Impact of Increasing Penetration of DERs on the System Strength of Islanded Grids

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Introduction

- As renewable penetration increases, it becomes more challenging to integrate inverted-based resources into the existing power grid.
- The integration of DERs into a weak power grid can cause undesired system stability issue.
- It is necessary to evaluate the system strength in order to further increase the penetration of renewable resources.
- The Composite Short Circuit Ratio (CSCR) and Weighted Short Circuit Ratio (WSCR) methods are used when a more accurate estimate of the system strength is required when there are several IBRs connected in the vicinity, compared to the conventional SCR method.

CSCR and WSCR System Strength Calculation

- The CSCR method considers the effect of interaction between adjacent IBRs. It is the ratio of the CSC MVA at the common bus without current contribution from the IBRs to the sum of the nominal power rating of all IBRs connected at the common bus.

$$CSCR = \frac{CSC_{MVA}}{\sum \text{Converter MW Rating}}$$

- The WSCR method assumes that all IBRs are connected to a virtual bus.

$$WSCR = \frac{\sum_i^N SCMVA_i * P_{RMWi}}{\left(\sum_i^N P_{RMWi}\right)^2}$$

System Description and Contingency Selection

- Power flow scenarios were prepared to conduct short circuit studies to determine the system strength of the islanded grid under different operating conditions.
- CSCR and WSCR metrics were calculated assuming that all existing conventional generation units available in the islanded grid are in service (regardless of the dispatching levels).
- Four additional conventional “Main Units” will be dispatched to provide additional system inertia to increase the system strength.

System Description and Contingency Selection (cont.)

- **Renewable Phase 1 (existing)** – 320 MW of renewable energy resources in service (including PVs and BESS).
- **Renewable Phase 2 (future)** – Additional 400 MW renewable energy resources in service for a total of 720 MW (a 125% increase of renewable energy resources).
- **Main Conventional Units** - Rated at 45 MW each (180 MW total).

Summary of Power Flow Scenarios

Scenarios	Renewable Phases	Main Units Dispatched (Conventional Generation)			
		Main Unit 1	Main Unit 2	Main Unit 3	Main Unit 4
1	Phase 1 (Existing)	×	×	×	×
2		✓	✓	✓	×
3		✓	✓	✓	✓
4	Phases 1 & 2 (Future)	×	×	×	×
5		✓	✓	✓	×
6		✓	✓	✓	✓

CSCR and WSCR Results

- **Note**: System strength is considered weak if CSCR and WSCR <2.0)

Scenario	Conventional Generation and Main Units in Service					Renewable Plants in Service	CSCR	WSCR
	All Conventional Generation	Main Unit						
		1	2	3	4			
1	✓	✗	✗	✗	✗	Phase 1 (Existing)	2.40	1.55
2	✓	✓	✓	✓	✗		3.43	2.18
3	✓	✓	✓	✓	✓		3.62	2.28
4	✓	✗	✗	✗	✗	Phases 1 and 2 (Existing and Future)	1.55	1.21
5	✓	✓	✓	✓	✗		1.91	1.95
6	✓	✓	✓	✓	✓		2.02	2.04

CSCR and WSCR – Representative Results for Scenario 6

Phase	Inverter-Based Resource	Inverter Rating (MW)	SCMVA* PRMW	Composite SC MVA
Phase 1 (Existing)	PV Plant 1	25	6,228	1,446
	PV Plant 2	30	21,261	
	PV Plant 3	30	21,261	
	PV Plant 4	30	7,890	
	PV Plant 5	30	7,246	
	BESS 1	25	62,607	
	BESS 2	16.2	19,759	
	BESS 3	23.8	17,667	
	BESS 4	24	33,302	
	BESS 5	16	5,984	
	BESS 6	16	11,339	
	BESS 7	16	11,339	
	BESS 8	20	5,260	
	BESS 9	20	4,831	
	75 MW BESS	75	160,319	
Phase 2 (Future)	BESS 10	80	325,250	
	BESS 11	80	108,247	
	BESS 12	80	108,247	
	BESS 13	80	108,247	
Total WSC MVA			1,046,285	
Total Renewable MW		717		
Composite SCR				**2.02**
Weighted SCR				**2.04**

Conventional Generation Dispatch Scenario 6		
Generation Dispatch	**Generation MW (Max)**	**Generation SC-MVA**
Main Unit 01	45	149
Main Unit 02	45	149
Main Unit 03	45	149
Main Unit 04	76	192
Conventional 1 (x2)	10	34
Conventional 2 (x2)	9	23
Conventional 3 (x6)	26	58
Conventional 4 (x3)	19	89
Conventional 5	40	110
Conventional 6	44	70
Conventional 7	44	70
Conventional 8	20	77
Conventional 9	21	49
Conventional 10	40	75
Total SC MVA		1,293

Summary for Phase 1 (Scenarios 1-3)

- CSCR and WSCR calculation results for **Scenario 1** indicate that the system strength is weak (WSCR=1.55 <2.0) when existing Phase 1 of renewable plants is connected to the system.

- CSCR and WSCR calculation results for **Scenarios 2 and 3** indicate that as long as there are at least three (3) Main conventional generation units are dispatched (in addition to all the existing conventional generation units), the system strength remains above the minimum 2.0 grid requirement.

Summary for Phases 1 & 2 (Scenarios 4-6)

- Adding future Phase 2 of renewable plants has a negative impact on the overall system strength. It can be observed that the CSCR values decrease between 35% to 44% (depending on the scenario) and the WCSR values decrease between 11% to 22% (depending on the scenario) when future Phase 2 is added.

- Both CSCR and WSCR results meet the minimum 2.0 criteria if all four (4) Main conventional generation units are dispatched (in addition to all the existing conventional generation units).

Conclusions

- System strength criteria is met (CSCR and WSCR >=2.0) when existing Phase 1 is connected as long as three of the Main conventional units are in service.

- Adding future Phase 2 has a negative impact on the overall system strength. It can be observed that CSCR values decrease 40% (depending on the scenario) and the WSCR values decrease 22% (depending on the scenario) when future Phase 2 is added.

Conclusions (Cont.)

- The islanded grid does not meet the system strength criteria (i.e., both CSCR and WSCR < 2.0) when both existing Phase 1 and future Phase 2 are connected, and there are less than three Main conventional units in service.

- In general, it can be observed that the system strength increases if the number of conventional generating units (including the Main units) that are in service increase when both existing and future Phases 1 and 2 of the renewable generation projects are connected.

Future Work

- Study results for all six scenarios indicate that the worst-case condition for CSCR and WSCR is observed in Scenario 4 when future Phase 2 is added, and all the Main conventional generator units are out of service.

- It is then recommended to conduct a **synchronous condenser sizing study** to determine its appropriate location and rating to meet the CSCR and WSCR >=2.0 criteria due of the addition of the new renewable Phases 2 and lack of conventional generators in the system.

- Another possibility to be considered is to convert some of the existing conventional generation units into synchronous condensers to meet the minimum CSCR and WSCR requirement.

References

[1] Integrating Inverter-Based Resources into Low Short Circuit Strength Systems. Reliability Guideline. NERC. December 2017.

[2] Modeling Inverter-Based Resources in Short-Circuit Programs. EPRI. October 2020.

[3] Stable Renewable Plant Voltage and Reactive Power Control. NERC ERSTF. June 11-12, 2014. GE Consulting.

QUESTIONS?