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Real-time phasor simulation test-bed for secondary voltage control of power grids using wide-area measurements

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Outline:

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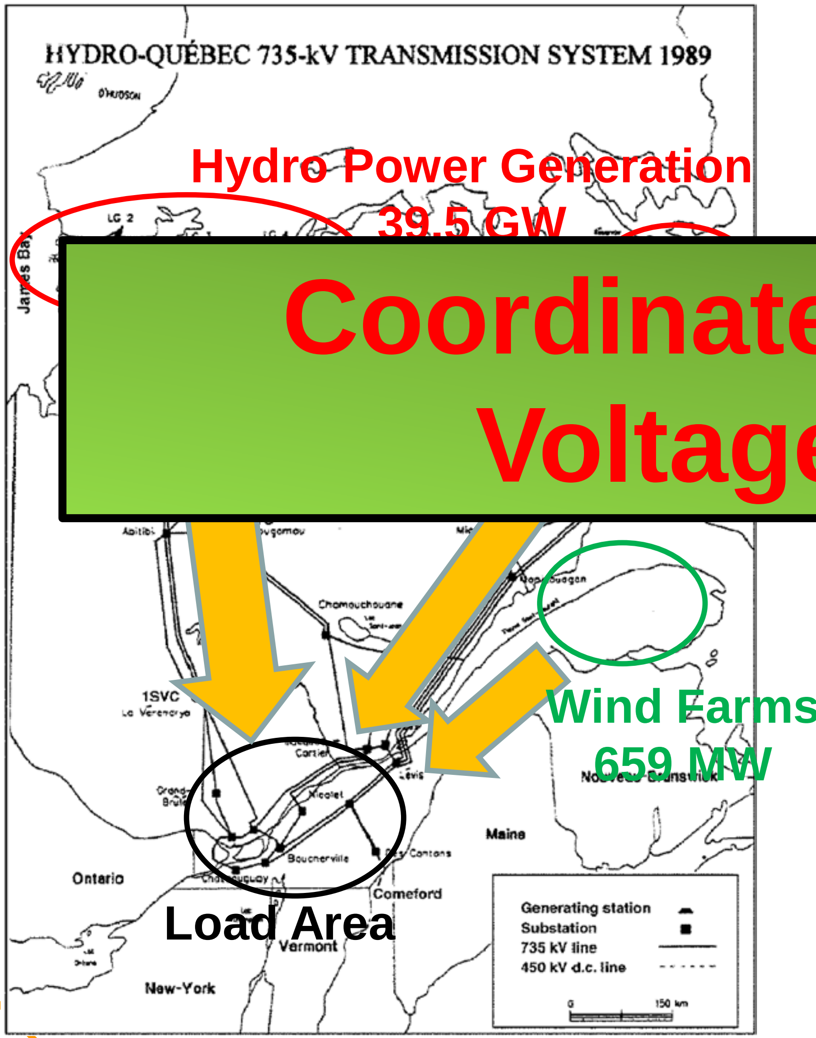
Problem statement

Overview of Hydro Quebec Network



Coordinated Secondary Voltage Control

Long distance

- Large amount of reactive power loss

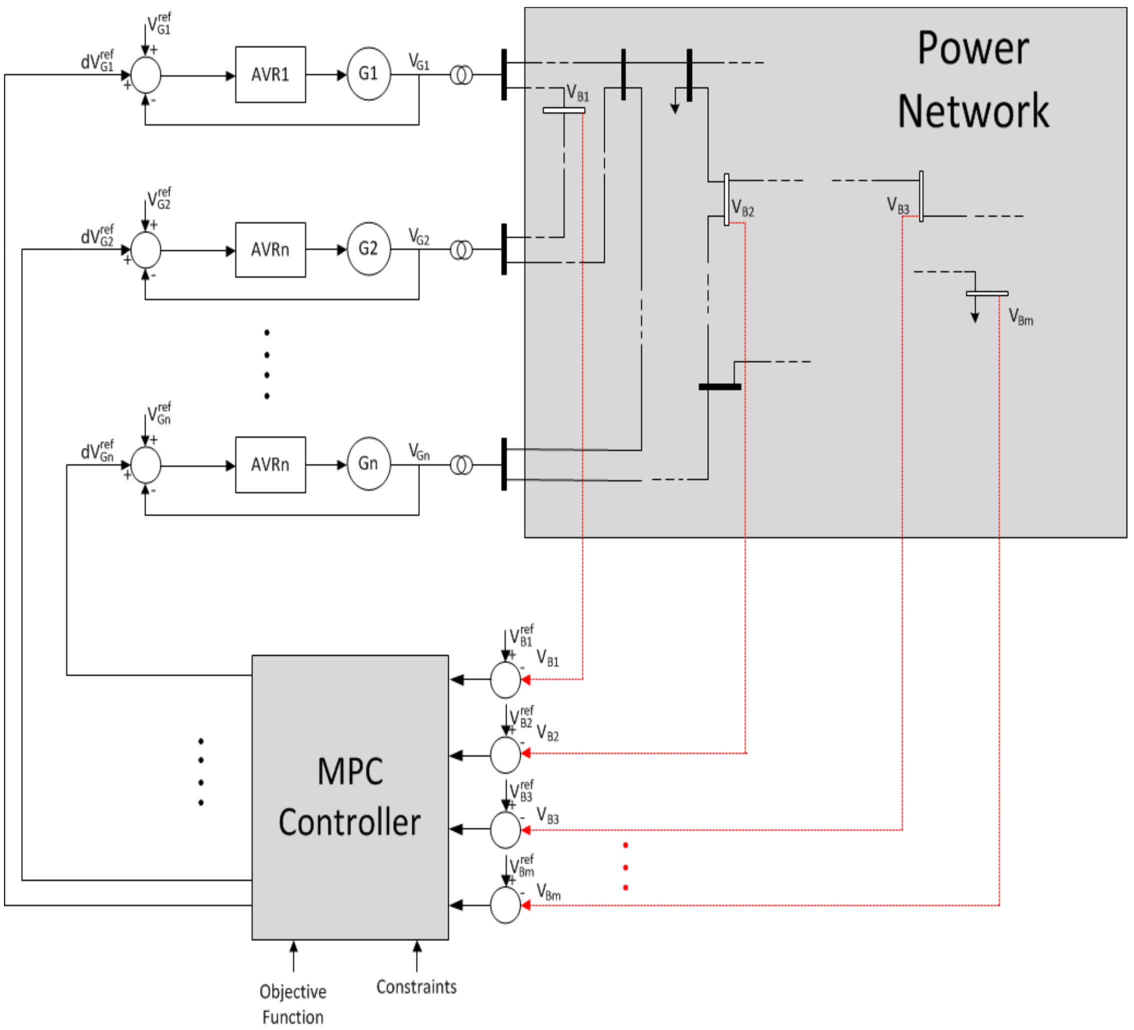
Manual operator based voltage control in secondary level

- Based on off-line calculations and pre-defined schedules
- No coordination between reactive power compensators

* http://www.hydroquebec.com/fr/

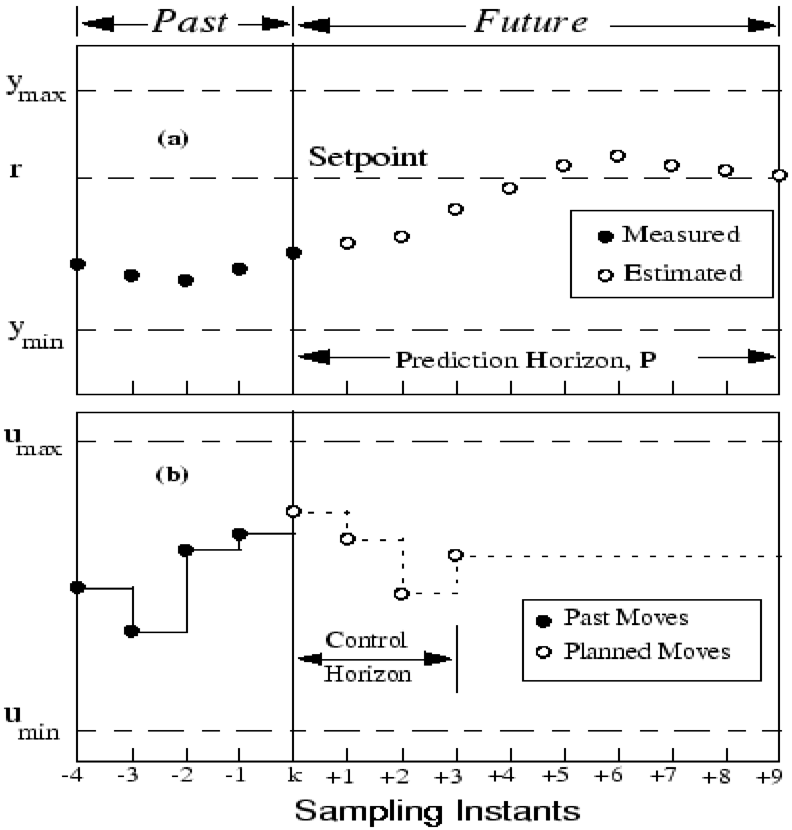
Secondary level Voltage Control

- Voltage regulation and tracking at sensitive buses called pilot nodes using:
  - Changing Vref of exciters on the machines
  - Changing Vref or Qref of Static Var compensators
  - Switching capacitor/inductor banks
  - ...
- Consider constraints: voltage of the buses and MVAR limits
- Time step of the controller: 10sec.
- Settling time (for 3%) in 1min



Model Predictive Controller

MPC Algorithm:



1) State estimation based on measured output and previous input/output set.

2) Use Identified LTI model to relate outputs for next P future steps, to next M future values of the inputs (M≤P). In this way we will have P equation and M unknown. P and M are prediction and control horizons respectively.

3) Solve Optimization problem with respect to unknown inputs in presence of given constraints

$$\min_{\Delta u(k),\ldots\Delta u(k+m-1)} \left\{ \sum_{j=0}^{m-1} \Delta u^T(k+j) R \Delta u(k+j) + \sum_{i=0}^{p-1} \Delta y^T(k+i|k) Q \Delta y(k+i|k) + \rho\varepsilon^2 \right\}$$

Subject to:

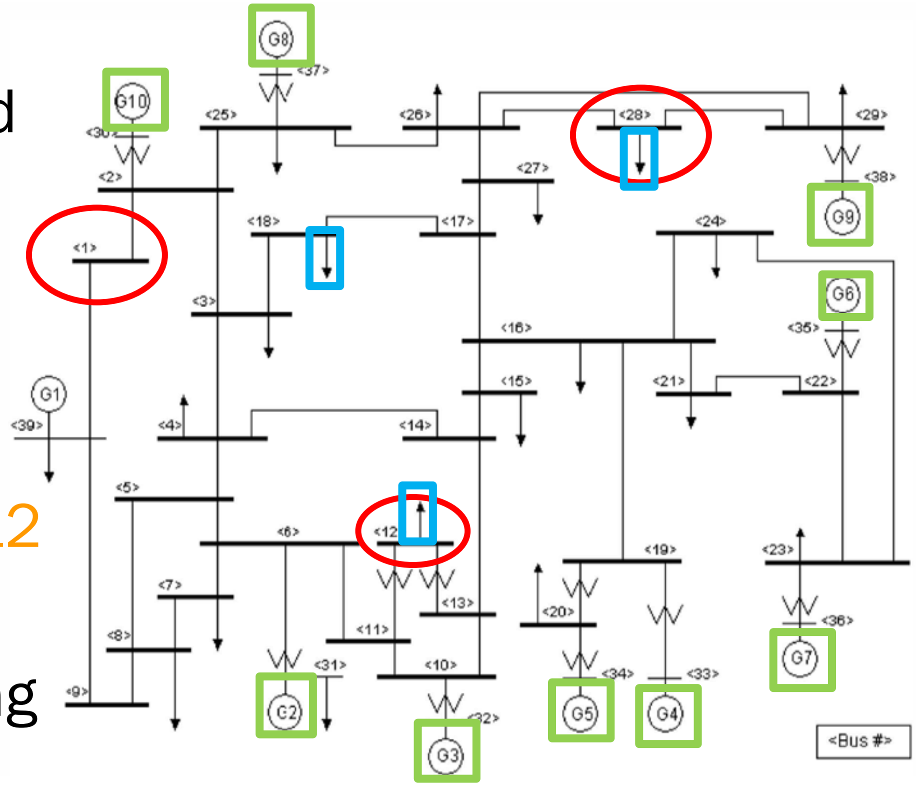
$$\begin{cases} u_{min} \le u(k+j) \le u_{max} & \\ \Delta u_{min} \le \Delta u(k+j) \le \Delta u_{max} & j = 0,\ldots,m-1 \\ y_{min} - \varepsilon \le y(k+i|k) \le y_{max} + \varepsilon & i = 0,\ldots,p-1 \\ \Delta u(k+l) = 0 & l = m,\ldots,p-1 \\ \varepsilon > 0 & \end{cases}$$

4) Apply the first element of control signal obtained from the optimization procedure.

5) Go to step 1 for next sampling time, k+1

Simulation Test Case

- IEEE39 bus system used as test case
- pilot buses to install PMUs: buses 1,12 & 28
- Identify linear model of the system: 12 states, 12 inputs, 3 outputs
- Controller designed using MPC toolbox in MATLAB

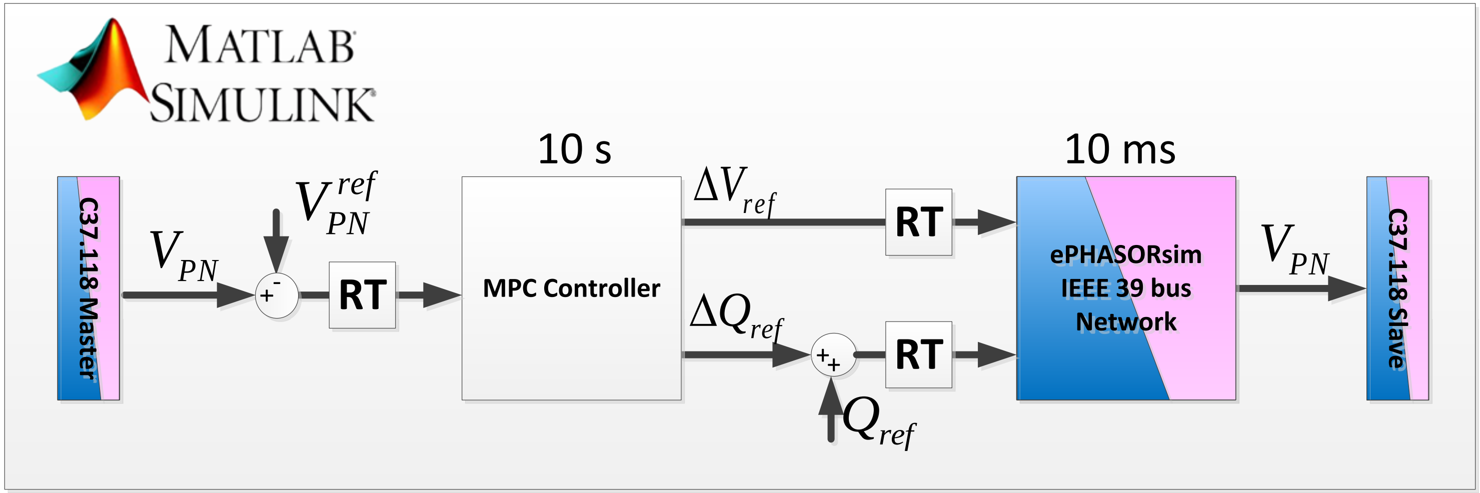


Selected Pilot buses

Change of Vref

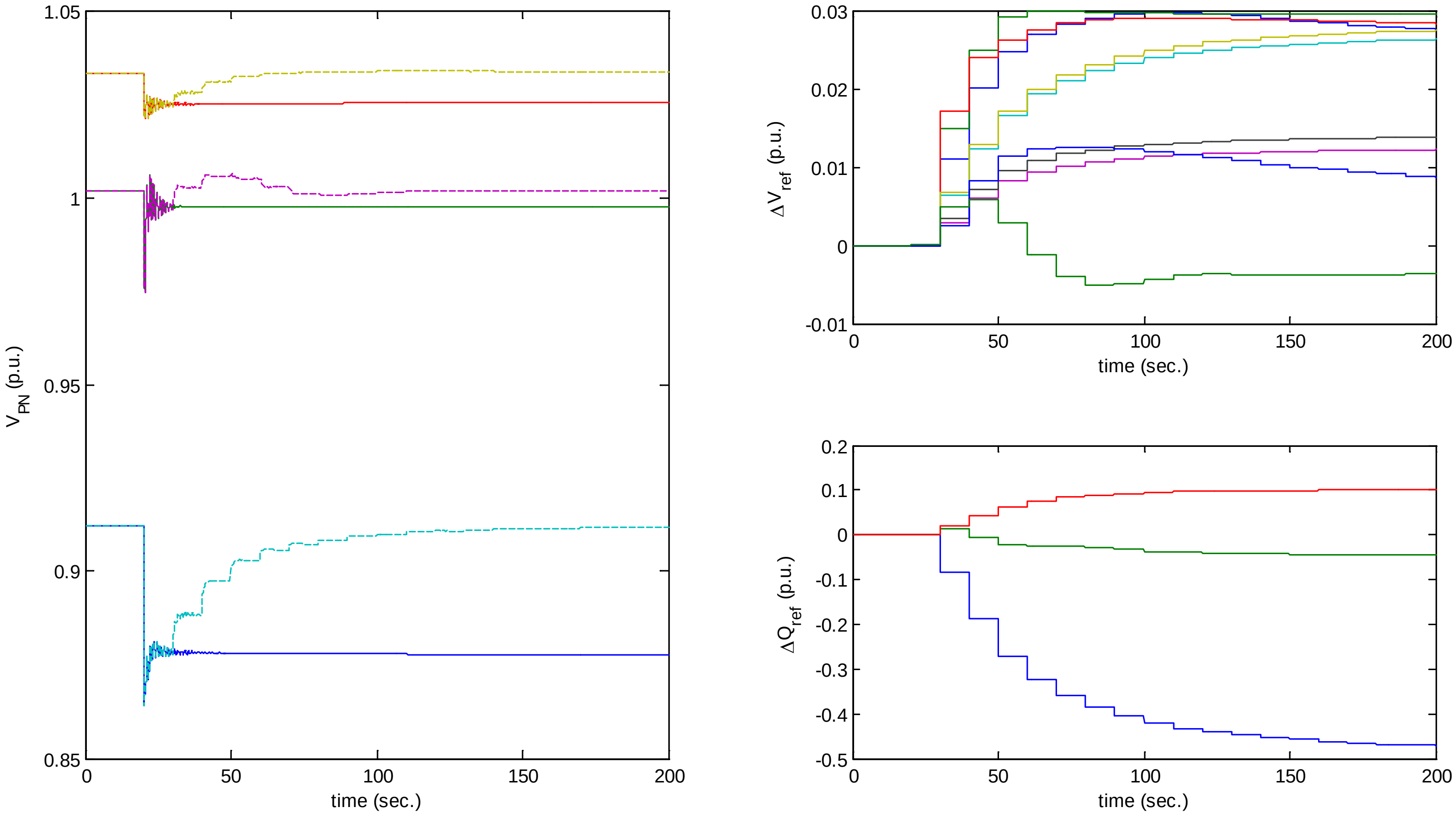
Change of Qref

Real-time testbed



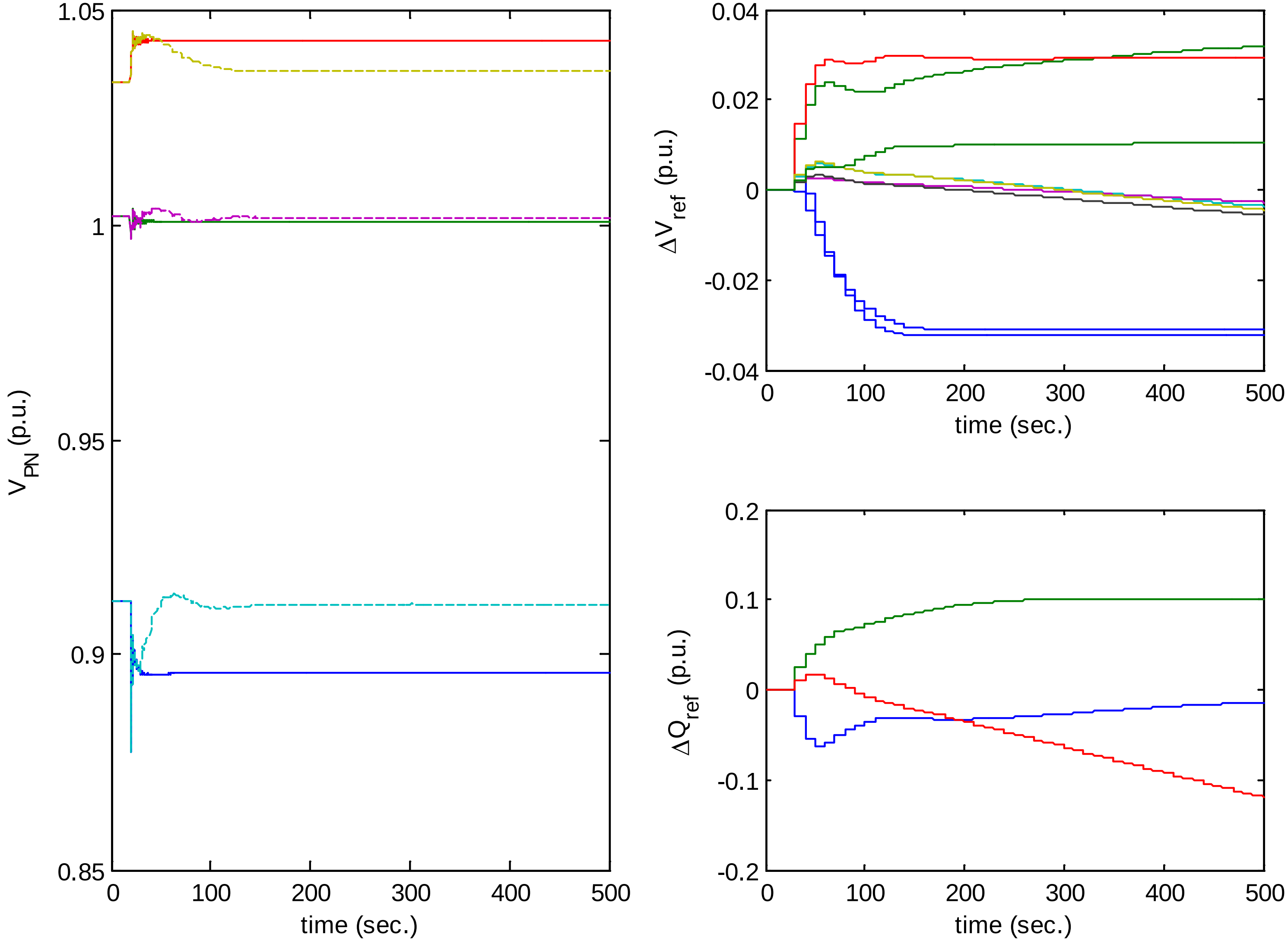
Simulation Results: Voltage Regulation

Trip generator: G3 is tripped at t=10s



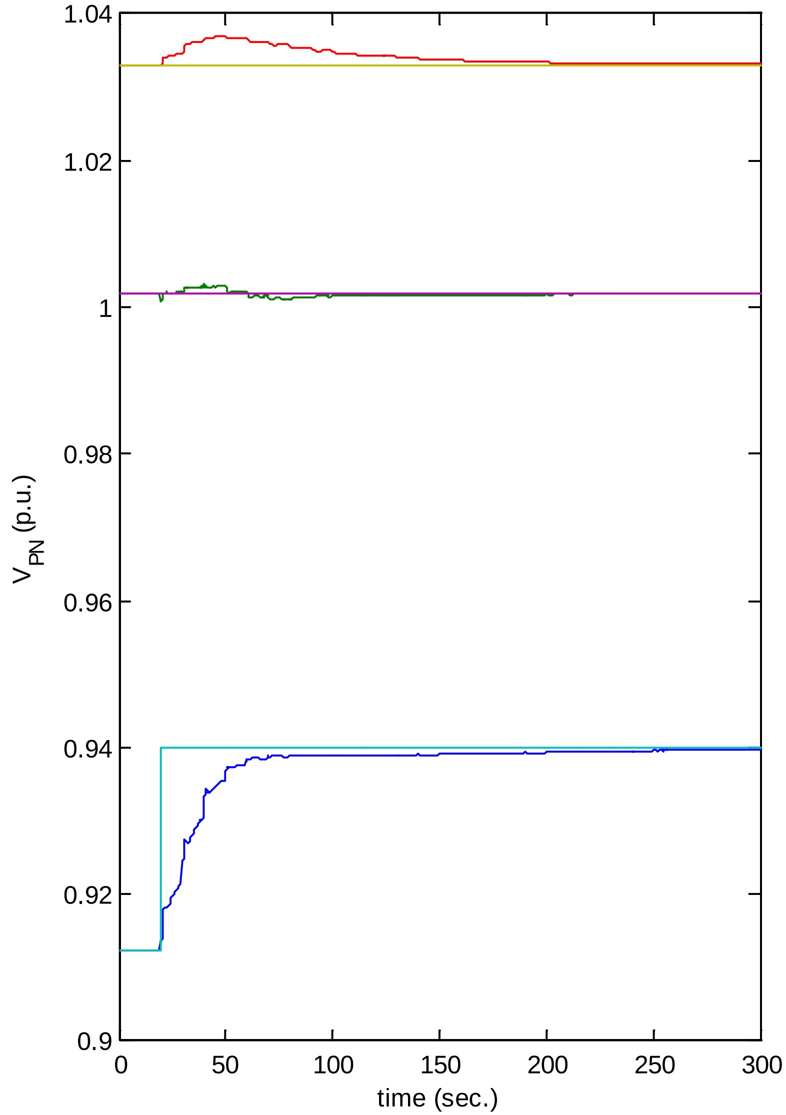
Simulation Results: Voltage Regulation

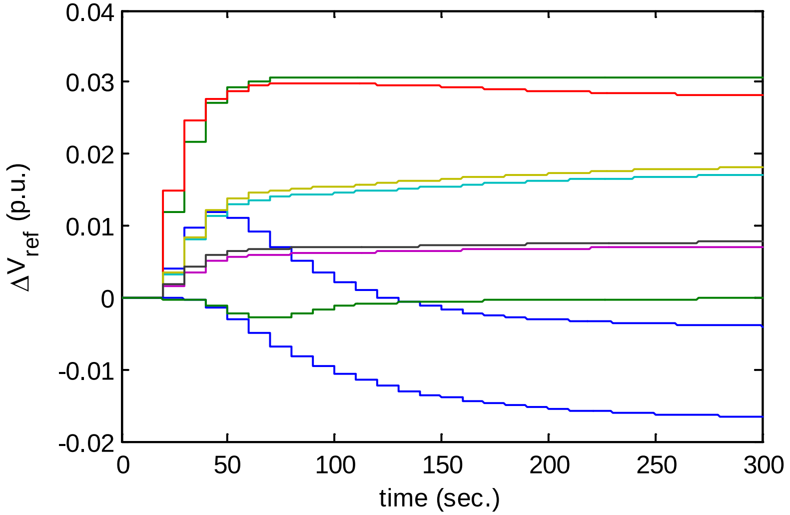
Trip Line: Bus 8 to Bus 9

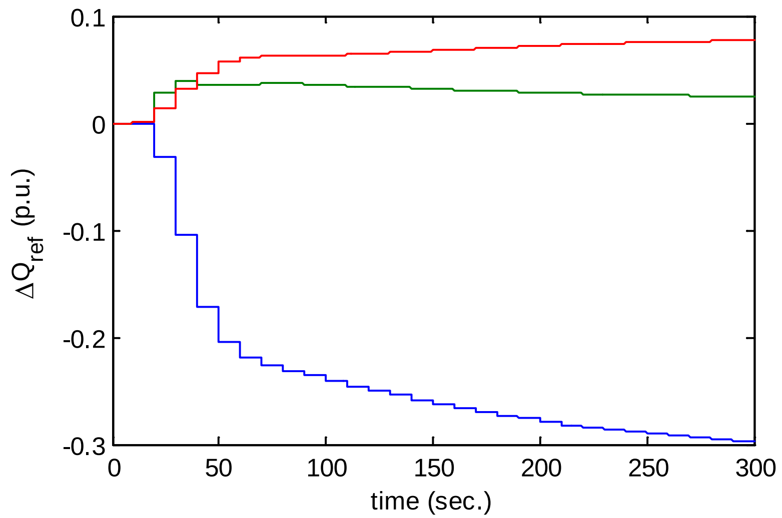


Simulation Results: Voltage Tracking

Chang Vref of Bus12 from 0.923p.u to 0.94p.u







Conclusion and future works

- MPC controller can handle voltage regulation and tracking at pilot buses in presence of disturbances.
- A real-time validation is necessary for control algorithms such as MPC who requires time for calculations of the control input.
- For larger scale networks, Centralized MPC computational burden may go beyond sample time of the controller. Decentralized MPC approach can be used as an alternative.

Acknowledgement

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- THANK YOU ALL

Question?