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Screening and Identification of Critical Locations in the New England Power Network with High Percentage of Inverter Based Resources

S. DUTTA*, Q. ZHANG*, D. RAMASUBRAMANIAN*, Q. ZHANG+, X. LUO+, X. FANG+, F. IBRAHIM+, J. PLOOF+
***Electric Power Research Institute, +Independent System Operator – New England**
USA

SUMMARY

The Independent System Operator of New England (ISO-NE) has a significant number of installations of transmission connected inverter-based resources (IBR), especially transmission connected wind generation. These resources are asynchronously connected to the grid through a power electronics interface. Most of the control systems of these IBRs rely on the voltage magnitude and angle at their terminals to largely be unaffected by its current injection for stable operation. In this context, the electrical system strength refers to the sensitivity of the inverter-based resources terminal voltage to variations of current injections. In a strong system, this sensitivity is low. In a weak system, this sensitivity is higher. From transmission planning and operations perspective, quantification of system strength is useful to identify potential issues. Further, a challenge is that for weak grid conditions, positive sequence models typically used in transmission planning tools like Siemens PTI PSS®E may be inadequate as they possibly cannot appropriately simulate the control interactions that may lead to system instability issues.

This paper performs an analysis to identify low short circuit strength buses for future scenarios of the ISO-NE footprint and gain insights into where low system strength issues could arise. Further, dynamic performance at few buses is evaluated by applying deep faults and assessing stability using time domain simulations. The effectiveness of using newer and more robust positive sequence simulation model in stability analyses is also ascertained.

KEYWORDS

Low system strength, positive sequence simulations, numerical robustness.

dramasubramanian@epri.com

INTRODUCTION

The Independent System Operator of New England (ISO-NE) has a significant number of installations of transmission connected inverter-based resources (IBR), especially transmission connected wind generation. These resources are asynchronously connected to the grid through a power electronics interface. Most of the control systems of these IBRs rely on the voltage magnitude and angle at their terminals to largely be unaffected by its current injection for stable operation. In this context, the electrical system strength refers to the sensitivity of the inverter-based resources terminal voltage to variations of current injections. In a strong system, this sensitivity is low. In a weak system, this sensitivity is higher. From transmission planning and operations perspective, quantification of system strength is useful to identify potential issues. Further, a challenge is that for weak grid conditions, positive sequence models typically used in transmission planning tools like Siemens PTI PSS®E may be inadequate as they possibly cannot appropriately simulate the control interactions that may lead to system instability issues.

This paper describes a study conducted in two phases to assess the severity of risks posed due to potential reduction in grid strength and to verify the ability to observe such risks in a traditional positive sequence simulation environment. Evaluation of the system strength in the network is carried out using the Grid Strength Assessment Tool (GSAT) [1] that has been developed by the Electric Power Research Institute (EPRI) as part of its annual research program. The GSAT evaluates a variety of different metrics related to system strength such as short circuit ratio (SCR) at the point of interconnection (POI) of an IBR, weighted and composite SCRs for a group of electrically close IBRs. These steady state metrics help evaluate the relative size of an IBR (or group of IBRs) in relation to the rest of the network which can subsequently provide a high-level notion of the capability of an IBR to maintain stability. However, since these metrics only utilize the steady state fundamental frequency impedance of the network and do not consider the IBR operating point and control parameters, the information that can be inferred from these metrics are to be carefully considered and it can be challenging to apply thresholds to demarcate between good and bad response from an IBR.

To help further obtain information regarding the potential behavior of IBRs in the power system, GSAT evaluates an advanced metric developed by EPRI. This advanced metric, denoted by a notion of critical clearing time (CCT), is based on the power flow solution of the network and IBR device along with use of proportional and integral gains of a generic phase locked loop (PLL) and an AC voltage controller, if it exists in the subject IBR [2]. With this information, a trajectory of current is assumed for the IBR device and clearing time for a fault at the POI is computed for each IBR to give an indication of how fast the fault needs to be cleared before the inverter at the bus can become unstable. As will be shown in the paper, the steady state SCR metrics and the advanced CCT metric complement each other for grid strength assessment and are recommended to be applied together.

In the first step of the analysis, GSAT is used to identify regions of low system strength. Existing positive sequence dynamic models can have numerical robustness limitations in regions of low system strength. Therefore, once regions of the network have been identified by GSAT, the next step of the evaluation procedure is to use improved positive sequence dynamic models to evaluate the dynamic behavior of the network at the identified regions. These improved models, labeled as REGC_C [3] in the simulation software, have been designed to be numerically robust at low system strength conditions. Further, this model has a representation of the inner current control loop and a phase locked loop that is typically present in IBRs. As a result of this representation, the model has an increased chance of providing insight into potential oscillatory issues that can arise with IBRs and low system strength conditions.

The rest of the paper is outlined with first outlining the results of the system strength evaluation followed by results of dynamic studies using the new models. Concluding remarks are then provided.

SYSTEM STRENGTH EVALUATION

Input data setup

Two power flow cases that represent 2026 scenarios of the ISO-NE footprint were provided by the ISO-NE, one for peak load condition and the other for light load condition. The power dispatch for the IBRs is different but each case has the same number of online IBRs in the region of interest for the study (31 in total) in the ISO-NE area, with a total of capacity of 8169MW. Since the goal is to evaluate the system strength metrics at the transmission connection point for each IBR rather than the generator terminals, the POI bus of each IBR needs to be identified. The POI bus is designated to be the first high voltage bus that comes out of the IBR branch beyond which the connections are not radial ahead of it. Multiple IBRs can share a common POI bus. In that case, the system strength metrics calculation at the POI bus takes all the IBRs connected to the same POI into consideration. The list of POIs identified for the 31 IBRs is shown in Table 1. An index is assigned to each POI bus as well as for each IBR for convenience. Since this case represents a future scenario, it is possible that the not all IBR projects in this list may actually interconnect to the network.

Table 1: POIs identified for online IBRs in the ISO-NE area

POI Bus Index	IBR Bus Index	Mbase (MVA)	POI Bus Index	IBR Bus Index	Mbase (MVA)
5	5	288	11	24	506
6	6	484	11	25	506
6	7	484	12	26	184
6	33	437	12	27	192
6	34	437	12	28	184
7	8	173	12	29	192
8	9	218	13	30	336
8	10	202	13	31	336
8	11	202	13	32	336
8	12	210	14	35	172
9	13	290	10	19	204
10	14	216	10	20	192
10	15	224	10	21	192
10	16	216	10	22	204
10	17	224	10	23	204
10	18	204			

Two basic input text files required for carrying out an analysis in GSAT are referred as *POI file* and *IBR file* in this paper for simplicity. In the *POI file*, the POI buses for each IBR and the corresponding MVA capacity of the IBR for the calculation of system strength metrics are entered. Note that MVA capacity is used instead of the actual power output to get conservative (i.e., the lowest possible) assessments on the SCR. In the *IBR file*, dynamic model parameters from the corresponding dynamic model data are used for the calculation of the advanced CCT metric.

Results

The SCRs of the POI buses for both the peak load case and the light load case are tabulated in Table 2 and visualized in Figure 1. These results show that the SCRs in the light load case are lower than those in the peak load case. This result is also intuitive as in the light load case, there are lesser number of committed synchronous machines and potentially an increased number of committed IBRs (by design and due to the non-coincidence of IBR generation output to load). In the present practice, a bus may be classified as “weak” if its SCR is below 5 and may be classified as “very weak” if its SCR is below 3.0. Based on the SCR results, POIs 10 and 13 are weak in the peak load case and become very weak in the light load case. POIs 6, 8, 9, 11 and 12 are very close to weak in the peak load case and become weak in the light load case. POIs 5, 7 and 14 are relatively strong buses in both cases with SCRs much higher than the threshold value of 5.

Table 2: SCR evaluated at the POI across both peak load and light load case

POI Bus Index	POI Bus kV	Total IBR MVA on POI Bus	SCR (Peak load)	SCR (Light load)
5	345	288	77.4	33.2
6	345	1842	6.1	3.4
7	115	173	20.8	15.9
8	115	832	5.7	4.3
9	115	290	5.6	4.5
10	345	2080	4.6	2.7
11	115	1012	5.2	3.7
12	115	752	5.1	4.6
13	220	1008	4.5	2.9
14	115	172	38.0	25.8

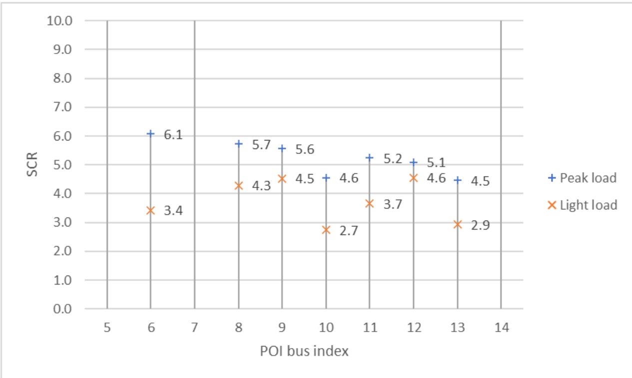


Figure 1: Visual representation of the SCR evaluated at the POI buses across peak and light load case

The advanced metric represented as CCTs of the IBRs for both cases are shown in Figure 2. It is worth mentioning that the advanced CCT metric is only a high-level screening metric that is intended to give an indication of how likely the IBR is to go unstable after a fault at the POI. It should not be understood as the precise CCT that is defined for the synchronous machines which indicates the time that the machine will go transiently unstable after a fault, if the fault is not cleared within the CCT. The advanced CCT is a new screening metric developed based on power flow conditions and generic dynamic model parameters without running a dynamic simulation [2]. For the IBRs that are identified to have low advanced CCT values, dynamic simulation in positive sequence domain is recommended to be carried out to further inspect their stability performance.

The typical threshold for the advanced CCT metric is recommended to be based upon the available protection clearing time at the POI buses. So, for example, if the fastest protection clearing time on the POI bus is 3 cycles, then this can be considered as a threshold. Any IBR whose value of advanced CCT falls lower than this value (which would also be indicated as a negative stability margin value by GSAT) can be identified for further study. Here, sensitivity studies can be performed. For example, if the value of advanced CCT is greater than faster protection clearing time, but lower than stuck breaker clearing time, this could become a sensitivity study. From Figure 2, it can be observed that most IBRs have smaller CCT values in the light load case as compared to the peak load case. IBRs 30, 31 and 32 on POI 13 have small CCT values in both cases (~6 cycles in the peak load case and ~4 cycles in the light load case). This is an indication that they can be prone to stability issues upon occurrence of faults and need to be investigated further with dynamic simulations and can possibly also require further detailed electromagnetic transient (EMT) analysis.

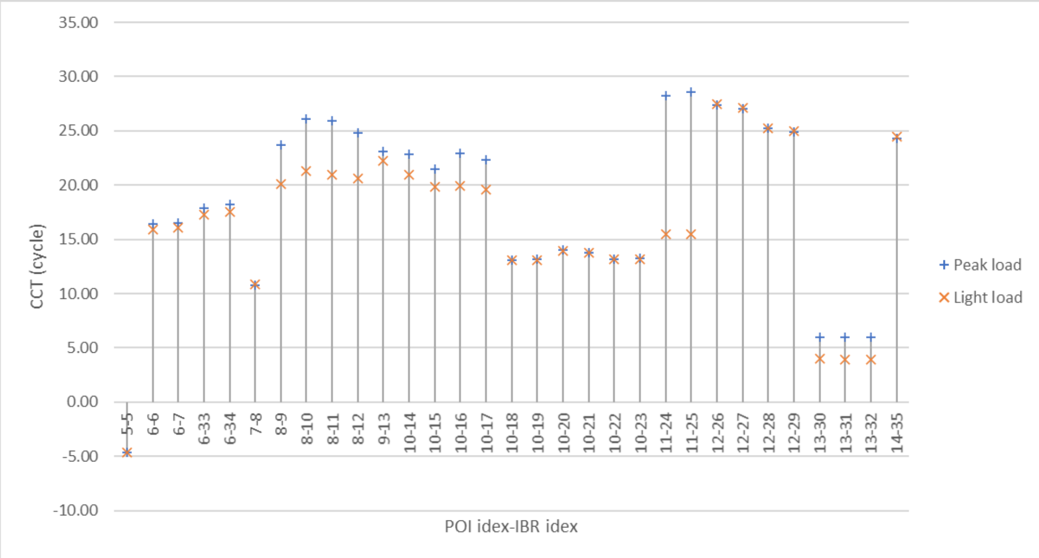


Figure 2: Advanced metric represented as CCT for pairs of POI-IBR index

It should be mentioned that SCR and advanced CCT are not always positively correlated since the advanced CCT also depends on the system operating point, such as active power output, reactive power output and complex voltage. For example, the SCR of POI 10 is slightly lower than that of POI 13 in light load case; however, the advanced CCT of the ten IBRs on POI 10 are all above 10 cycles, which are larger than those of the three IBRs on POI 13. According to [2], an IBR with higher real power generation is more prone to transient instability. Meanwhile, in normal operation conditions, generating (absorbing) reactive power together with real power improves (worsens) transient stability of the IBR. Based on these two conclusions, the higher values of advanced CCT for the IBRs on POI 10 as compared to those on POI 13 can be explained as follows. From Table 3, IBR 14 through 17 on POI 10 have much lower active power output (~35% of P_{max}) as compared to IBRs 30, 31 and 32 on POI 13 (100% of P_{max}) in the peak load case. Although IBRs 18 through 23 are also loaded to 100% of their P_{max}, their reactive power output is much higher than those of IBRs 30, 31 and 32. Both facts result in higher CCT values of IBRs on POI 10 as compared to those on POI 13. In the light load case, similar conclusions can be made – although all IBRs are loaded to their P_{max}, the IBRs on POI 10 are all generating reactive power whereas those on POI 13 are all absorbing reactive power, which makes the IBRs on POI 13 more vulnerable to transient stability issues. This is in some way like the stability performance of a synchronous machine, where a machine that is under-excited (absorbs reactive power) tends to be more vulnerable to stability issues as compared to those that are over-excited (inject reactive power).

Table 3: Operating point of IBRs on POI 10 and POI 13

POI Bus Index	IBR index	Pmax (MW)	Peak load case		Light load case	
			Pgen (MW)	Qgen (Mvar)	Pgen (MW)	Qgen (Mvar)
10	14	226.8	76.8	-21.6	226.8	33.0
10	15	235.2	85.2	-21.6	235.2	33.0
10	16	226.8	76.8	6.9	226.8	27.8
10	17	235.2	85.2	6.9	235.2	27.8

10	18	211.8	211.8	51.6	211.8	51.6
10	19	211.8	211.8	51.6	211.8	51.6
10	20	199.4	199.4	48.6	199.4	48.6
10	21	199.4	199.4	51.1	199.4	51.1
10	22	211.8	211.8	54.3	211.8	54.3
10	23	211.8	211.8	54.3	211.8	54.3
13	30	342.7	342.7	15.3	342.7	-32.8
13	31	342.7	342.7	15.3	342.7	-35.2
13	32	342.7	342.7	15.3	342.7	-35.2

Another observation from Figure 2 is that IBR 5 on POI 5 has a negative CCT value. It should be noted that this IBR is set to operate in a reactive power control mode, instead of voltage control mode. As a result, there can be an expectation that the device could have a larger potential for instability especially upon the occurrence of a fault.

To observe the impact of system topology changes on the system strength metrics, a list of 13 maintenance outages, either *n-1* or *n-k*, was considered. The maintenance outage is assumed to be in place before the system strength metrics are evaluated. Therefore, each maintenance outage corresponds to a different power flow scenario. The variation in SCRs for these maintenance outages across the peak and the light load case is shown in Figure 3 and Figure 4 respectively. It can be observed that maintenance outage 4 has the most significant impact on both cases. In the peak load case, it weakens POI 6 by a significant amount of 65% and POI 8 by 23%. In the light load case, it weakens a broad range of POIs (POIs 6, 9, 10, 11, 12 and 13) by 20-30%. Another observation is that maintenance outage 4 decreases the SCR of POI 8 in the peak load case, whereas it increases the SCR of POI 8 in the light load case. The increase of SCR on POI 8 is not expected. Further investigation indicates that this could be due to the problem that the power flow case diverges with maintenance outage 4 in the light load case, and as a result, voltages across the network are invalid values and should not have been used. Following the conduction of this study, this divergence in the power flow case has subsequently been corrected.

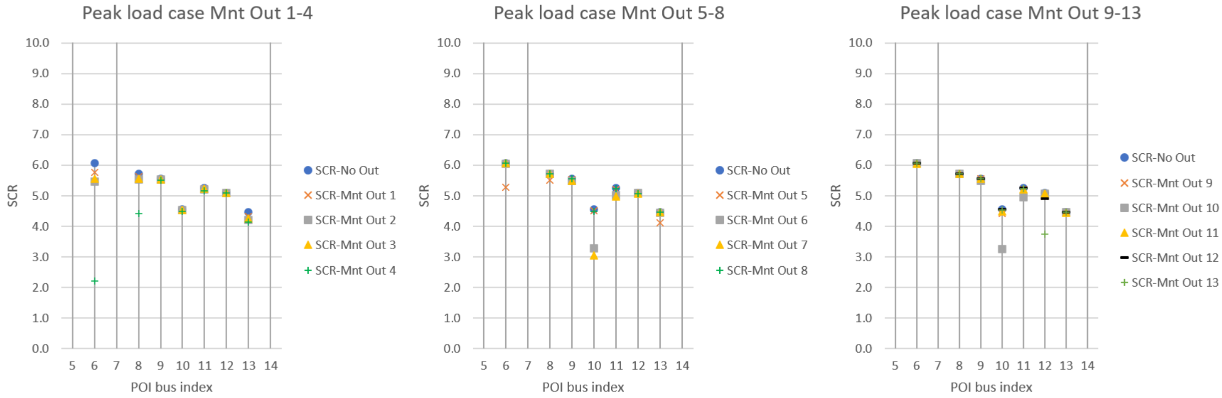


Figure 3: SCRs of the peak load case with maintenance outages considered

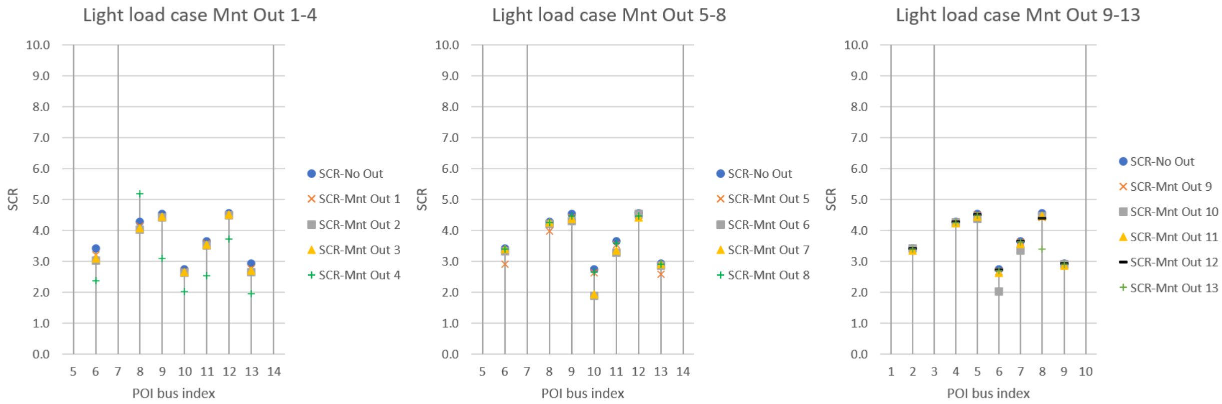


Figure 4: SCRs of the light load case with maintenance outages considered

The difference of the advanced CCT with maintenance outages in the peak load case with respect to the base case values are shown in Figure 5. The values are shown in percentage of differences since the absolute changes in advanced CCT values are very small for all IBRs. As can be seen from these results, maintenance outage 4 has the most impact to the CCT values in terms of percentage variation. This is consistent with the finding on SCR reduction caused by this maintenance outage. For the peak load case, the advanced CCT of IBRs 9, 10, 11 and 12 on POI 8 are reduced by about 10-15%. However, as mentioned above, the absolute value changes are very small. For example, with an 15% reduction, the advanced CCT for IBR 9 changes from 23.9 cycles to 19.9 cycles, which is still well within the stable region. At few locations, there is an increase in CCT which can be attributed to the change in reactive power flow at the location due to the outage. For the light load case, since maintenance outage 4 causes a divergence in the power flow solution, no results are obtained. Although advanced CCTs are not available in this case, it is still an indication of the high impact of maintenance outage 4 on the light load case. Other maintenance outages other than the maintenance outage 4 (Mnt Out 4) do not cause significant variations in the advanced CCT values for both cases (less than 4% difference with respect to the base cases). A point to note here is GSAT evaluates CCT from the perspective of a large signal change (i.e., fault applied at the POI). Hence, the assumption is that the pre-fault operating point is a stable operating point from a small signal perspective. It is possible that these maintenance outages can result in small signal instability, which may require further investigation.

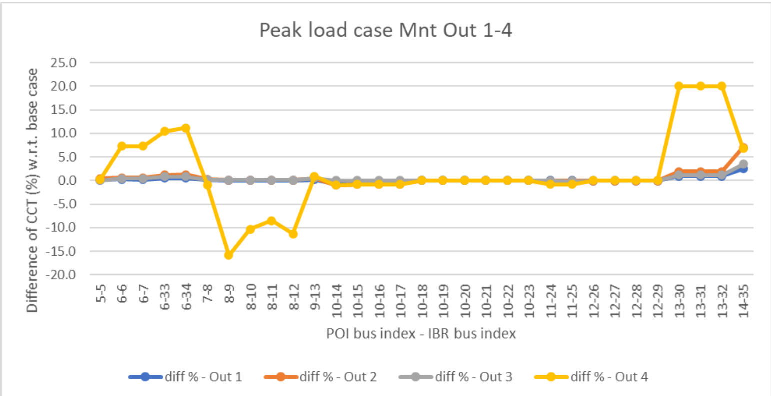


Figure 5: Difference in advanced CCT values with respect to the base for maintenance outages 1 - 4 on the peak load case

In addition to change in system topology, the system strength metrics (especially the advanced metric) was also evaluated over selections of different controller gains. One example is the change in the metric depending on the values of PLL gains. Theoretical analysis that investigates the influence of the proportional and integral (PI) gains of the PLL (kpPLL and kiPLL) and those of the outer voltage controller (kvp and kvi) on the advanced CCT metric is provided in [2]. Designing gains of the PLL control loop can be highly specialized. Therefore, conducting sensitivity analysis around the gains can provide insights on their potential impact on the grid stability performance. For brevity, the results of only one sensitivity analysis are discussed in this paper, as shown in Figure 6. It is seen that a smaller value of gain increases the advanced CCT and improves the transient stability of the IBR, and vice versa. From [2], it is known that the parameter has contradicting effects on PLL transient stability during and after the fault. During the fault, use of a large value of gain can adversely affect the PLL transient stability as it can cause angle to spread. However, after the fault is cleared, larger value of gain helps to dissipate the control effort gained in the PLL integrator during the fault by converting it into a damping term, which is beneficial to the PLL transient stability. Based on results obtained, it can be concluded that in this study, the impact of gain is dominated by the "during fault" time period, in which a larger value has adverse impact to the transient stability of the PLL.

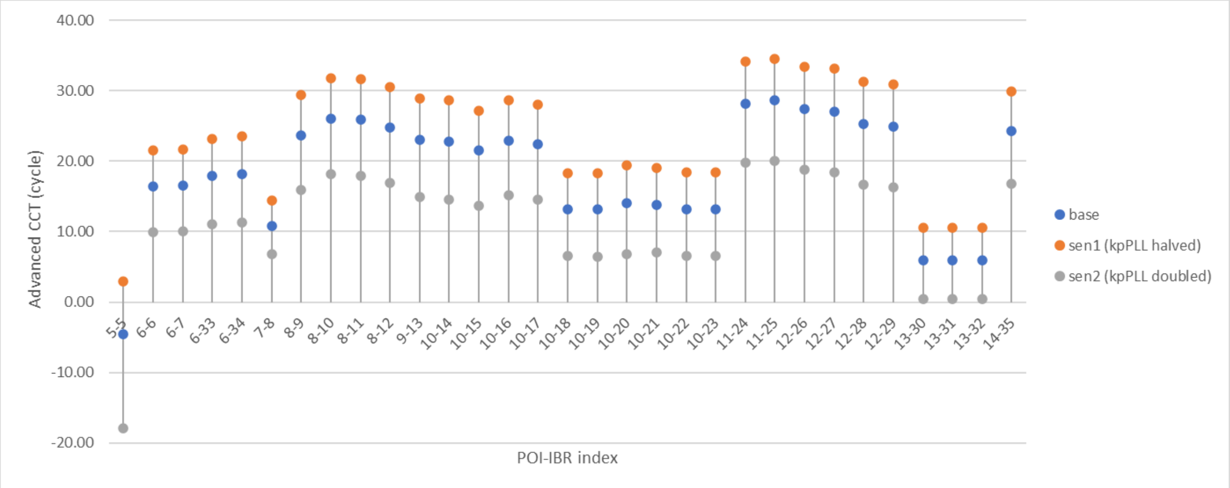


Figure 6: Advanced CCT values of the IBRs in the peak load case with sensitivity around parameters values of the PLL

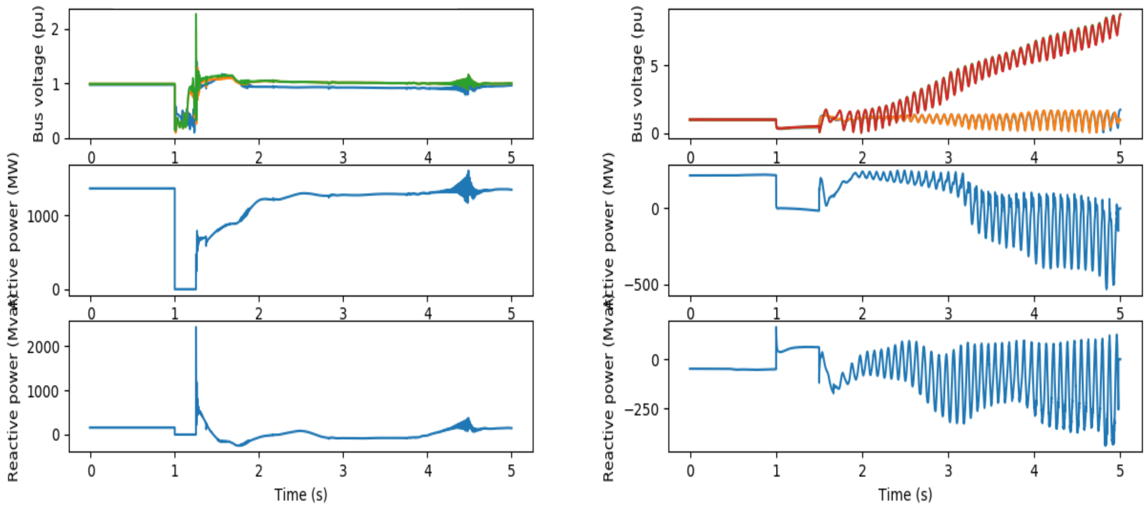
Based on the results of the system strength screening, few POI locations were identified for further dynamic analysis as discussed in the following section.

TIME DOMAIN DYNAMIC ANALYSIS

The time domain evaluation was carried out in a positive sequence simulation environment. The aim of the analysis was not only to verify the results from the system strength screening effort, but also to evaluate the applicability of a new numerically robust simulation model named as REGC_C [3]. The dynamic simulations were run in two sets. In the first round, existing IBR generator models were kept as-is. These were a combination of WECC generic REGC_A models and user defined models (UDMs). In the second set of simulations, 29 IBR generators connected to the above-mentioned POI buses were replaced with REGC_C. When replacing the UDMs, in addition to REGC_C model, REEC (exciter) and REPC (plant controller) models were also added to provide the functionalities of the UDM. The two sets of dynamic simulations with different dynamic models were performed to compare the effectiveness of the newer REGC_C in representing dynamic performance of IBRs against existing models. It should be noted that this study was conducted from the perspective of evaluating the potential efficiency of newer robust positive sequence models. Further, a detailed comparison of REGC_C performance against the provided UDM was not carried out.

(i) Analyses at POI Bus 10

The POI Bus10 is a 345kV bus, where 10 IBRs are interconnected. In the base case, the short circuit MVA at this bus is 8121MVA. From GSAT analyses, the critical clearing time for the IBRs connected to the POI ranges between 15-22 cycles. When dynamic simulations are run by using existing models i.e., REGC_A and UDM, the observation made is shown with Figure 7:(a). For a 17cycle fault duration, voltages and power response show stable behavior. While the response is stable immediately after fault clearance, a separate minor disturbance seems to occur at around t=3s. It is believed to be caused by the change of the state (exiting the fault mode) of the power plant controller UDM. Similar phenomena were observed in the simulations on other concerned POIs. This seeming distortion does not necessarily indicate instability of the IBRs or the system. As such, though it could be further minimized by certain parameter tuning, it was not pursued in this study. Further, it was not possible to increase the fault duration further since for a 18-cycle fault duration, the positive sequence simulation crashed. The cause of software crash is possibly numerical but investigating it was beyond the scope of this study.



(a) **(b)**

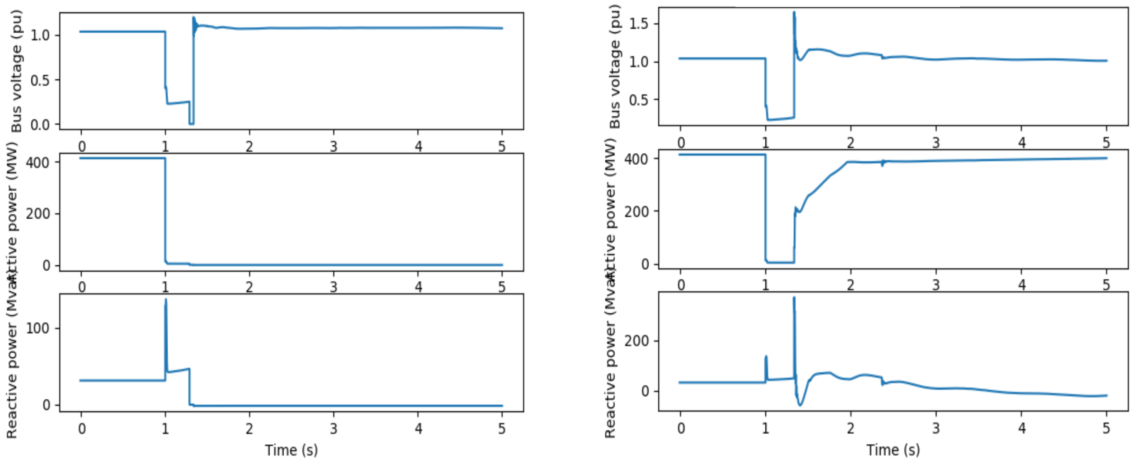
Figure 7: At POI bus 10, V, P, and Q with (a) 17cycle fault duration with existing models (b) 30cycle fault duration with REGC_C model

When the dynamic simulations are performed after replacing the IBR generator models with the REGC_C models, the improved numerical robustness of the model is clearly observed from Figure 7:(b), since longer faults can be applied without software crashes. In addition, as can be observed with Figure 7:(b), even an unstable behavior can be observed for a 30cycle fault. Since a 22-cycle response is stable, the critical clearing time is expected to be between 22 and 30 cycles which is close to the GSAT results. Clearly, the REGC_C models were better in evaluating weak grid instability for this POI bus.

(ii) Analyses at POI Bus 6

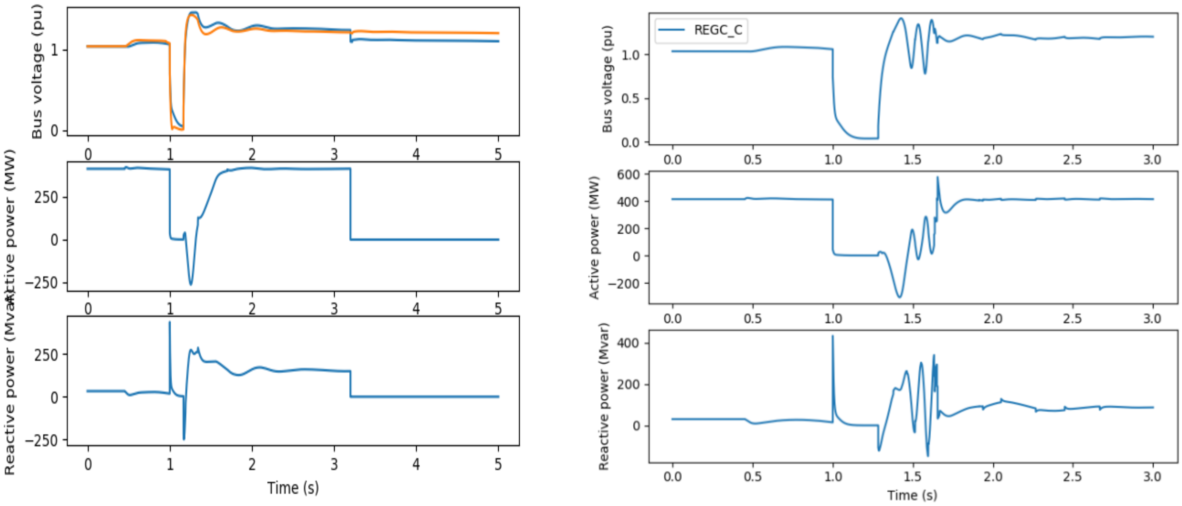
The POI Bus 6 is a 115kV bus to which 4 IBRs are interconnected. Based on GSAT, the CCT of IBRs at this POI is ~10-20 cycles. The short circuit MVA is 4882MVA. With existing models i.e., REGC_A and UDMs, the observation is shown in Figure 8. For the 20-cycle fault, the wind plants tripped due to instantaneous frequency protection. Since the actual frequency protection most likely does not act exactly as the simulation model behaves, the simulation was re-run with the instantaneous frequency protection disabled to examine the overall stability if the IBR remains connected. This approach, if applicable, was used across analyses of other POIs. In this case however, for a fault duration of 25 cycles, the simulation crashed. Hence, faults longer than 25 cycles could not be applied.

When the dynamic simulations are performed after replacing the IBR generator models with the REGC_C models, the following observations are made, as shown in Figure 9. With these models, even on a 10-cycle fault, the wind plants tripped on frequency protection settings. The frequency relay is activated because frequency reaches 63.8Hz. Frequency trip relays at both IBR units are subsequently disabled. Response is unstable at 17-cycles which is in the range predicted by GSAT results. Hence, at Bus 6 POI the GSAT results were validated using the REGC_C models.



(a) **(b)**

Figure 8: At POI bus 6, V, P, Q with (a) 20-cycle (freq protection) (b) 20-cycle (no freq protection) fault duration

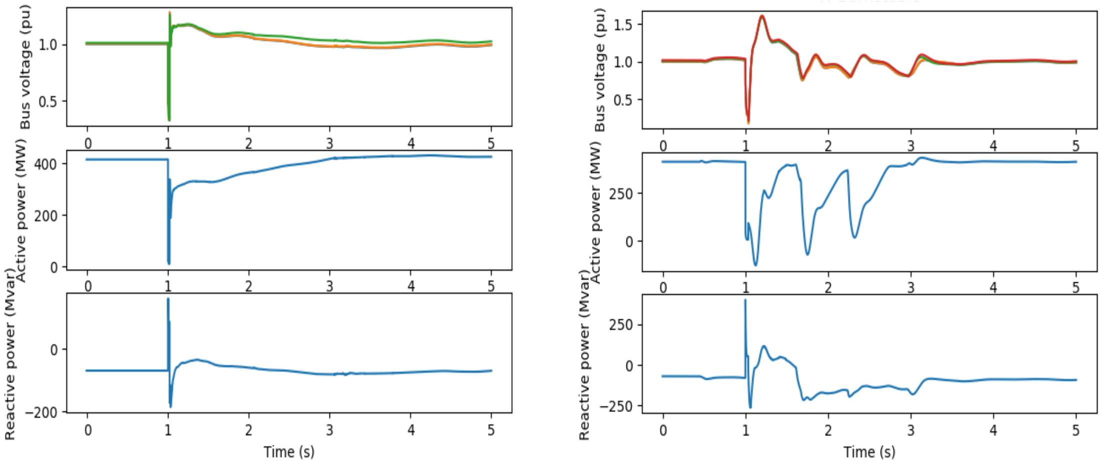


(a) **(b)**

Figure 9: At POI bus 6, V, P, Q with (a) 15-cycle (b) 17-cycle fault duration

(iii) Analyses at POI Bus 8

The POI Bus 8 is a 345kV bus to which 4 IBR generators are interconnected. The SCMVA measured at the bus is 7572MVA and critical clearing time based on GSAT is ~10-12 cycles. With existing models i.e., REGC_A and UDMs, the simulation result is shown in Figure 10 (a). For the 1-cycle fault, a stable response was observed but for longer fault duration the wind plants tripped. With REGC_C models, the observation made is shown in Figure 10 (b). The simulations for 1 and 2 cycle fault duration showed significant oscillations in power and voltage before settling. However, at 5 cycle fault duration, the wind plants tripped. For this particular POI, the GSAT results could not be correctly verified since the wind plants tripped before the critical clearing time could be determined by increasing the fault duration. However, the use of the REGC_C model potentially allows for improved numerical robustness of results. Here, the intention is not to state that the UDM models should be outright replaced with generic models. However, it is possible that the internal structure of the UDM models could be improved based on a structure similar to the REGC_C model structure that allowed for improved numerical robustness.

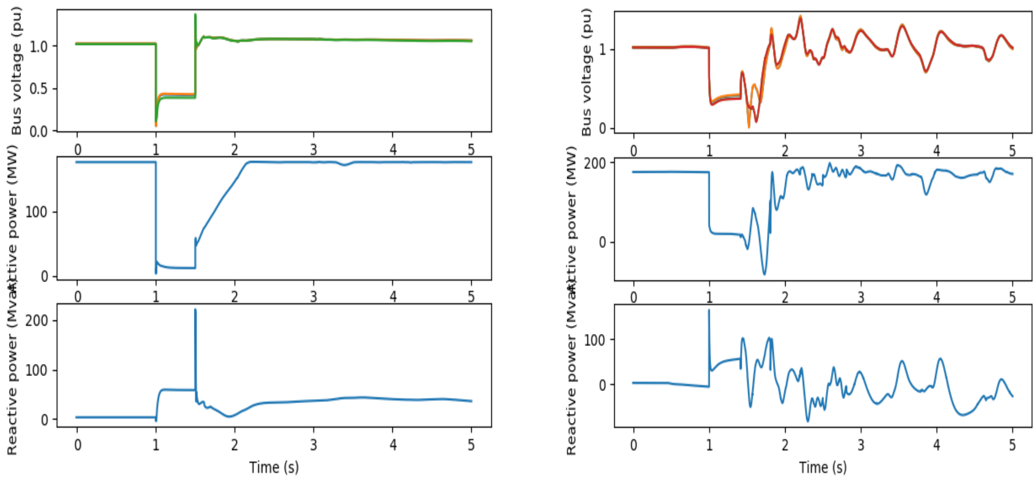


(a) **(b)**

Figure 10: At POI bus 8, V, P, Q with (a) 1-cycle fault duration and existing models (b) 2-cycle fault duration and REGC_C models

(iv) Analyses at POI Bus 12

The POI Bus 12 is a 115kV bus with four IBR generators interconnected to it. The SCMVA at this bus is 4329MVA and critical clearing time based on GSAT is ~25-30 cycles. Dynamic simulations based on existing models are not able to show any instability even when the fault duration is increased to a large value, as shown in Figure 11 (a).



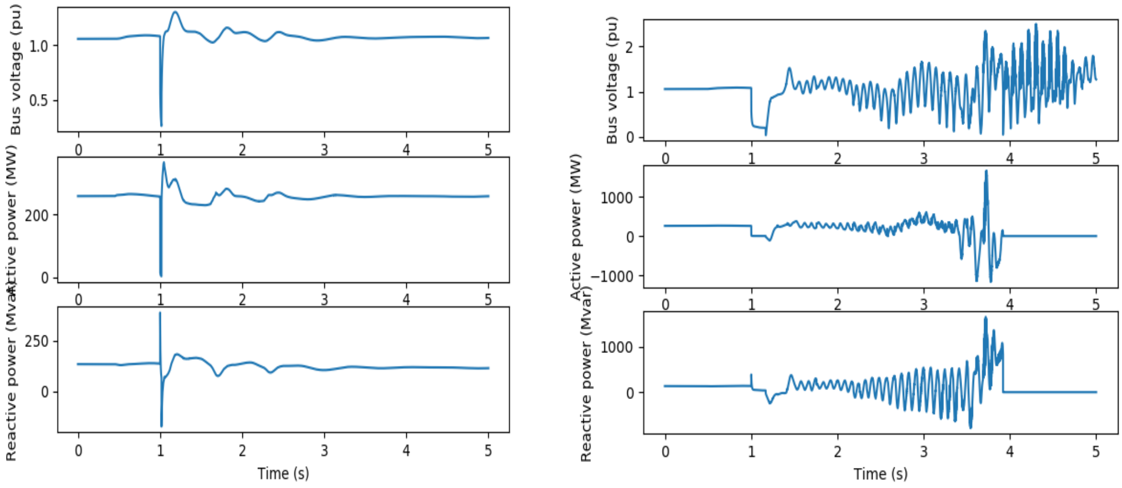
(a) **(b)**

Figure 11: At POI bus 12, V, P, Q with (a) 30-cycle fault duration and existing model (b) 25-cycle fault duration with REGC_C model

However, when the simulations are run by replacing the existing models with REGC_C, the observation made is shown in Figure 11 (b). Instability can be observed clearly with oscillatory behavior for fault duration greater than 25 cycles, which validates the findings of GSAT. Here it should be mentioned that the existing generic models (such as REGC_A) assume an ideal phase locked loop and do not represent the dynamics of the inner current control loop. When the model is replaced with the REGC_C model, the backend electrical control model is still retained as the same model. Hence, only the REGC_A model is replaced with the REGC_C model. A sensitivity study on the values of PLL gains could be carried out to identify values that could result in a stable operation for longer duration faults.

(v) Analyses at POI Bus 5

The POI Bus 5 is a 345kV bus. The SCMVA is 11652 at this bus. GSAT estimate for CCT at this bus is -5. Attempts of simulations with existing models even for 1 cycle fault results in a simulation crash. A negative value of CCT from GSAT immediately indicates a location where further analysis is required. This is because a negative value from GSAT is observed when an analytical solution is not possible to be obtained. Simulations with REGC_C model do not crash PSSE, showing numerical robustness of REGC_C models. In addition, as shown in Figure 12, the instability is clearly observed at longer duration faults.



(a) **(b)**

Figure 12: V, P, Q with (a) 1-cycle (b) 10-cycle fault duration

A summary of the simulation observations is provided in Table 4.

Table 4: Comparison between GSAT, existing models, and REGC_C models

POI Bus	CCT from GSAT	Results using existing models	Results using REGC_C model
Bus 10	15-22	Simulation crashes at 18 cycle fault duration	30 cycle fault simulations can be run without crash but response deteriorates at >22 cycles. Oscillations observed
Bus 6	10-12	Simulation crashes for fault duration>1 cycle	Ran for >1 cycle. WP trips at around 5 cycles. Extreme power swing observed
Bus 8	10-20	Plant trips for a 20 cycle fault on frequency protection settings; on disabling protection, simulation crashes at 25cycle, no oscillations	Between15-17 cycles obtained with disabled frequency trip. For longer duration faults, although oscillatory instability does not occur, the model trips on over voltage, UDM model replaced with tuned REGC_C
Bus 12	25-30	No simulation crashes/oscillations/WP trips observed	Instability observed as oscillatory behavior at >= 25cycles
Bus 5	-5	Even a 1-cycle fault caused a simulation crash (3ph bolted fault cannot be applied)	Simulation doesn’t crash, instability identified when the fault duration is extended to 10 cycles

CONCLUSION

This paper discussed an analysis to identify low short circuit strength buses for future hypothetical scenarios of the ISO-NE footprint and insights were obtained on locations at which low system strength issues could arise. Further, dynamic performance at few locations has been evaluated by applying deep faults and assessing stability using time domain simulations. In doing so, the use and effectiveness of newer and more robust positive sequence simulation model in stability analyses is also ascertained.

The results show the method in which the Grid Strength Assessment Tool can be applied to screen for locations where inverter instability may arise. The various metrics evaluated in GSAT are recommended to be used in a complimentary manner. A low value of SCR can be used to trigger a study even if the CCT is high as the low value of SCR can point towards small signal interactions that may occur. A high value of SCR however does not mean that a study is not required as if the CCT is low, it could imply that the IBR device has lower fault ride through capability, which is to be investigated. In this manner, both metrics can be used. Further, by using the improved positive sequence simulation models for IBRs, more insight can be obtained in order to make a determination on when and where EMT studies are to be carried out. It is to be noted that the intention of the paper is not to suggest that EMT studies or user defined models are not needed. Rather, the intent is to showcase that improved positive sequence simulation models can be used as an additional step in the screening process to identify locations and scenarios where EMT studies are required. Further, it is possible that user defined models could be improved based on lessons learned while developing the improved positive sequence simulation models.

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