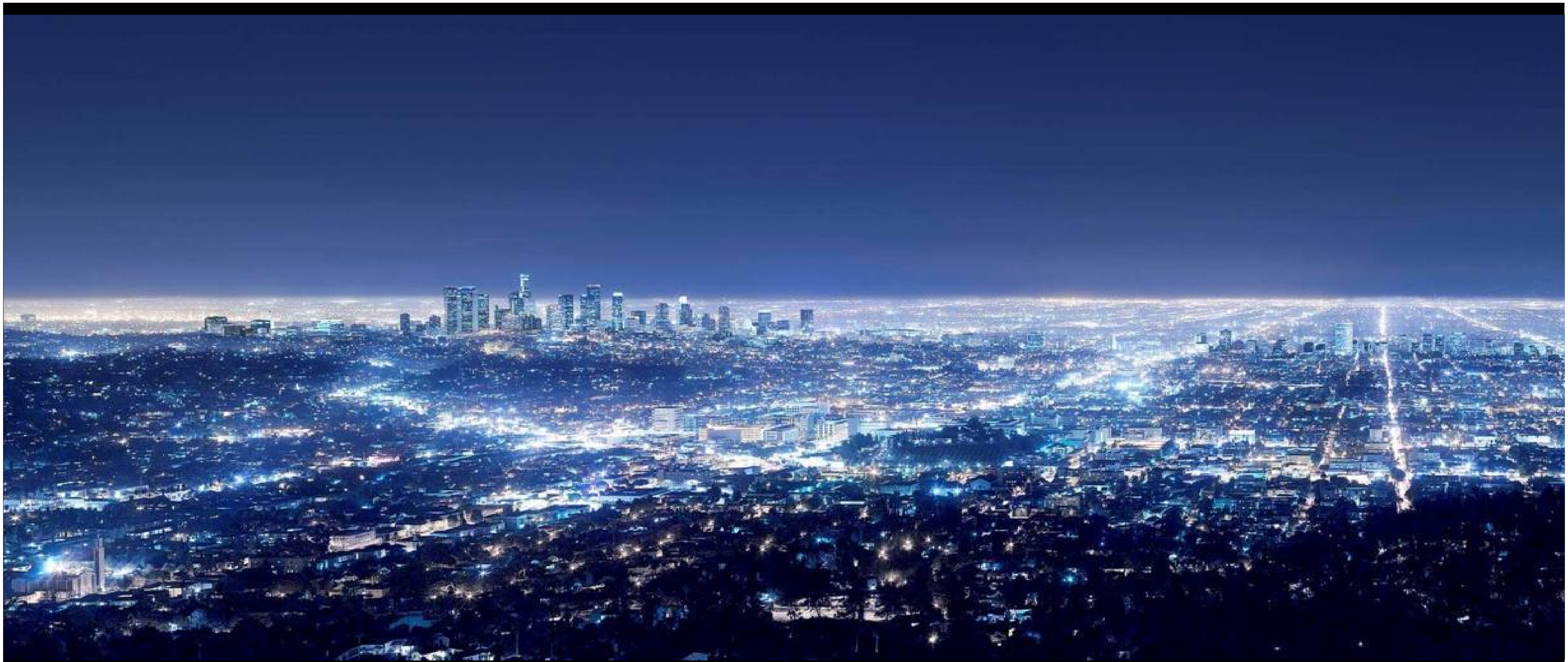

Feb 2014

APC in the Italian Energy Market

Coordination of multiple refinery utilities to implement optimal power plan

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Presentation Agenda

- Introduction
  - Italian Energy Market - 'MSD'
  - Site utilities configuration
- Application basis
  - Objectives
  - Architecture
- Implementation
  - Production Plan Management System
  - DCS strategy
  - APC
  - Challenges

ABB

Electrical Grid basics

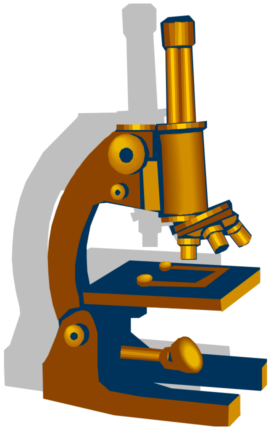
- Power Production must match Power usage at all times to preserve frequency stability
- Grid management trim Power Production continuously to achieve balance, 24x7
- Changes are due not only to changes in demand but also to production changes from high priority supplies e.g. wind, solar

- Power producers able to implement real-time control of energy following Grid dispatch requests have a price premium e.g. MSD market
- Power producers that cannot implement real-time control sell at ordinary, lower price e.g. MGP market

Italian Energy Market - ‘MSD’ brief concepts

Grid requirements: provide various energy contributions:

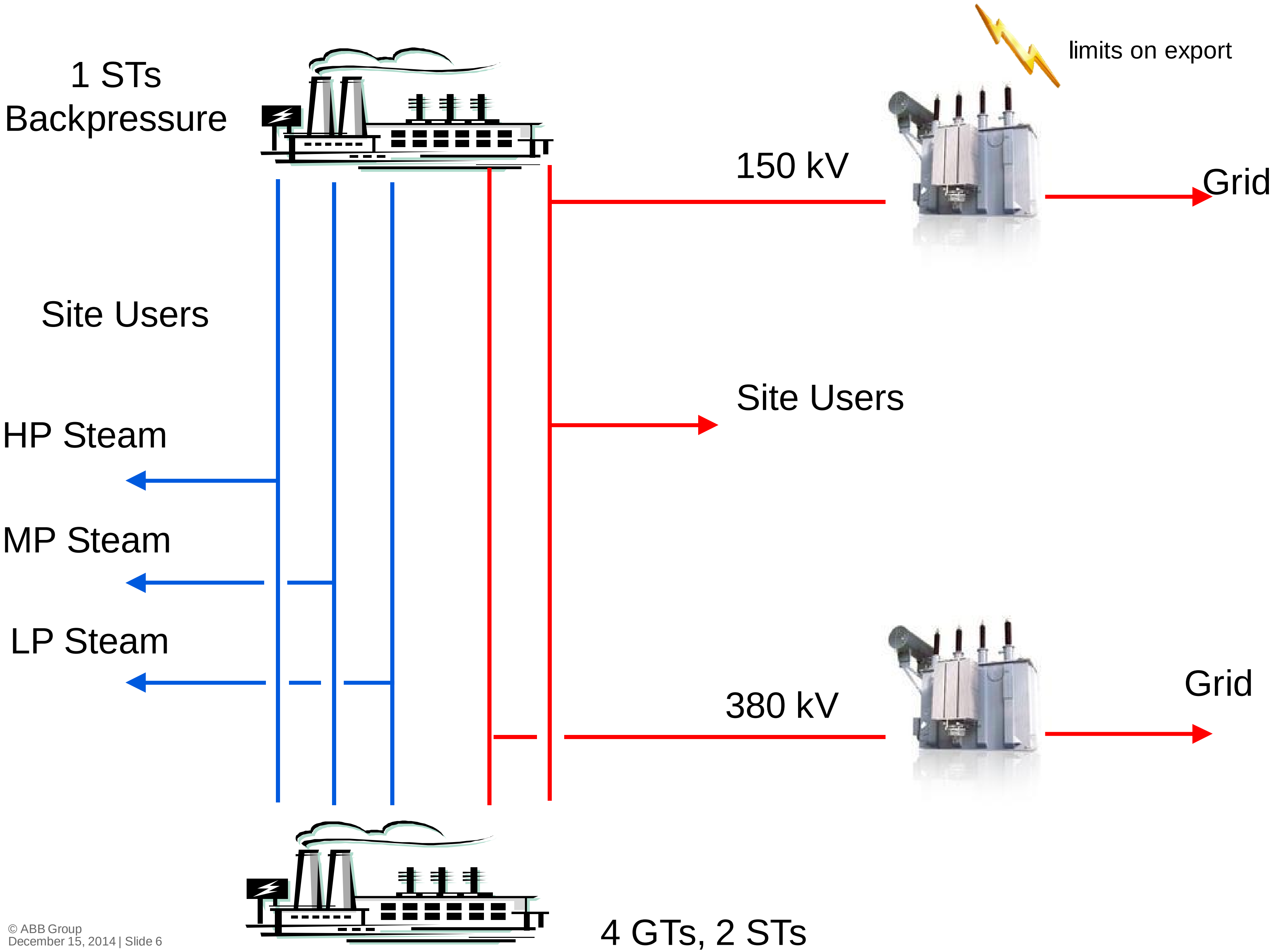
- Primary contribution: direct GT response to frequency changes, timeframe tens of seconds
- Secondary contribution: quick changes in energy production following direct request from grid control via RTU connected to DCS; request comes as a real-time trim signal applied to a contractually agreed plant max contribution
- Tertiary contribution: periodic changes (every 15 minutes) in energy production following a schedule approved by grid and available to open market bid/sale.



Site status

- Two twin combined cycles, 4 GTs, 2 ST with steam export to site users (refinery, petrochem site), 480 MW
- Backpressure FG/FO fired plant, production of max 48 MW.
- Complex site, with strong usage of steam and power (~70 MW, 200 t/h of steam)
- Three levels of steam (HP, MP and BP), combined cycles and backpressure units connected to all steam headers
- Need to access to MSD market while preserving steam/energy supply - quality and reliability

Site utilities configuration



Site overall objectives

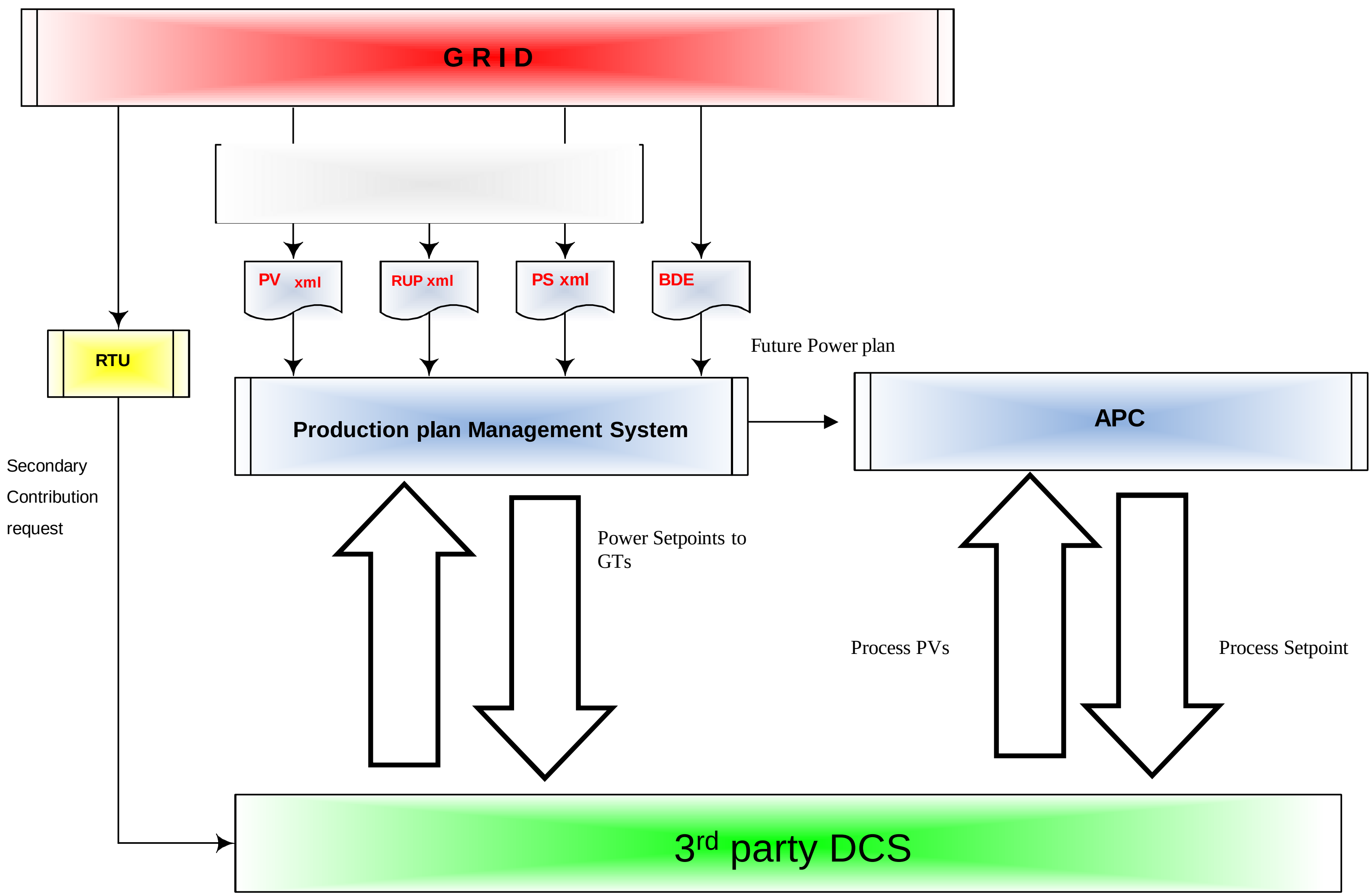
- Satisfy site requests for steam and energy, maintain steam headers quality
- When energy price is high, take advantage of available power - maximize production of backpressure plant so to maximize export and profits
- When energy price is low, minimize production of backpressure plant so to minimize production costs
- In all cases, trim backpressure plant so to satisfy production with minimum production cost

Multiple time-horizons

- Primary contribution implementation – GT level
- Secondary contribution implementation – DCS level & Production Plan Management software
- Tertiary contribution implementation – need to coordinate multiple plant loads
- Optimization

- Need to have multiple automation layers running with objectives set on very different time horizons – from seconds to an hour

Control architecture



Control architecture – layered approach (1/2)

- DCS control layer to
  - Control total current production by moving all GTs, considering Hi/Lo limits and saturation
  - Provide response to secondary contribution changes via RTU
- Production Plan Management System able to:
  - Compute energy production over 15 m interval
  - Control/compensate energy imbalances
  - Process Grid plan messages
  - Present detailed HMI related to production plans
  - Store plans production data for monitoring and accounting purposes

Control architecture – layered approach (2/2)

- APC Layer to:
  - Maintain limits on power export (limits on two separate export lines, 150 and 400 kV)
  - Maintain pressure and pressure control ability
  - Maintain GTs margins, both current and future
  - Optimize cogen/backpressure balance to minimize costs
  - Keep process values within constraints

Production Plan Management

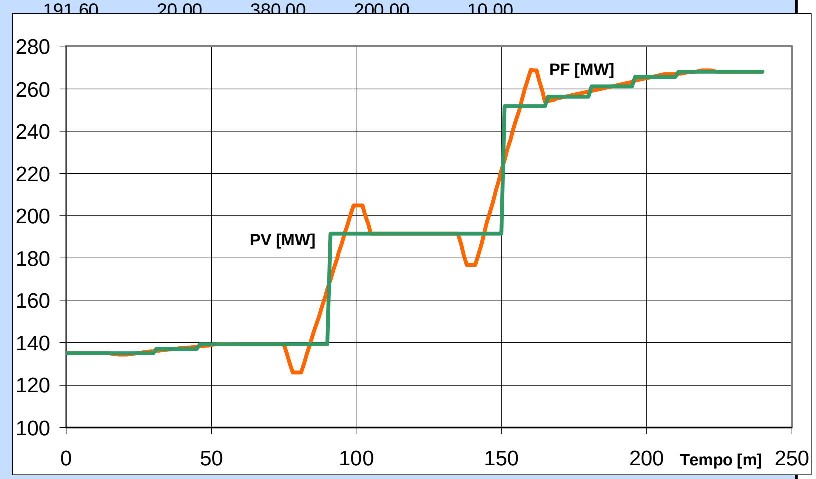
- Receives Power Plan from Grid before midnight and handles any update requests (BDE)
- Computes feasible Power Plan in MW from Grid ideal Power Plan, considering secondary band, RUP and practical physical limitations.
- Minimize difference between realistic and ideal Power Plan (integral over time) subject to Min/Max power limits and max ramp rates.
- The computed plan is then passed to the DCS for implementation.
- Real-time assessment of actual energy exchange is performed.
- Real time compensation of any deviation from the planned Power Plan is implemented by the DCS
- SAPP software from ABB

INPUT DATA

Orario	Min	PV GRTN [MWh]	Potenza media GRTN [MW]	Semi banda [MW]	Pmax [MW]	Pmin [MW]	Grad Max [MW/min]
5.45	0.00	33.75	135.00	20.00	380.00	200.00	10.00
6.00	15.00	33.75	135.00	20.00	380.00	200.00	10.00
6.15	30.00	34.26	137.05	20.00	380.00	200.00	10.00
6.30	45.00	34.78	139.10	20.00	380.00	200.00	10.00
6.45	60.00	34.78	139.10	20.00	380.00	200.00	10.00
7.00	75.00	34.78	139.10	20.00	380.00	200.00	10.00
7.15	90.00	47.90	191.60	20.00	380.00	200.00	10.00
7.30	105.00	47.90	191.60	20.00	380.00	200.00	10.00
7.45	120.00	47.90	191.60	20.00	380.00	200.00	10.00
8.00	135.00	47.90	191.60	20.00	380.00	200.00	10.00
8.15	150.00	62.90					
8.30	165.00	64.07					
8.45	180.00	65.24					
9.00	195.00	66.42					
9.15	210.00	67.00					
9.30	225.00	67.00					

OUTPUT DATA

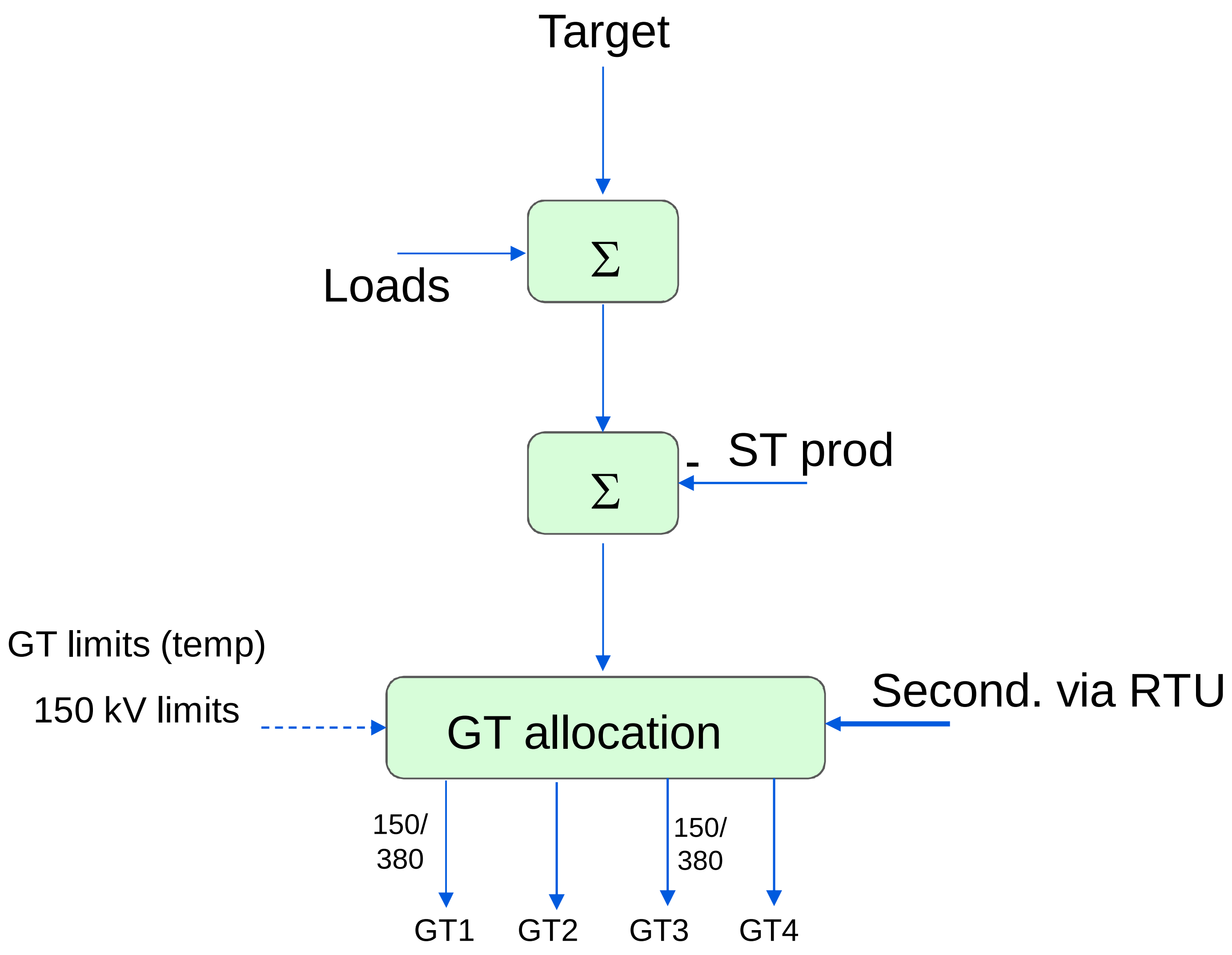
Min	PF [MW]
0.00	135.00
1.00	135.00
2.00	135.00
3.00	135.00
4.00	135.00
5.00	135.00
6.00	135.00
7.00	135.00
8.00	135.00
9.00	135.00
10.00	135.00



Power Plan Management – Client View

- Real time view of Power Plan implementation
- Ideal and Feasible Plan
- Real time compensation of energy unbalances compared to plan
- Can see changes in plant capability due to e.g. external temperature
- SAPP client

DCS Control strategy



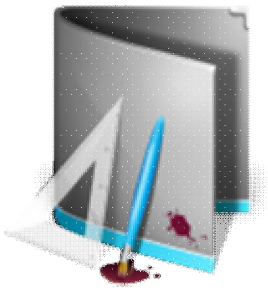
APC Design basics (1/2)

- Main CVs
  - Power Net Export (150 Kv transformer)
  - Power Net Export (380 Kv transformer)
  - Backpressure plant physical limits, e.g. ST temp
  - MP steam header pressure
  - LP steam header pressure
  - GTs – avoid saturation
  - Various actuators - avoid saturation

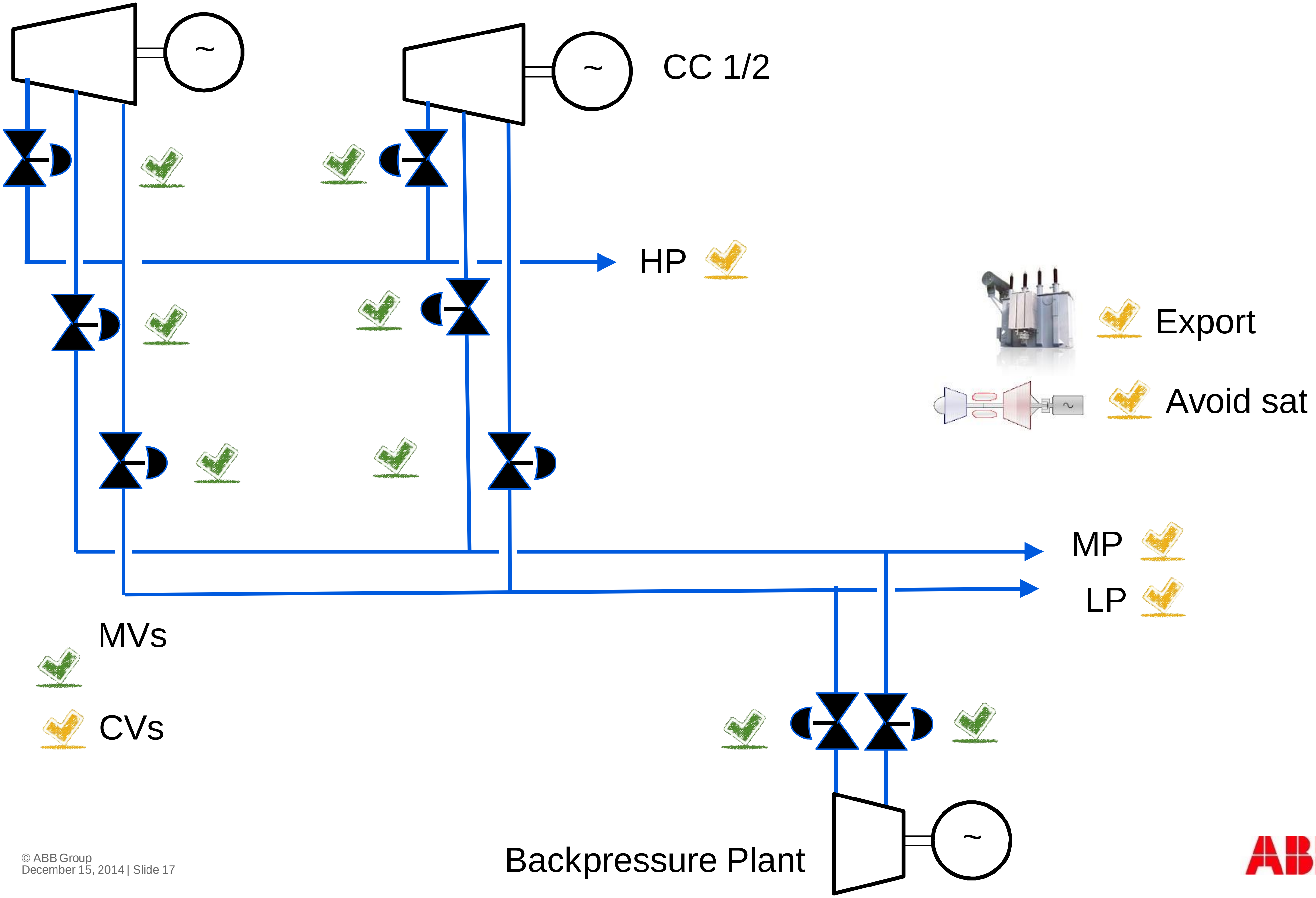
  - Minimize Backpressure plant production when possible (both limit and LP)

APC Design basics (2/2)

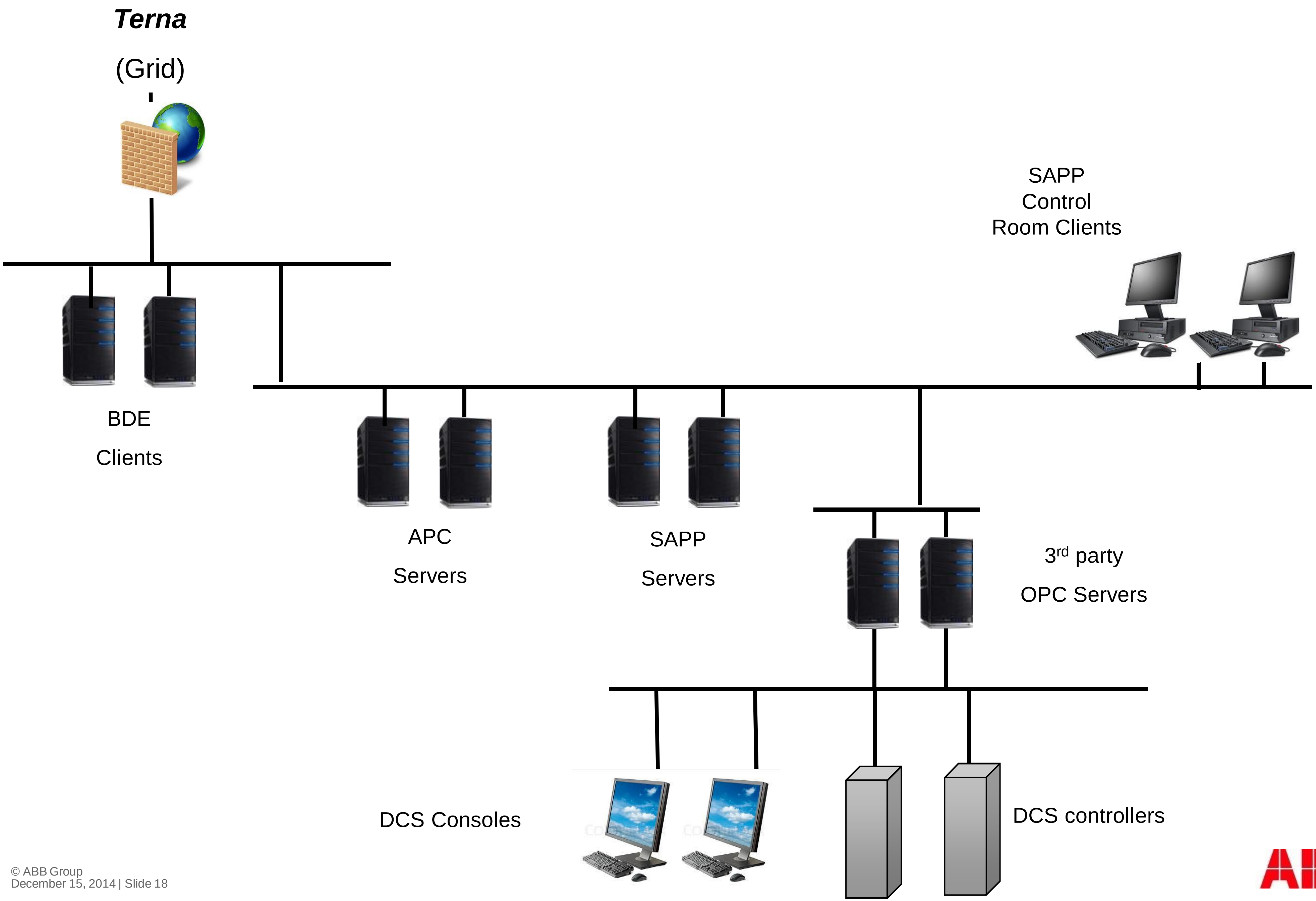
- Main MVs
  - CC1 and CC2 HP steam draws
  - CC2 and CC2 MP steam draws
  - CC1 and CC2 LP steam draws
  - BP HP steam draw
  - BP MP steam draw
  - BP LP steam draw
  - CC1 and CC2 ST inlet pressure MP



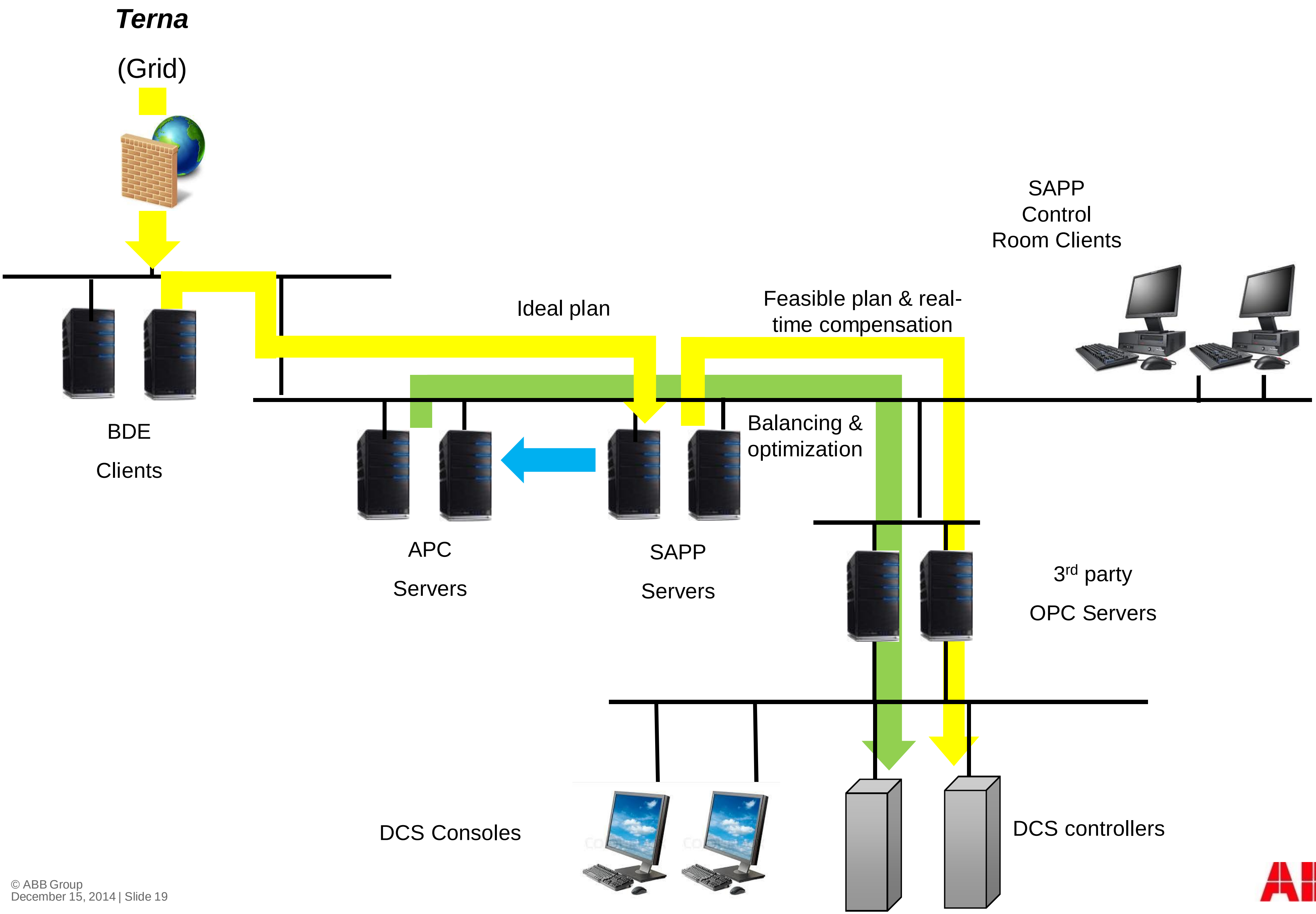
APC main variables



System Architecture



System Architecture – Information flow



Project challenges - schedule

- Project execution in 5 months (award to end commissioning)
- Multiple parties involved – DCS automation from 3rd party. ABB designed DCS schemes, designed and implemented Power Plant Management layer and APC
- Challenging implementation schedule and environment: this project was part of multiple implementation packages executed by the customer between March and Sept 2011 – ranging from DCS upgrade to IT and telecom infrastructure setup. Delays on APC would have made impossible to deliver the complete solution.

Generator interconnection changes

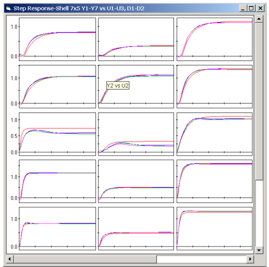
Generator interconnections to 150 kV/380 kV may and will change over time e.g. due to maintenance.

Typically, 3 generators are kept on 150 kV. Table lists possible connections to 150 kV, all others to 380 kV.

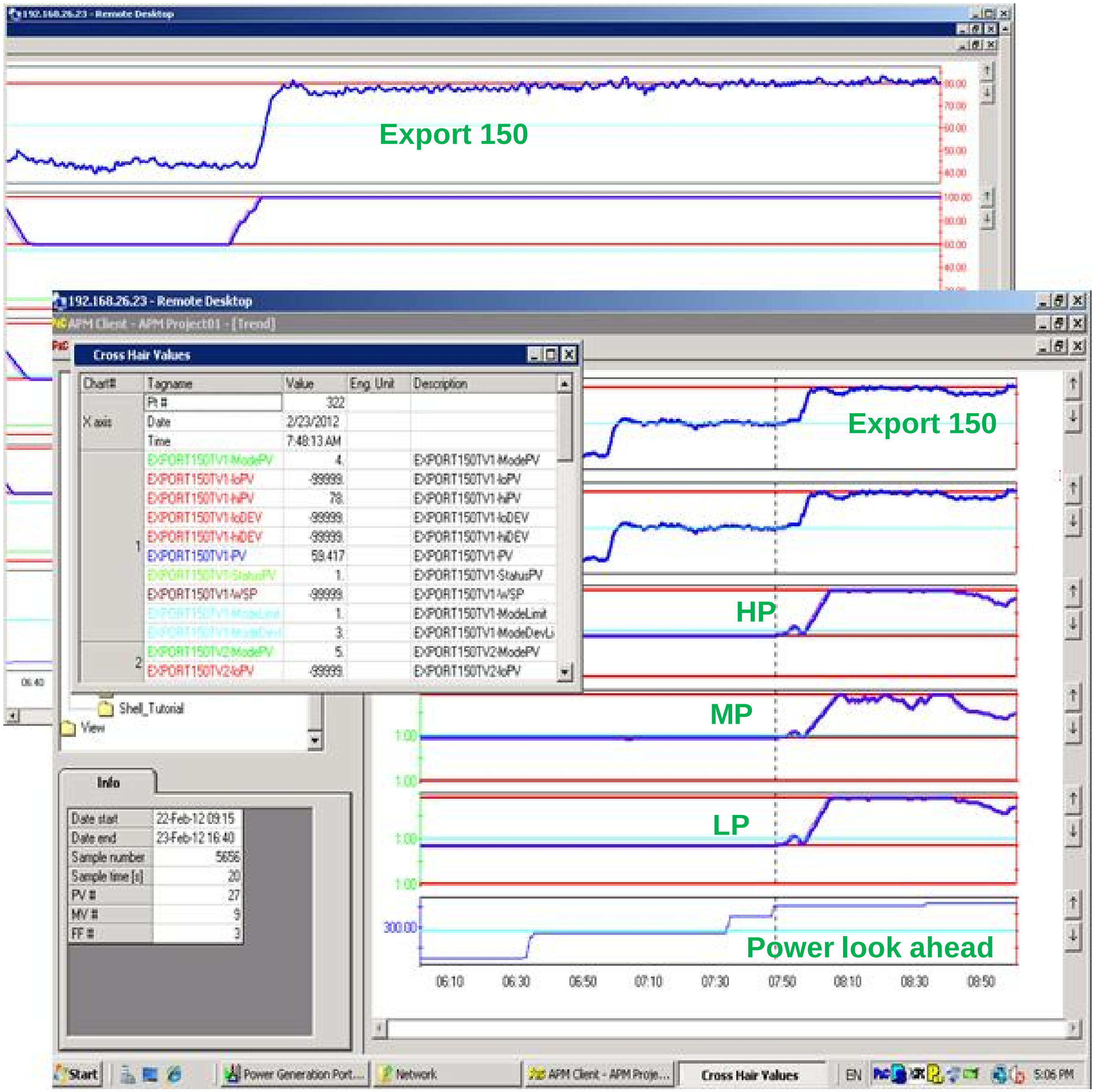
As interconnection changes, impact on MVs to power export CV changes.

<u>APC handles all cases.</u>

Case	GT1	GT3	ST1	ST2	Backpressure
1	X			X	X
2		X	X		X
3	X		X		X
4		X		X	X
5	X				X
6		X			X

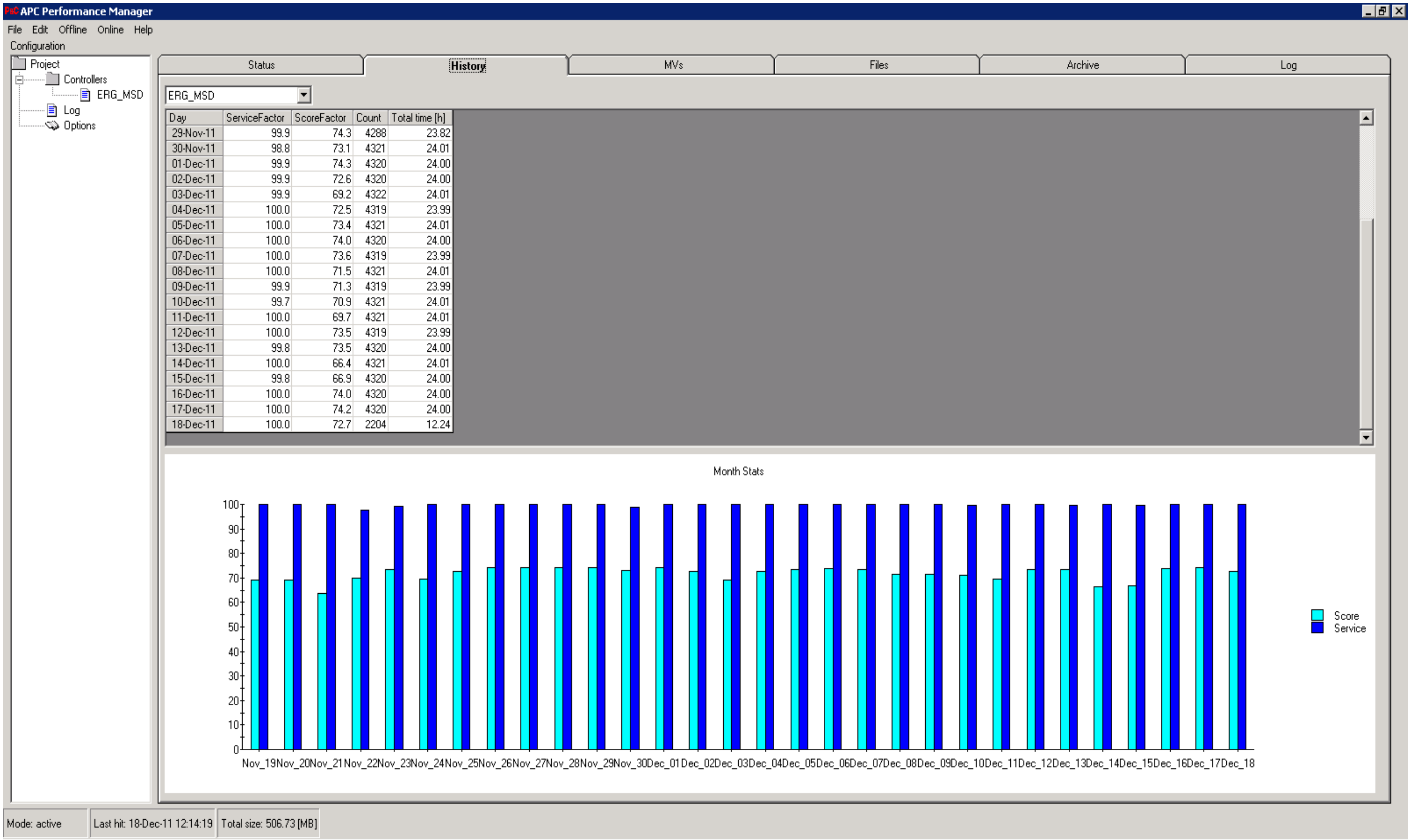


Load increase, use of HICs



- Production increase early morning
- Schedule information anticipate actual load request increase (~20 min ahead)
- APC reduces steam export from CC so to increase Power Production from BP unit
- APC moves MVs ahead to reduce ratio 150 kV/380 kV export i.e. increasing steam export from 150 kV linked gen vs. 380
- As MW export is close to maximum limit, the APC system trims backpressure power plant by modulating CC steam export

Service Factor sample



Day	ServiceFactor	ScoreFactor	Count	Total time [h]
29-Nov-11	99.9	74.3	4288	23.82
30-Nov-11	98.8	73.1	4321	24.01
01-Dec-11	99.9	74.3	4320	24.00
02-Dec-11	99.9	72.6	4320	24.00
03-Dec-11	99.9	69.2	4322	24.01
04-Dec-11	100.0	72.5	4319	23.99
05-Dec-11	100.0	73.4	4321	24.01
06-Dec-11	100.0	74.0	4320	24.00
07-Dec-11	100.0	73.6	4319	23.99
08-Dec-11	100.0	71.5	4321	24.01
09-Dec-11	99.9	71.3	4319	23.99
10-Dec-11	99.7	70.9	4321	24.01
11-Dec-11	100.0	69.7	4321	24.01
12-Dec-11	100.0	73.5	4319	23.99
13-Dec-11	99.8	73.5	4320	24.00
14-Dec-11	100.0	66.4	4321	24.01
15-Dec-11	99.8	66.9	4320	24.00
16-Dec-11	100.0	74.0	4320	24.00
17-Dec-11	100.0	74.2	4320	24.00
18-Dec-11	100.0	72.7	2204	12.24

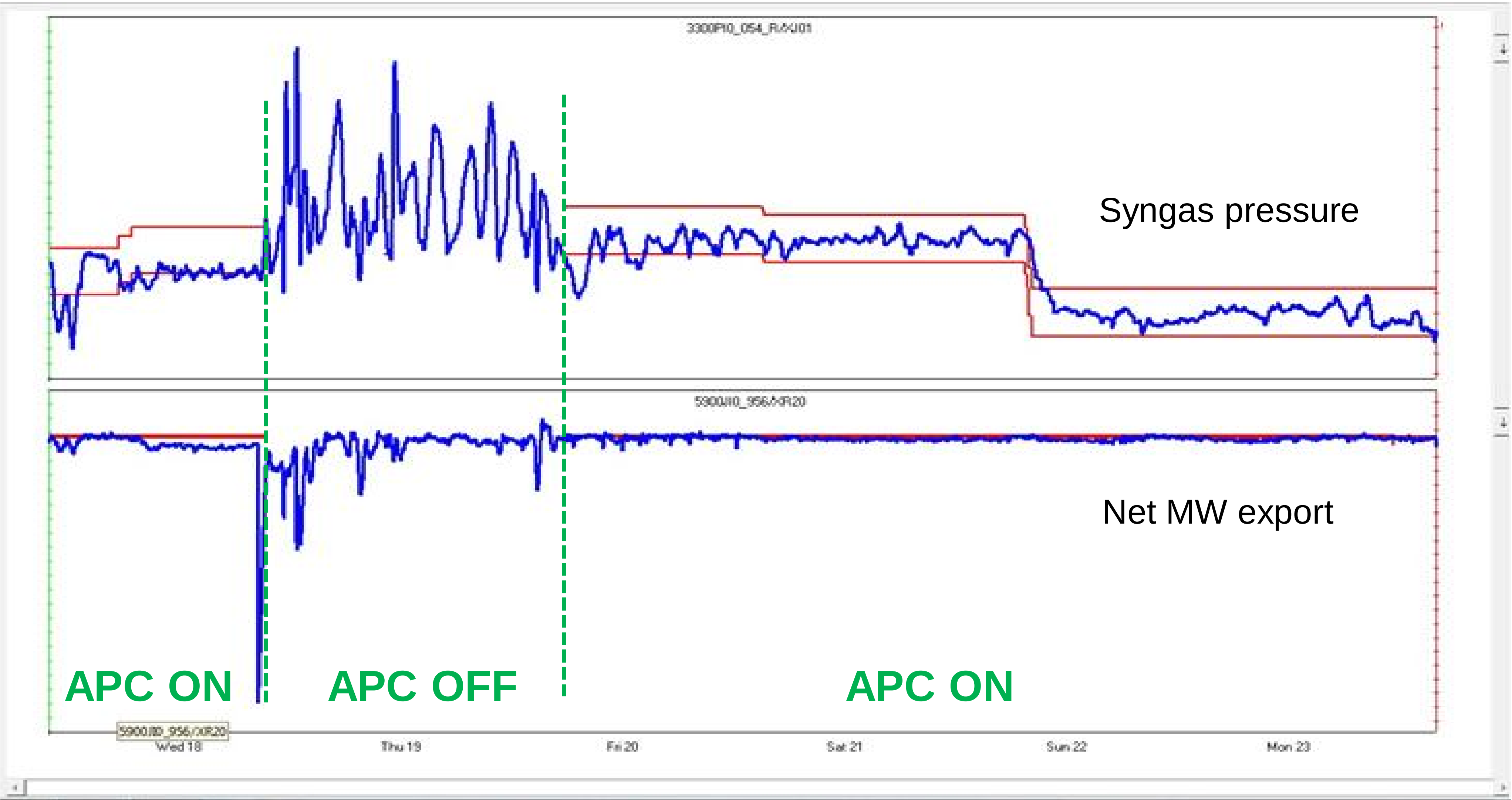
Summary - APC application to Power Gen

- Applications to Power Gen provides tangible benefits with outstanding reliability

- Another example, IGCC 530 MW Power Plant located 5 km apart, features a large APC installation from ABB
- Tangible benefits – average 3 MW production increase due to APC

- Total of ~ 1100 MW managed by APC !

APC APPLIED TO IGCC



PV – Blue

Limits - Red

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