Pilot Node Control for Frequency-Constant Grid Operation in Power Systems with Zero Inertia

Nizam Halawi, Hassan Alhomsi, Franz Linke, Steffen Schlegel, and Dirk Westermann

Power Systems Group, Technische Universität Ilmenau, Ilmenau, Germany

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Motivation

- Carbon free energy system by 2050
- 100% renewable energy sources with the majority of generation at distribution grid level
- Inertia challenges due to decommissioned synchronous generators
- Need for reconsideration of power frequency control method
- Voltage Angle Control as a new method for energy balancing
- Decreasing setpoints in voltage angle control

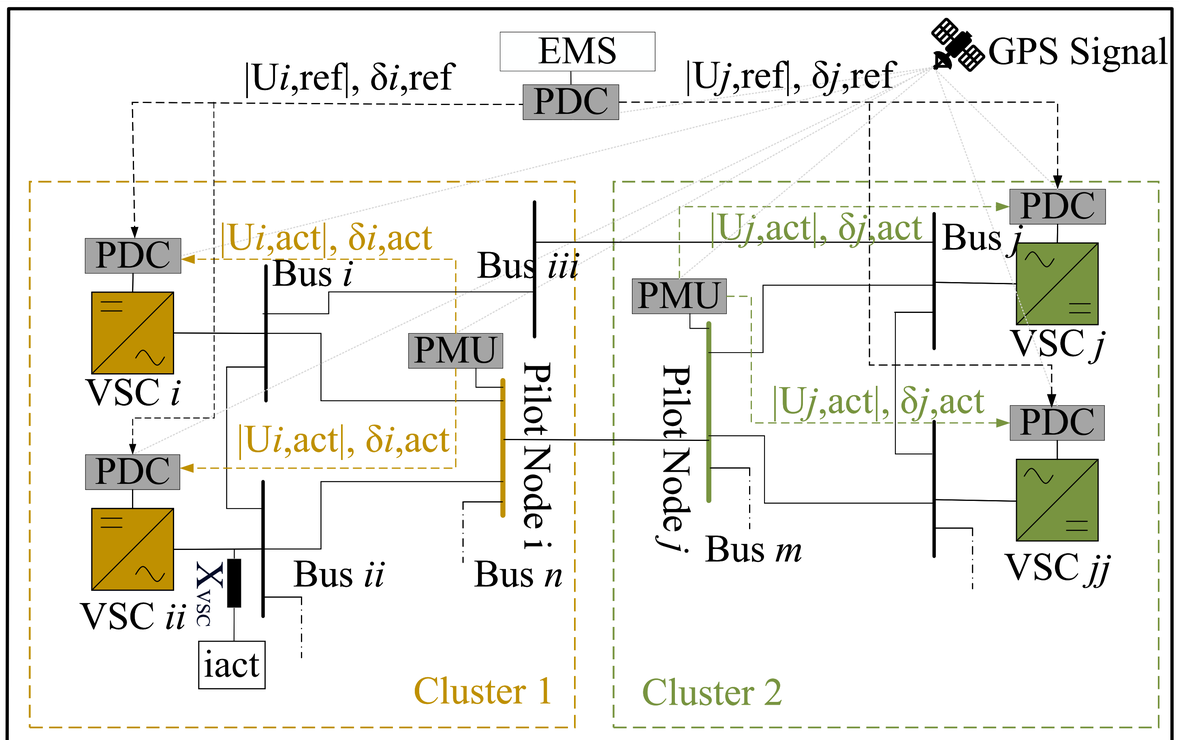
Research Qustions

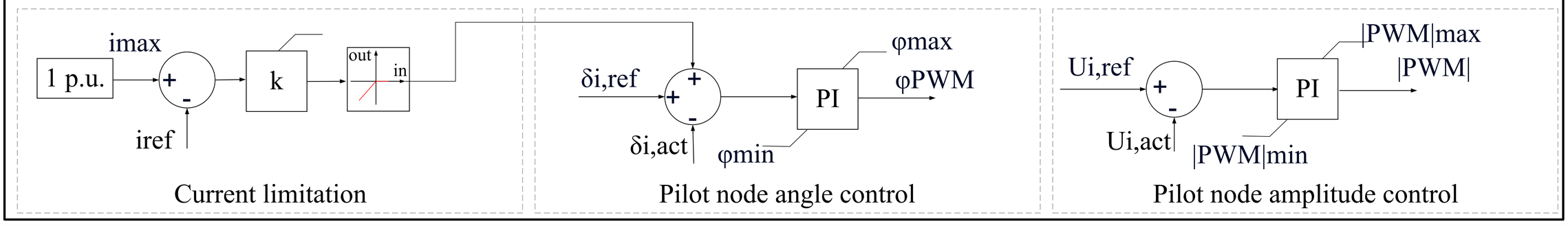
- How can the number of controlled buses be reduced?
- How can angle-based control be implemented to control the power flows across the lines?

- Simplified system control and reduced complexity
- Controlled utilization of key transmission lines
- Ensures stability and prevents overloads

Methods

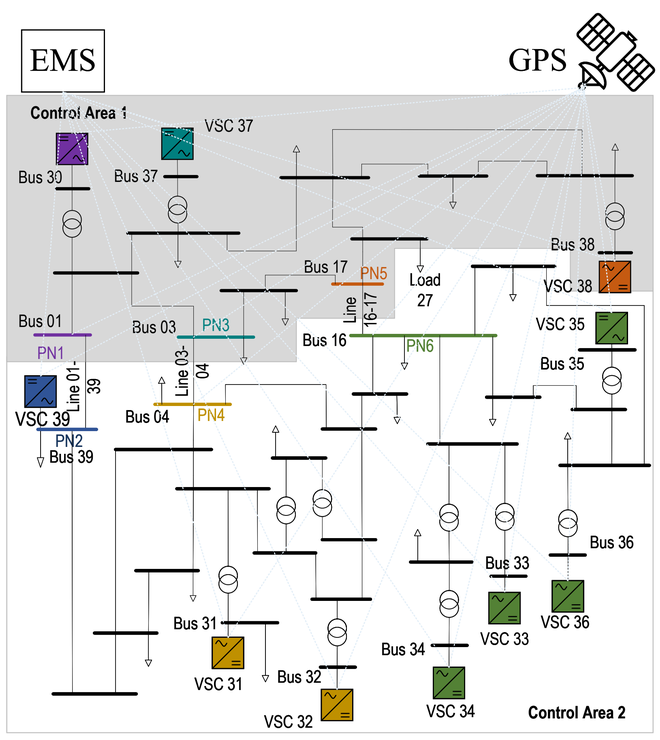
- Constant voltage angle at pilot nodes
- VSC cluster selected to control the pilot node
- Each VSC connected to energy storage system
- VSCs reaction to changes in voltage angle to keep it constant.
- Power supply from VSCs with decreasing voltage angle, power storage with increasing voltage angle.
- Acual voltage angle and magnitude (Ui,act|, δi,|act) at the pilot node
- Reference Values from TSO (|Ui,ref|, δi,ref).
- Cluster Selection via sensitivity analysis.
- 3-Loop Control: voltage magnitude, voltage angle, current-limiting





Study Case

- Test Grid: IEEE 39-Bus System
- Global reference signal for setpoint adjustments
- VSC cluster selection based on VSC-shift-factor, selecting 6 clusters
- Voltage angle setpoint defined relative to reference voltage
- Load increase at Bus 27 from 136 MW to 172 MW



Results

The method reduces the number of nodes to be controlled

Ability to control the utilization of the tie line and avoid overloading

Stable frequency and immediate response to grid changes — Grid-forming properties of the inverters are available

Positive control power injection by some VSCs in certain operating scenarios

Further work: VSCs in the distribution network controlling voltage angle at the transmission connection point, enabling grid-forming capabilities.

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Technische Universität Ilmenau
Department of Electrical Engineering and Information Technology
Power Systems Group
Univ.-Prof. Dr.-Ing. Dirk Westermann (fg-eev@tu-ilmenau.de)

Contact:
Nizam Halawi
nizam.halawi@tu-ilmenau.de