Control of Switched Shunts in Inverter-based Resources (IBRs)

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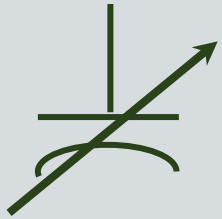
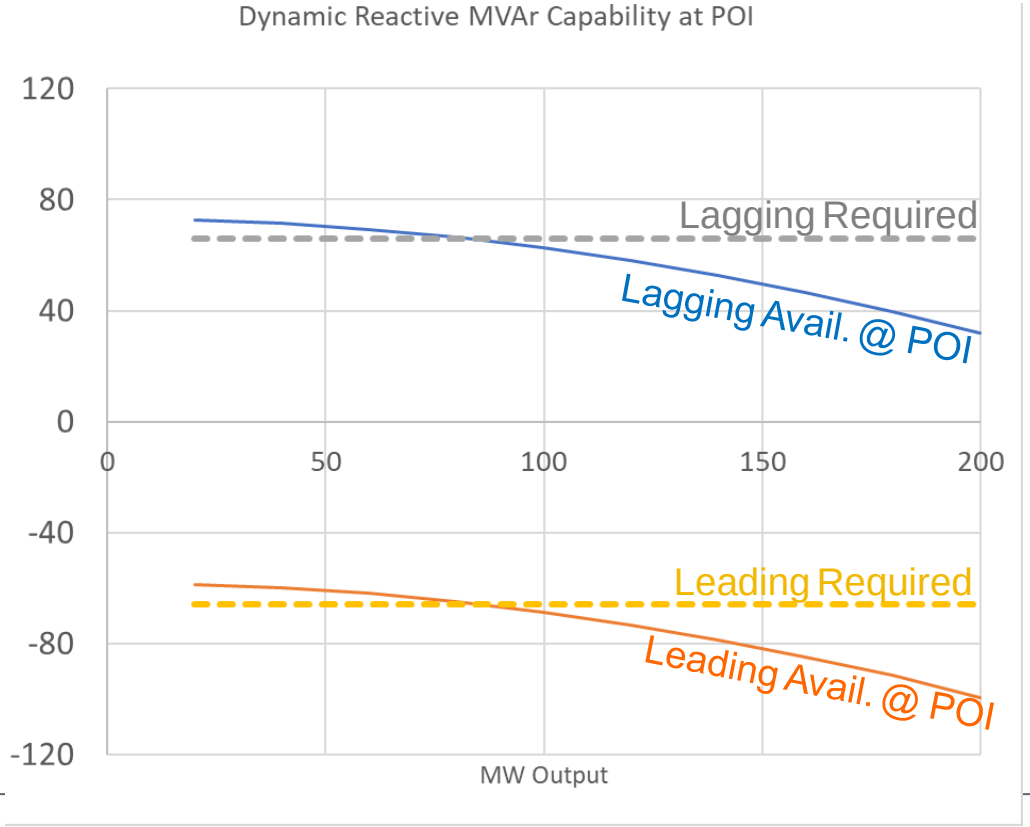


Motivation

- Vast majority of IBRs appear to rarely operate their switched shunts
  - Poor utilization of equipment
  - Cripples lagging capability (especially dynamic lagging capability) at POI when under high dispatch

Reactive losses in collector system skews the reactive capability at the POI especially under high MW dispatch.



Background

- ERCOT has observed poor coordination of switched reactive shunts at many wind and solar farms
  - E.g. Not having enough shunt capacitors in service when wind / solar output is high
  - Excessive switching delays in meeting 0.95 power-factor requirements at the POI

- Pre-positioning shunts can help ensure dynamic reactive capability at the POI by controlling shunts to offset collector losses
  - Control schemes which do not pre-position may need closer examination to ensure they provide adequate dynamic capability at the POI under all scenarios.
  - Aligns with Protocol 3.15 (17): [Switched shunts] should only be used to compensate reactive losses behind the POI

- Developers often have the option of purchasing wind turbines / inverters with additional reactive capability (like 0.90 power factor)
  - Purchasing **better** power-factor turbines allows for more forgiving shunt controls
    - Simpler controls and simpler for plant operator → less chance equipment mis-operation affects revenue → worth the minor cost difference
    - Many projects are already using 0.90 pf turbines / inverters

Observations and Current Common Practices

- Vast majority of IBRs appear to rarely operate their shunts in normal conditions
  - Poor equipment utilization and coordination can cause problems at higher IBR penetrations

Control Scheme	Steady State Support	Dynamic Support	Concerns
Voltage-triggered shunts	✗	✗	The shunts and turbine are both trying to respond to and control voltage. Increased risk of mis-coordination
"Generator Unloading" (Used by many Power Plant Controllers)	✓	✗ (Depends)	*This common PPC shunt control method may not be optimal for grid stability*

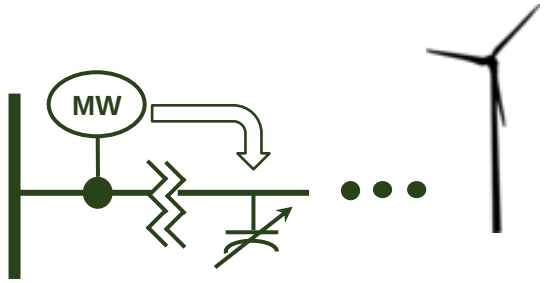
Generator Unloading – Shunts are adjusted to minimize generator reactive exchange. Dynamic support depends on initial conditions going into a disturbance, thus one needs to carefully consider the different scenarios and the potential for mis-coordination.

Proposed Concept – Shunt Pre-Positioning

- Improved coordination of shunts could provide better system voltage support under normal and disturbance conditions.
- Pre-Positioned shunts means that the generators are better positioned to quickly move the POI between 0.95 lagging to 0.95 leading pf
  - Frees wind turbines / solar inverters to perform voltage regulation and quickly respond to dynamic events while shunts dedicated to offset collector losses

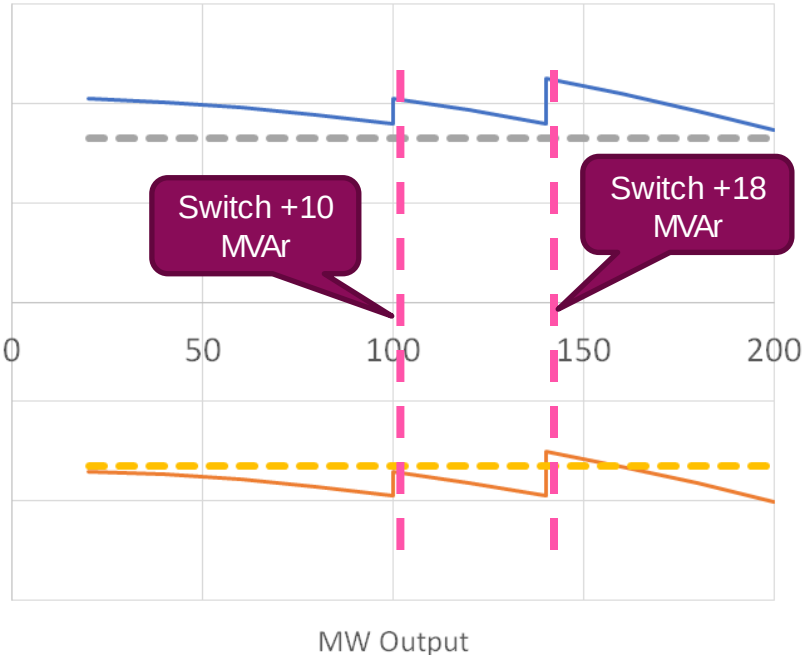
Control Scheme	Steady State Support	Dynamic Support
Voltage triggered shunts	✗	✗
"Generator Unloading" (Used by many Power Plant Controllers)	✓	✗ (Depends)
Pre-Positioned Control	✓	±0.95 pf dynamic assured @ POI

Proposal: Pre-Position Shunts Based on *MW Trigger*



- Switch shunts based on MW flow
  - Reactive losses depend on MW flow
  - Simple to implement using PPC or MW relays
  - Inherently coordinated. No risk of hunting or mis-coordination
  - Shunts offset losses, ensuring turbine/inverter native reactive capability reaches the POI
    - Can enhance stability
    - Preserves dynamic reactive capability, which is superior for responding to grid events
    - Shunts follow changes in real power output which is slowly-varying over several minutes
  - Add hysteresis and delays to avoid rapid switching
    - For example, switch in service the first shunt block when wind above 110 MW and switch block out when wind drops below 80 MW for 3 minutes

Switch capacitors at 100 MW, 140 MW



Key Takeaways

- "MW-Trigger" is an elegant method of pre-positioning that is also inherently coordinated
  - Coordinated for good voltage control
  - Pre-positioned for fast response and dynamic stability
  - Shunts controlled to offset collector losses, aligned with Protocol 3.15 (17)

- Other methods providing similar performance may also be considered
  - Generator Unloading, which is commonly used today, may also work but needs careful attention to operating scenarios which could result in mis-coordination and poor dynamic capability at the POI

- Consider 0.90 power-factor generators (or better) for operational simplicity

- Next Steps
  - Revise the Interconnection Reactive Study Scope to reflect the desired control methodology of static VAr devices
  - Review the control practices of the existing IBRs

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