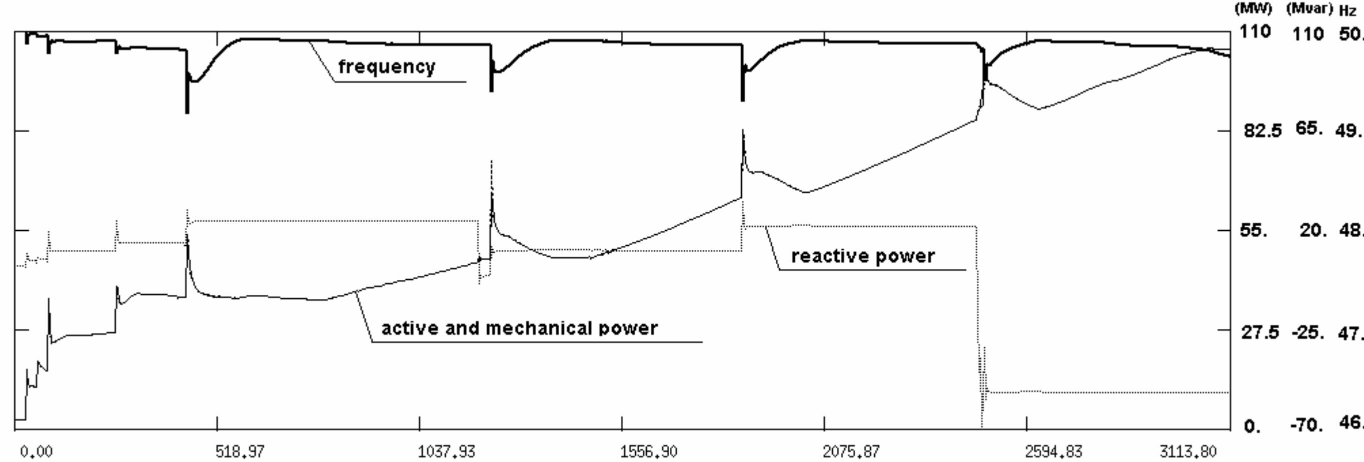
Power plant ramping

simulations

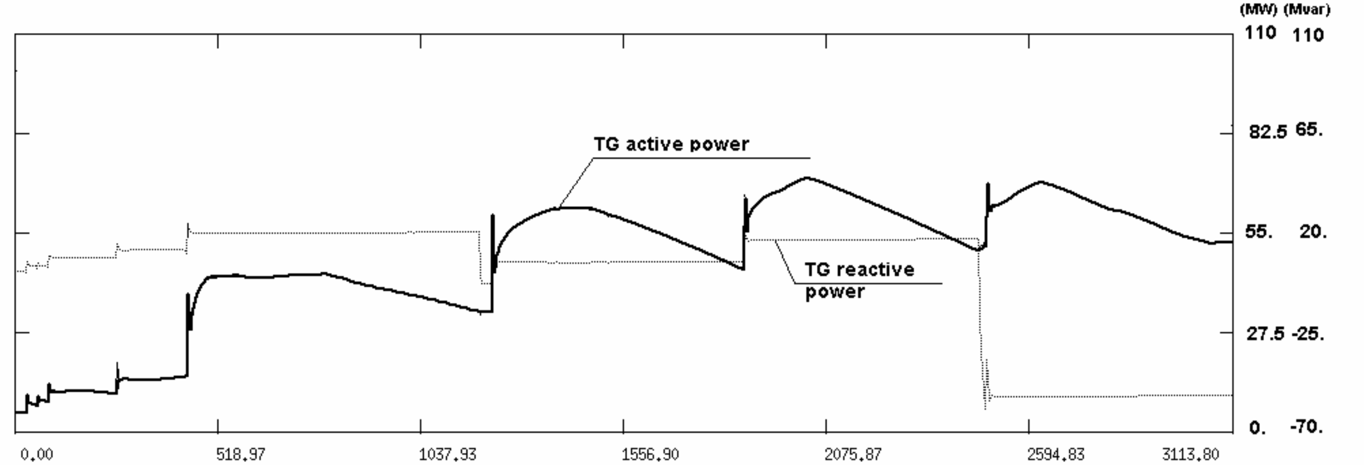
SPP and GT synchronized



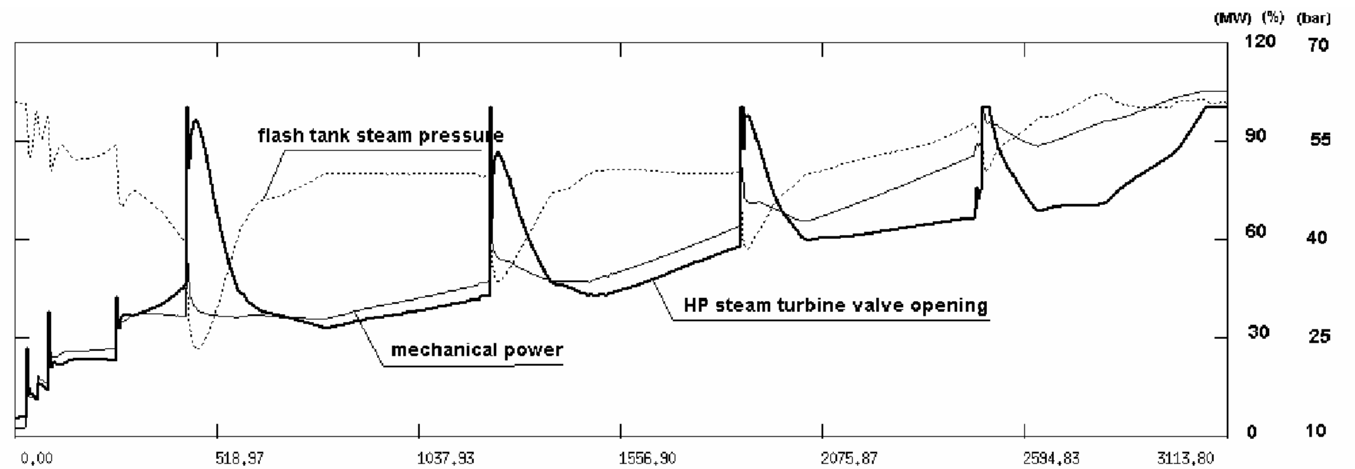
Frequency
and
SPP outputs



GT outputs



Control valve
position
and
FT pressure



Conclusions

The study carried out has shown that

- The GT section can effectively help the SPP section under the start-up and ramping phases
- A load scheduler control system is crucial to coordinate the load requests to the GT and the SPP generators during the manoeuvre
- The repowered thermoelectric power unit can therefore assume the role of "early-restoration plant“.