Large-Scale Solar PV in Australia
Experience, challenges and case studies.

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Introduction

ABOUT US

Ingeteam is an international corporation, with state of the art own technology on Rotating Machines, Power Electronics and Automation and control. We strive to understand our clients’ needs, to offer the most suitable and competitive products, systems and services.

Our people is key for our success. We apply Continuous Innovation to continuously streamline the operations, processes and organization, to stay lean, nimble, and be competitive. Our aspiration is to be a leading OEM in all the targeted business sectors.

KEY FIGURES

Present in 22 countries and new markets.

3,900 employees around the world.

5.5% of turnover invested in R&D every year. +500 persons.

More than 75 years in the electrical sector.

General offices and factories in SPAIN.

KEY SECTORS

Power electronics.

Electric Machines

Automation Solutions

O & M Services

Laboratories
APPLICATIONS

Wind Energy – 45 GW installed worldwide.

Solar PV – 15 GW installed worldwide.

Hydropower – 8.6 GW / new generation up to 80 MV.

Marine & Ports – More than 600 vessels propelled with our technology.

Power Transmission & Distribution – from 3.3 kV to 500 kV

Water – 900 MW installed pumping power.

Railway Traction – More than 400 traction units including High Speed Trains.

E-Mobility – More than 3500 charging stations.

Steel & Metals – More than 600 references worldwide.

Other sectors - Oil & Gas / Mining / Energy efficiency solutions/ others
Ingeteam Australia Ltd.

Based on Wollongong since Jan 2014.

1.5 GW solar PV installed.

Main commercial lines focus on Solar PV, Mining and grid solutions (STATCOMs, Storage, etc).

Services: commercial, project management, grid integration services, solar inverter and PPC modelling service, spare parts warehousing, etc.
Our experience in the last two years

- **Many projects** to deal in a very short time. Projects from 50 MW to 700 MW.

- **New NER rules.** Introduced new requirements difficult to satisfy under any condition or operation level.

- **Modelling is the key element to demonstrate NER compliance in all clauses.**

  **PSSE and PSCAD**

- **For commissioned plants**, the benchmarking between model and real measurements takes a long time due, among other reasons, the so many re-tunings and weather dependency.

- Essential for successful business: **collaborative work**

  EPC/DEVELOPER – CONSULTANCY – INGETEAM
1. Grid connection rules, simulation studies and compliances (part of R1 validation test)

1.1. One of the main challenges is to demonstrate through simulation studies that Inverter must achieve reactive current injection rise time ≤ 40ms and settling time ≤ 70ms during any LVRT/HVRT event.

- This rule is non-negotiable standard and more generic regardless of any equivalent fault impedance applied at the point of connection (POC).
- The grid impedance has a lot of influence on the inverter current dynamics. LVRT/HVRT events are usually very short. Therefore, it is impossible for the inverters to predict the grid equivalent impedance before the fault (at normal SCR), during the fault (SCR increases) and after the fault (SCR decreases due to N-1 condition).
- Trying to comply the max 40ms rise and 70ms settling time for all faults and grid conditions will lead instability problems. Particularly, for low SCR grid (weak grid):
  - a small current injection may vary the terminal voltage a lot, which will lead the PLL synchronization problem.
  - a lower SCR grid will lead to faster current injection but less damped response, whereas higher SCR grid will result in a faster damped but slower rise time.

Our approach to comply this particular rule:

Thanks to our engineers and their hard works, with our current simulation models (both PSCAD and PSSE) we can demonstrate better performance of our inverter and can comply the requirements of the rise time and settling time for most of the LVRT/HVRT cases.
Key challenges and experience

1. Grid connection rules, simulation studies and compliances (part of R1 validation test)

Below is an example demonstrates that our new simulation model can achieve reduced rise time of lq injection around 20ms during a three-phase to ground fault (which is an extreme fault scenario):
Another new requirement is that, the inverter must inject negative sequence reactive current during any asymmetrical fault conditions.

- There is no clear indication in NER to establish the sequence current ratios ($iq_{\text{neg}} / iq_{\text{pos}}$) during different types faults.
- High injection of negative sequence ($iq_{\text{neg}}$) will reduce the capability of active current injection ($id_{\text{pos}}$) during the fault.

Our approach to comply this particular rule:

We have introduced a dynamic sequence current ratio ($iq_{\text{neg}} / iq_{\text{pos}}$) calculation based on the types and depth of the faults.
Key challenges and experience

1. Grid connection rules, simulation studies and compliances (part of R1 validation test)

Below an example shows that the invert fault rides through the most adverse fault-scenario (two-phase-to-ground fault) applied at the POC.
1.3. Unrealistic fault scenarios are using to test the inverter performance, which are high resistive fault and three phase zero impedance fault at POC.

- Grid impedance is usually inductive, high resistive fault (which has very low X/R ratio) is not common and may not occur realistically. This type of fault test, inverter sees a large voltage phase angle changed during the fault and after the fault recovery which may cause the PLL synchronization error, particularly for low SCR grid.
Three phase fault with zero impedance at POC may rarely occur, which causes the plant to completely decouple from the grid and creates a large voltage angle changed to the inverter during the fault and after the fault. PLL may lose synchronization.

**Key challenges and experience**

1. Grid connection rules, simulation studies and compliances (part of R1 validation test)
1. Grid connection rules, simulation studies and compliances (part of R1 validation test)

1.4. Benchmarking issue between PSCAD and PSSE simulation results to validate the plant performance.

- PSCAD uses EMT simulation and PSSE uses RMS simulation environments. Both software has different simulation capabilities. Thus, the simulation results can vary a lot.

For example, for some particular cases (specially in low SCR grid condition), PSSE model can produce a large voltage spike during fault clearance, which will not observe in the PSCAD model and also in a real field. It is due to:

  - PSSE software uses instantaneous RMS values (voltage and current) to calculate the output P and Q.

  - Also, PSSE does not have DC side design capability while PSCAD has. Therefore, DC dynamic can’t include in the PSSE simulation, which can reduce the voltage spike.

Our approach to solve this problem:

To reduce the voltage spike during the fault recovery, we use filtering technique in the output power calculation in our PSSE model.
Key challenges and experience

1. Grid connection rules, simulation studies and compliances (part of R1 validation test)

Below figure shows an extreme fault case scenario (a 0.2pu residual voltage fault applied at POC) with considerable low SCR fault level. It can be seen, there is a large voltage spike at fault clearance in both inverter terminal and POC, and a reactive power spike at POC. It can be seen that there is a negligible peak in the inverter terminal reactive power, compared to the one observed at POC. The Q spike at POC is mainly due to the 15MVar capacitor bank.
Key challenges and experience

1. Grid connection rules, simulation studies and compliances (part of R1 validation test)

Below some obtained results from both our PSCAD and PSSE results to demonstrate the model results alignment. It can be seen that the models are perfectly aligned well.

An extreme three phase fault with residual 0% voltage applied at POC, SCR equal to 3 and X/R equal to 3.
2. Real field test performance and simulation model validation (part of R2 validation test)

2.1. Another big challenge is to validate the real field tests results and the simulation results to comply with the registered GPS

- In simulation studies with the PSCAD/PSSE, the simulation models use an aggregated inverter model and equivalent line impedance, whereas in the real field, there are many inverters connected to several line sections.
- The clouding event, temperature derating of inverter and also DC side design can’t be accurately model in the simulations.

Our approach to validate the test results:

Our simulation models can replicate closely the real field test results.

Below figure shows a real case study results obtained from a 87 MW PV plant and compared with the PSSE simulation results. A ±5% voltage steps are applied at POC (66kV) to assess the plant’s voltage control dynamic response. The benchmarking between the real field test results and PSSE simulations results are closely aligned within the 10% error band which fulfilled the requirements.
2. Real field test performance and simulation model validation (part of R2 validation test)

The V, Q, P response at POC to ±5% Vref changes

(a) -5% Vref change step applied  (b) +5% Vref change step applied
2. Real field test performance and simulation model validation (part of R2 validation test)

2.2. Issues with Communication setups, DC side sizing and metering equipment in the plant

We have experienced many problems due to the bad design of the plant. We don’t supply communication setups, DC sizing and power quality metering equipment which are usually supplied by the third party who is responsible for the PV plant commissioning.

Recently we have experienced:

- The metering (CTs and VTs) accuracy error is > 2% in a 100MW plant, which is around 2MW measurement error. This is very high.

- The plant control relies on the measurements provided by the meter at POC. If the data from the meter is not accurate, the plant control will react accordingly. We have seen that the power quality meter data was frozen and constantly provided same data for a long time, while the POC actual (V, P and Q) data was different, which cased voltage oscillation in the grid.
Question?

Thank you