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STATCOM Application to Address Grid Stability and Reliability: Part I

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Outline of Presentation

- Objective
- Background
- Application Environment
- Potential Need for Advanced Technologies and Summary

Objective

- Review key aspects of North American Electric Reliability Corporation (NERC) reliability criteria violations and fault-induced delayed voltage recovery (FIDVR)
- Discuss challenges utilities are facing that are affecting overall grid stability and desired device characteristics to address the challenges
- Discuss potential for advanced solutions such as the STATCOM and comparison to another more widely applied solution, the SVC

Background
The Rules- NERC Transmission Planning Standards

Category	Contingencies	System Limits or Impacts		
	Initiating Event(s) and Contingency Element(s)	System Stable and both Thermal and Voltage Limits within Applicable Rating [a]	Loss of Demand or Curtailed Firm Transfers	Cascading Outages
A No Contingencies	All Facilities in Service	Yes	No	No
B Event resulting in the loss of a single element.	Single Line Ground (SLG) or 3-Phase (3Ø) Fault, with Normal Clearing: 1. Generator 2. Transmission Circuit 3. Transformer Loss of an Element without a Fault.	Yes Yes Yes Yes	No [b] No [b] No [b] No [b]	No No No No
	Single Pole Block, Normal Clearing [e]: 4. Single Pole (dc) Line	Yes	No[b]	No
C Event(s) resulting in the loss of two or more (multiple) elements.	SLG Fault, with Normal Clearing [e]: 1. Bus Section 2. Breaker (failure or internal Fault)	Yes Yes	Planned/ Controlled[c] Planned/ Controlled[c]	No No
	SLG or 3Ø Fault, with Normal Clearing [e], Manual System Adjustments, followed by another SLG or 3Ø Fault, with Normal Clearing [e]: 3. Category B (B1, B2, B3, or B4) contingency, manual system adjustments, followed by another Category B (B1, B2, B3, or B4) contingency	Yes	Planned/ Controlled[c]	No
	Bipolar Block, with Normal Clearing [e]: 4. Bipolar (dc) Line Fault (non 3Ø), with Normal Clearing [e]: 5. Any two circuits of a multiple circuit towerline[f]	Yes Yes	Planned/ Controlled[c] Planned/ Controlled[c]	No No
	SLG Fault, with Delayed Clearing [e] (stuck breaker or protection system failure): 6. Generator 7. Transformer 8. Transmission Circuit 9. Bus Section	Yes Yes Yes Yes	Planned/ Controlled[c] Planned/ Controlled[c] Planned/ Controlled[c] Planned/ Controlled[c]	No No No No

Background
The Rules- NERC Transmission Planning Standards
[Continued]

D [d] Extreme event resulting in two or more (multiple) elements removed or Cascading out of service	3Ø Fault, with Delayed Clearing[e] (stuck breaker or protection system failure): 1. Generator 2. Transmission Circuit 3. Transformer 4. Bus Section 3Ø Fault, with Normal Clearing[e]: 5. Breaker (failure or internal Fault) 6. Loss of towerline with three or more circuits 7. All transmission lines on a common right-of way 8. Loss of a substation (one voltage level plus transformers) 9. Loss of a switching station (one voltage level plus transformers) 10. Loss of all generating units at a station 11. Loss of a large Load or major Load center 12. Failure of a fully redundant Special Protection System (or remedial action scheme) to operate when required 13. Operation, partial operation, or misoperation of a fully redundant Special Protection System (or Remedial Action Scheme) in response to an event or abnormal system condition for which it was not intended to operate 14. Impact of severe power swings or oscillations from Disturbances in another Regional Reliability Organization.	Evaluate for risks and consequences. ▪ May involve substantial loss of customer Demand and generation in a widespread area or areas. ▪ Portions or all of the interconnected systems may or may not achieve a new, stable operating point. ▪ Evaluation of these events may require joint studies with neighboring systems.

Background
The Rules- NERC Transmission Planning Standards
[Summary]

- NERC Categories C and D drive infrastructure requirements
- Under revision with more cases, definitions, and utility responsibilities- January 2015 next approval?
  - P0-P7 and Extreme Events
- Many more intricacies, implications, and questions beyond the time we have here today..
- What about congestion management?

Planning standards will only continue to become more onerous as the industry accumulates experience, different technologies, and regulatory mandates

Background
Fault-Induced Delayed Voltage Recovery (FIDVR)

- Root Cause: Small induction motors that drive single-phase residential air-conditioners
- Phenomena: Induction motors stall on low voltage (< 0.80 p.u.), absorb reactive power many times greater than rated, and are not able to be tripped off for long period of time
- End Result: When load pockets with significant penetration of FIDVR-prone motors (> 50%) experience stalling voltage is pulled down and can result in voltage collapse

Application Environment

- What are the key contingencies required by planning for NERC Category C and D?
- What are the fault clear types, sequences, and timing?
- What is the tolerance to the loss of load and remedial action schemes in place?
- What is the percent penetration of FIDVR-prone load?
- What is the corridor congestion and ability to import power?
- What is the penetration of Mechanically Switched Capacitor (MSC) banks and P-V nose characteristics?

Application Environment
[Continued]

- What are the limiting peak and light load conditions?
- What are the potential overvoltage conditions?
- What are the voltage regulation requirements and dynamic reserves (and response time) required?
- What is the generation profile and range of short-circuit strengths (response characteristics and low order harmonic resonances)?

The answers to these questions are trending in a direction towards more onerous application requirements and thus more robust solution needs

Application Environment
[Continued]

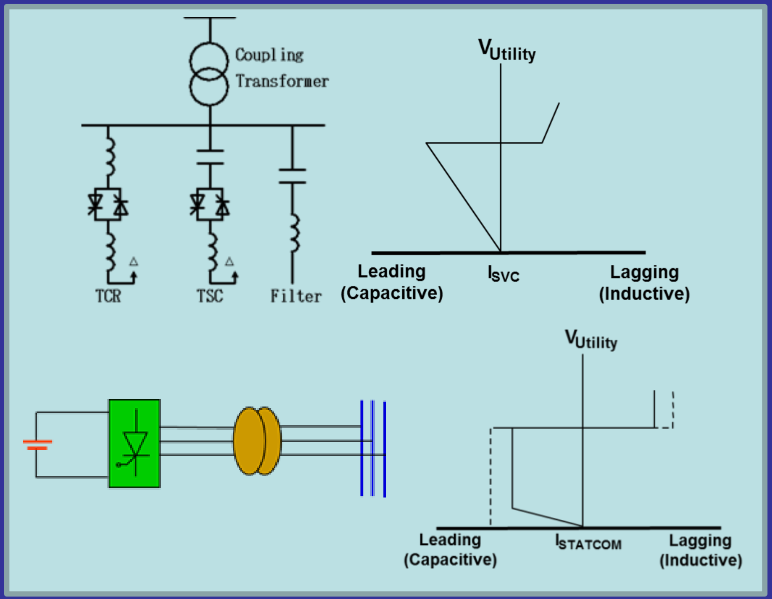
- Increased regulatory requirements
- Decommissioning of local generation sources
- Integration of renewable resources and generation profile
- Saturated use of MSC and Load Tap Changers (LTC)
- Limited right of way and increased spatial constraints
- Localized load growth
- Public pressure for ‘green’ solutions and increased utilization of existing infrastructure

Application Environment
[Summary]

Challenge || Primary Solution Characteristic->	Voltage Regulation and Fast-Acting Capable (a)	Act in Weak, Low Voltage, & Overshoot Environment + Black Start (b)	Have Reduced Harmonics & Filtering Requirements (c)	Reduced Spatial Requirements (d)	Increase Utilization of Existing Equipment & Adaptability (e)
NERC Criteria / Avoid Load Loss (1)	x	x			
FIDVR Response (2)	x	x			
Reduced Local Generation (3)	x	x	x		x
Increased Remote Generation (4)	x	x	x		x
Generator Dispatach Constrained (5)	x	x	x		x
Saturated LTC and MSC (6)	x	x			x
Right-of-Way Constraints (7)				x	x
Load Growth and Sensitivity (8)	x	x	x	x	
Public and Political Pressure (9)				x	x

Potential Need for Advanced Technologies

	SVC	STATCOM
Voltage Regulation and Fast-Acting Capable (a)	x	xx
Act in Weak, Low Voltage, & Overshoot Environment + Black Start (b)	x	xx
Have Reduced Harmonics & Filtering Requirements (c)		xx
Reduced Spatial Requirements (d)		xx
Increase Utilization of Existing Equipment and Adaptability (e)	x	xx



System Voltage P.U.	SVC P.U. Q	STATCOM P.U. Q	STATCOM Benefit (Multiple of Increased Q Relative to SVC)
0.40	0.160	0.40	2.50
0.45	0.203	0.45	2.22
0.50	0.250	0.50	2.00
0.55	0.303	0.55	1.82
0.60	0.360	0.60	1.67
0.65	0.423	0.65	1.54
0.70	0.490	0.70	1.43
0.75	0.563	0.75	1.33
0.80	0.640	0.80	1.25
0.85	0.723	0.85	1.18
0.90	0.810	0.90	1.11
0.95	0.903	0.95	1.05
	Average (0.40-0.95):		1.59
	Average (0.40-0.65):		1.96

Potential Need for Advanced Technologies
[Continued]

- Local load >> Local generation (2:1?...)
- Local generation disappearing and load growing
- Large penetration of FIDVR-prone load (>50%)
- ‘Long’ remote breaker fault clearing times (10-14 cycles?) and substation configurations leading to many outage elements
- Transmission constrained load pocket(s)
- Historical record of experience

Potential Need for Advanced Technologies
[Summary]

- Reactive Var requirements can vary from a few percent to orders of magnitude higher (30%) of total MW of load pocket
- STATCOM Mvar requirements relative to SVC Mvar requirements can vary from a marginal difference to nearly 50% (half the Mvar requirements of SVC)

Mvar's Required -> -- Use of VSC-Based Technology to Reduce Requirements of Solution	Low "+" Asymmetry	High "+" Asymmetry
Near 50% Var Reduction Realizable	Most Favorable Application for STATCOM	STATCOM Application May Be Favorable
Minimized Var Reduction Realizable	SVC Application May Be Favorable (Unless Weak System)	SVC Application Likely Favorable (Unless Weak System)

Note 1: Optimal solution is application dependent and trends should not be overly generalized, though may be treated as guides or starting points for analysis.

Note 2: Hybrid solutions for both STATCOM and SVC are realizable.