ASIA-PACIFIC
SOLAR RESEARCH CONFERENCE

A Case study and Experience On Large Scale Grid-Connected Solar Photovoltaic Plant Integration in Australia

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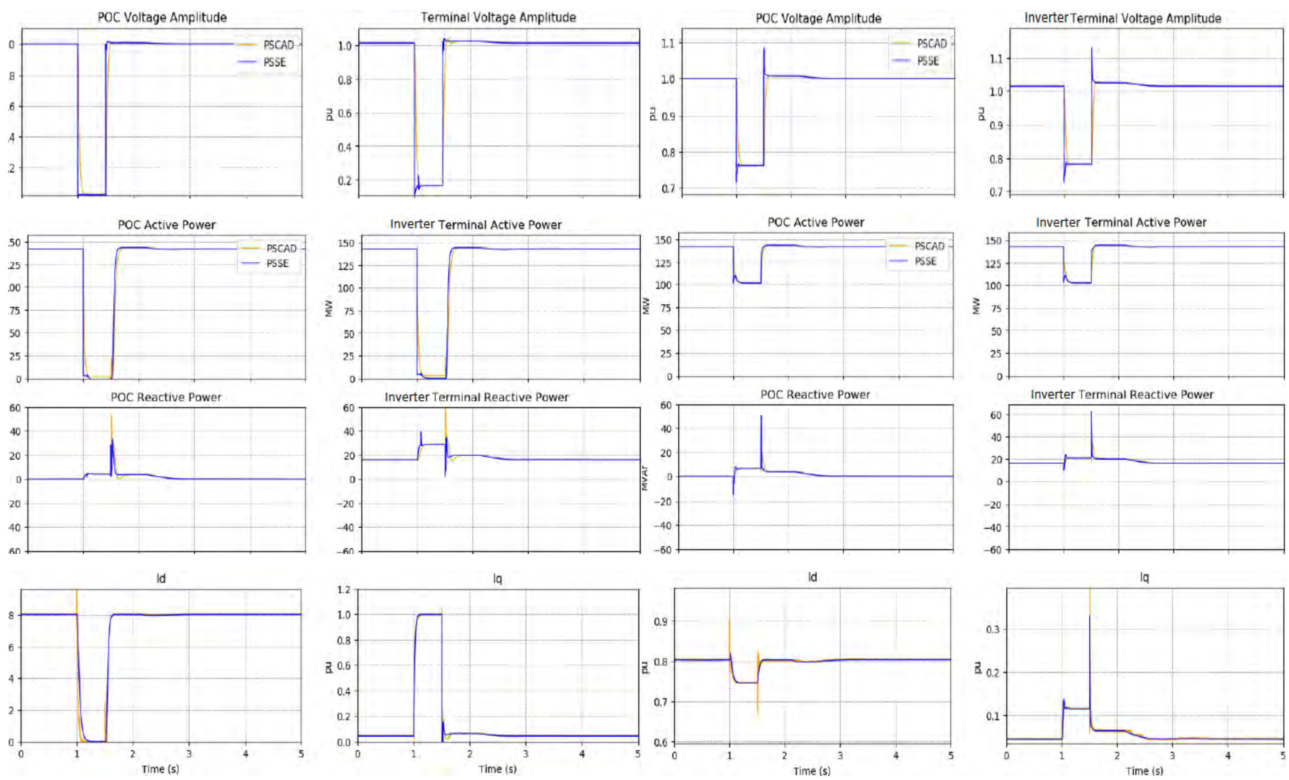
Abstract: The continuing cost reductions in solar technology, as well as international and national commitments to meet renewable energy target triggering an increasing number of solar photovoltaic (PV) installations into Australia's electricity grid. This rapid growth of the large-scale PV integration creates massive technical challenges to the grid operators and the regulators, as the grid is not ready to accommodate such uncertain generation source without any grid reinforcement. Compared to the Europe and the United States, Australia's vast size and low population density mean that locations with good solar resource tend to be on the end of the long electricity lines, or in a location on the electricity network that has a high impedance (or resistance/reactance). The integration of power electronic-based PV inverter units equipped with the complex fast-acting control system in such portions of the grid poses significant challenges on the system stability and security.

Australian Energy Market Operator (AEMO) has provided standard guidelines (AEMO, 2019) known as National Electricity Rules (NER) for performing numerous grid-connection studies prior connecting the solar farm to the grid to ensure that it can fulfill all the obligations. A critical component of the grid-connection studies is to assess the accuracy and robustness of the solar plant's computer-based models developed using both PSSE and PSCAD software in accordance to Generator Performance Standard (GPS) compliance based on NER. The benchmarking studies between the two models must be accurate enough to provide the confidence that the models are usable, numerically robust and represent the real plant under all expected operating conditions. Subsequently, an onsite model validation tests are carried on during different commissioning stages to evaluate the GPS compliance with the developed simulation model(s) against the real field-measured responses. The main technical challenges that inverter manufacturers are currently facing to integrate their central PV inverters into the Australian grid are as follows:

- In Australia, the electrical grid presents high impedance levels in some points where Short Circuit Ratio (SCR) is significantly low, and in some cases, the resistive component is more prevalent (i.e. X/R is very low). SCR is a measure of the strength of the grid to which the equipment is connected. When the resistive impedance (i.e. low X/R ratio) or a zero-impedance fault is applied at the point of connection, a negative active power peak may be overserved at the inverter terminal depending on SCR of the grid. It is due to Phase-Locked Loop (PLL) of the inverter loses synchronization with the grid voltage when the grid SCR is very low.
- The National Electricity Rules (NER) have imposed some strict limits for the power electronic-based asynchronous generators connecting to the grid, which are more generic regardless the characteristics of the point of connection (POC) of the grid. This creates substantial challenges for the inverter to fully comply with these rules. For example, an important component of the grid-connection studies is to assess the plant voltage control strategies to ensure the grid stability under all fault conditions. The NER mandatory requirement for the inverter to achieve the rise time and settling time of reactive current injection approximate to 40ms and 70ms during Low Voltage Ride Through (LVRT) and High Voltage Ride Through (HVRT) events under any equivalent grid fault impedances. The grid impedance has a lot of influence on the voltage dynamics. Lower SCR values will lead to a faster rise time but less damped response time, whereas higher SCR values will result in a faster damped but slower dynamic response.
- The benchmarking studies between the simulation environment and the field test results must be accurate enough to compliance with the registered GPS. It is often quite difficult to emulate the real grid behaviours into the simulation environment. As, the simulation models perform grid

studies considering a single machine interface model with a lumped grid impedance, while the real grid is connected to several lines and inverters, which make difficult to replicate the exact plant behaviours overlayed with the simulation results.

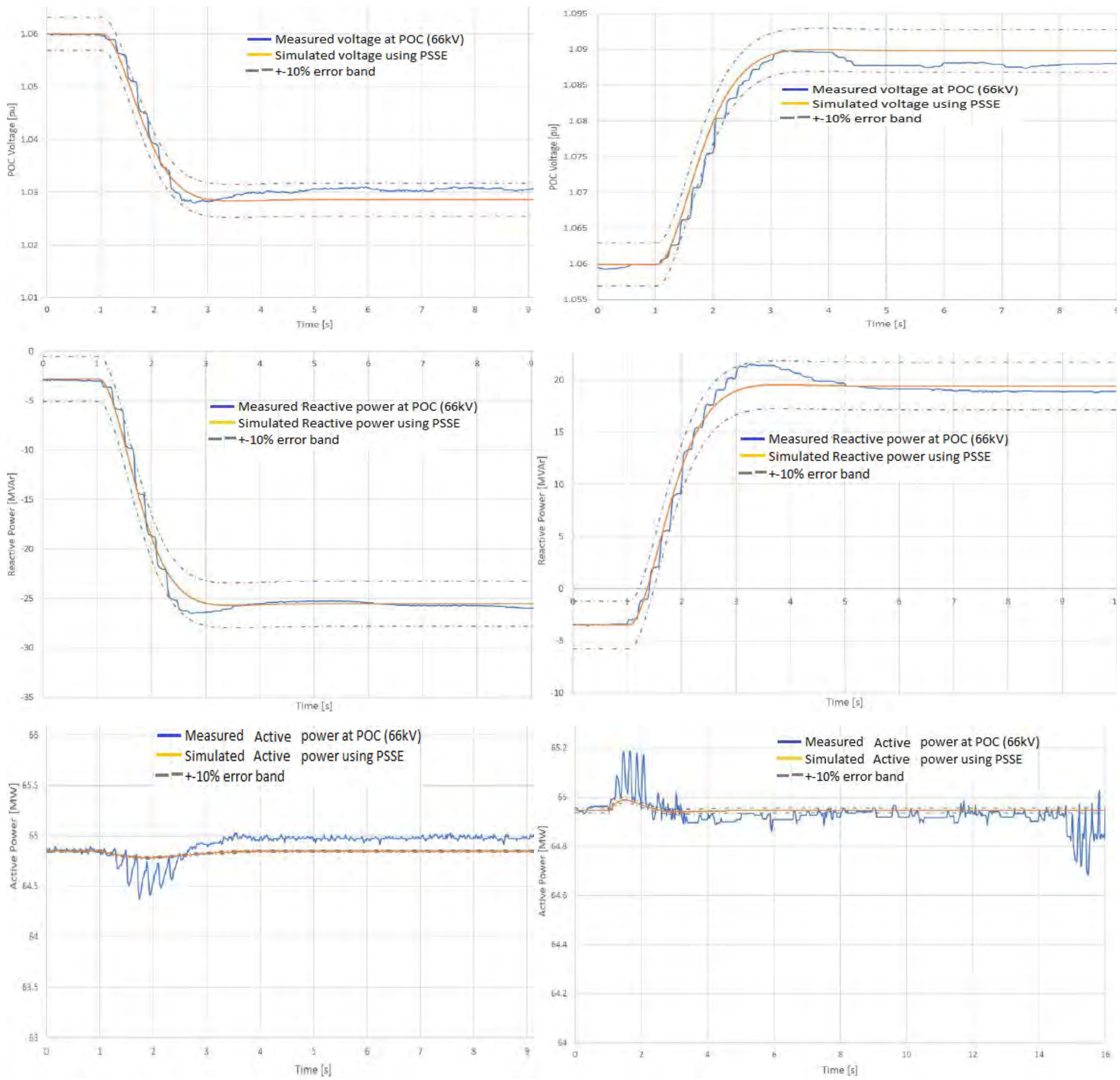
This paper highlights the performance of the Ingeteam's large-scale PV inverter against some national electricity rules in Australia following with a recent onsite model validation test. Ingeteam is one of the pioneers of the PV inverter manufacturer worldwide. Ingeteam's inverters are deployed in several large-scale PV plants in Australia. The developed novel voltage control techniques (Rahman, et al. 2018) inside the inverter and the power plant controller can smooth the voltage variations after the fault recovery as well as allow a prompt active and reactive power restoration regardless of any grid conditions. Figure. 1 demonstrates the inverter's LVRT performance during (a) a zero fault and (b) a shallow fault at POC with very low grid SCR and X/R values. It can be observed that the strict limits of the rise time (40ms) and settling time (70ms) are well maintained and no negative peak power is observed, as well as the accuracy of PSCAD and PSSE simulation results.



(a) residual voltage equal to zero% (b) residual voltage equal to 75%

Figure.1. 3-phase solid fault at POC with SCR =3 and X/R =3 using two different residual faults

Figure. 2 depicts two voltage control test results obtained from a real 87 MW PV plant. It can be seen from simulation results that ±5% voltage steps are applied at POC (66kV) to assess the plant's voltage control dynamic response. The response times are compliant with the agreed GPS. Also, the simulation results obtained from the PSSE correctly aligned with the measured field test results.



(a) -5% Vref change step applied (b) +5% Vref change step applied

Figure. 2. The V, Q, P response at POC to ±5% Vref change

References

AEMO, 2019, 'National Electricity Rules Version 123.' Available at: https://www.aemc.gov.au/sites/default/files/2019-07/National%20Electricity%20Rules%20Version%20123%20excluding%20Chapter%204A_0.pdf

Rahman M M., Alonso O., Agorreta Malumbres J L., Arricibita D., Gomez D. and Senosiain R G., 2018 'A Novel Fault Ride-Through Technique for Grid-Connected Large Scale Solar Photovoltaic Inverter', Asia-Pacific Solar Research Conference. Available at: http://apvi.org.au/solar-research-conference/wp-content/uploads/2018/11/196_DI_Rahman-M_2018.pdf