Studying the Impact of IBR Modeling on the Commonly Applied Transmission Line Protective Elements

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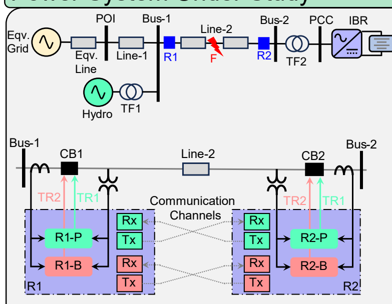
Motivations/Objectives/Problem Statement

- ❑How does the type of the primary source on the DC side of the IBRs impact the functionality of the protective relay elements?
- ❑How does the type of the voltage source inverter modeling of the IBRs impact the functionality of the protective relay elements?
- ❑How does the type of the control scheme of the IBRs impact the functionality of the protective relay elements?
- ❑How does the type of the fault current limiter scheme of the IBRs impact the functionality of the protective relay elements?

Contributions

- ❑ Identifies the dominant factors among the IBR modeling aspects, both qualitatively and quantitatively, that impact the functionalities of the relay elements
- ❑ Provides the required modifications in the fault prediction algorithms to be included in fault study software
- ❑ Provides a platform to modify settings for existing protection schemes or design new protection algorithms.

Power System Under Study



- ❑ Equivalent grid: 3-ϕ, 57.1-kV, synch. gen. behind impedance
- ❑ 3-ϕ, 6.9-kV, 7.5-MVA hydro turbine generator via a 3-ϕ, Y-Δ, 57.1/6.9-kV, 7.5-MVA transformer
- ❑ 3-ϕ, 0.48-kV, 14-MVA IBR via a 3-ϕ, Δ-Y, 57.1/0.48-kV, 14-MVA transformer

Protection System Under Study

- ❑ Line differential element → phase current (87LP)-on each phase, ground current (87LG)-one element, negative-sequence current (87LQ)-one element
- ❑ Direction element → directional supervision negative-sequence directional element, zero-sequence directional element
- ❑ Distance element → distance elements using quad and mho characteristics, supervised by impedance-based directional, fault type identification logic.

IBR Model

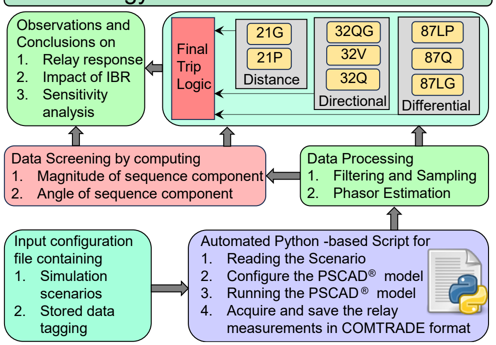
Controller Type		
Outer Power Control		Inner Current Control
Active Power	Reactive Power	
Open-loop P dispatch	Open-loop Q dispatch	dq domain
Closed-loop P dispatch	Closed-loop Q dispatch	$\alpha\beta$ domain
V_{dc} control	V_{ac} control	Sequence domain

Current Limiter		
Current Limiter Scheme		Windup Protection
Saturation – based		Anti-windup for PI controller.
d-axis priority	q-axis priority	
Latching – based		Anti-windup for PR controller.
d-axis priority	q-axis priority	

Controller Type		
Primary Control	Outer Voltage	Inner Current
Pf-QV droop	dq domain	dq domain
Virtual Synchronous Machine	$\alpha\beta$ domain	$\alpha\beta$ domain
	Sequence domain	Sequence domain

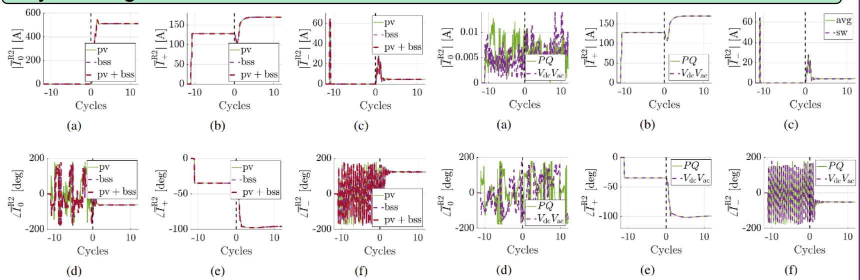
Limiter Logic		
Current Limiter		Windup
Saturation – based		Anti-windup for PI controller
d-axis priority	q-axis priority	
Latching – based		Anti-windup for PR controller
d-axis priority	q-axis priority	

Methodology

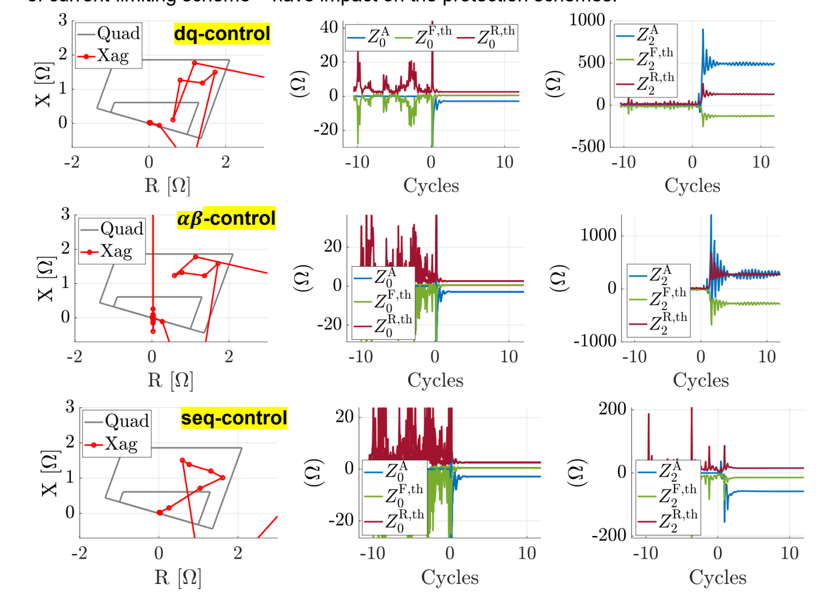


- ❑ AG fault at 'F' with R_f = 0.01Ω with TF2 as Y-Δ and Δ-Y
- ❑ BC fault at 'F' with R_f = 0.01Ω with TF2 as Δ-Y
- ❑ {# types of DC source}×{# type of VSI model}×{# type of outer-power control} for GFL cases: fixed current control, current limiter scheme
- ❑ {# types of inner-current control}×{# type of current limiter scheme} for GFL cases: fixed type of DC source, VSI model, and outer-power control
- ❑ {# types of outer-power control} for GFM-IBR cases with fixed type of DC source, VSI model, inner-voltage control and current limiter scheme
- ❑ {# types of inner-voltage control}×{# type of current limiter} for GFM-cases with fixed type of DC source, VSI model.

Key Findings



- ❑ Types of DC source, VSI model, types of outer-power controller→ No impact.
- ❑ Types of inner-current controller for GFL-IBR, inner-voltage controller for GFM-IBR, and types of current-limiting scheme→ have impact on the protection schemes.



Conclusions

- ❑ Protection engineers should desensitize negative-sequence-dependent elements if the IBR does not to use explicit negative-sequence current control.
- ❑ Negative-sequence directional elements require sufficient negative-sequence current with correct angle.
- ❑ The study can assist in proposing modifications to fault prediction algorithms and facilitate the development of a platform for protection algorithm design.

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