Simulation Studies Required for Renewable Energy Integration

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1. Introduction

Renewable Energy (RE) Facilities need to conduct compliance studies, in order to prove that their facility has the necessary capability in order to meet the currently published grid code [1], as well as ensure that the farm does not contravene the existing NRS and other published standards. These studies, though not limited to, are:

- Reactive Power Capability
- Loadflow Analysis
- Losses
- Short Circuit / Fault Level Contributions of RE generators
- Power Quality – Harmonics and Flicker

Dynamic simulations including low voltage ride through capability and determining accurate fault levels will also be required (after successful bid notification)

2. Voltage / Reactive Power Requirements

2.1. Reactive Power Capability

Voltage regulation is essential to ensure correct operation of all connected loads; therefore control of reactive power at the point of common coupling (PCC) is required in order to ensure the network voltage is regulated within specified limits. Voltage regulation requirements are defined by the network owner, utility or municipality. Grid code [1] requires the farm to be able to operate at leading and lagging power factor of 0.95 for farms larger than 20 MW and 0.975 for farms smaller than 20 MW.
Accurate fault level and network impedance at the PCC as well farm layout and generator reactive power capability curves are required to evaluate these criteria. It is important to note that grid code [1] specifies requirements at the PCC and manufacturers specify reactive power capability at the generator terminal. This makes knowledge of the farm layout critical to account for the reactive power consumption within the farm.

2.2. Network Voltage Profiles and Loading

Due to the variability of the output of RE generation and further taking into account the variability of network loading, you cannot evaluate the farm at a single operating point. Network voltage profiles and loading should be evaluated for at least the following operating points:

- High generation + High network load
- Low generation + Low network load
- High generation + Low network load
- Low generation + High network load

where generation refers to the farm output. Additionally contingency analysis of the network should be done for each of the above mentioned operating points.

2.3. Rapid Voltage Change (RVC)

In line with NRS 048-4 [2], if a farm is to be totally disconnected from the network; the voltage at the PCC pre and post disconnection must not change by a specified percentage. This percentage is dependent on the repetition rate of changes in a period of time and the voltage level at the PCC as described in NRS 048-4 Table A5 [2].
In the event of non-compliance the following options are available:

- Change the farm operating power factor.
- Reduce the farm active power output; (this is not ideal as to the objective of farms is to sell as much power as possible.)
- Consider increasing the fault level at the PCC; it is important to discuss with the network provider future upgrade plans to the network that may increase the fault at the PCC.

Ideally the farm should operate at unity power point power factor with maximum output but if the RVC criteria require you to change the operating level at the PCC, it is imperative that the network provider is informed accordingly.

3. Losses

Electrical networks are designed and optimized to transport electricity through HV systems and distribute it through the MV/LV systems. RE farms connected to the MV/LV systems may cause increased losses depending on the operating scenario. Hence network losses must be evaluated for the four main operating points as stated in section 2.2.
Losses within the farm result from long internal cables (up to 10-12kM in some cases) and transformer impedances. Typically the farm design would aim to keep the farm losses below 2 percent.

4. Short Circuit / Fault Level Analysis

When considering RE farms, classical short circuit methods based on steady state analysis are not always accurate for the following reasons:

- Controllers (power electronic converters) are fast enough to control short circuit currents from the first milliseconds and cannot be considered in the steady state calculations.
- Highly non-linear behaviour due to special protection mechanisms (crow-bar, chopper resistance, etc.)

Classical short circuit calculation methods provide acceptable results when verifying the short circuit levels of existing or new installations (e.g. verify short-circuit level, circuit-breaker capacity, sizing, etc.)

When accurate results are required a time-domain simulation should be used (e.g. analysis of protection relay mal-operation, sizing of associated power electronic devices, development and test of control concepts etc.)
Accurate time domain simulations require detailed controller models which must be sourced from the manufacturer.

5. Power Quality

5.1. Harmonics

Harmonics or harmonic distortions are a function of the PCC location. Hence even a small contribution from the farm that is connected to the network at a point which is susceptible to harmonics issues can have huge implications to the network. This suggests that an accurate network representation is needed when conducting power quality studies. Compatibility levels for harmonic distortion for electrical network are stipulated in NRS 048-4 Table A1 [2].

5.2. Flicker

As mentioned with harmonics, flicker analysis in also network dependent and the location of the RE farm plays a major role in the outcome of the analysis. Compatibility levels for both long term and short term flicker for connection to an electrical network are stipulated in NRS 048-4 Table A4 [2] for the various voltage levels at the PCC.

6. Low Voltage Ride Through

One of the requirements in the grid code [1] specifies the required capability of a farm to “ride through” a low voltage at the PCC. Critically it states that post fault the voltage at the PCC is allowed to be at zero for not more than 150 milliseconds and should recover to at least 0.85 p.u. within 2 seconds. According to compliance test standard for wind [3] low voltage ride through compliance is only required to be shown prior to the farm commissioning and connection.
As with the short circuit / fault level analysis any time domain simulations require accurate controller models which must be sourced from the manufacturer.

7. Protection

RE farm protection is set based on the fault levels calculated by the utility / municipality / network provider. These fault levels must be checked thoroughly to establish the following criteria:

- For what operating condition was this calculated (network topology, generating pattern)?
- What calculation method was used to achieve the value (planning criteria or operational criteria)?
- Is this maximum or minimum value? (You need both to set protection)

Network protection must further consider:

- Reverse power flow
- Accurate fault level contributions from farm (dynamic simulations including detailed controller models)
- Accurate breaker rupturing capacities

8. Sub-Synchronous Control Instability

Interconnection studies for any generator or power electronic equipment in the vicinity of a series capacitor should account for system configurations that can give rise to sub-synchronous oscillations. Subsynchronous Resonance or Subsynchronous Control Instability can occur when wind farms are connected to networks with series capacitor compensation. The “Cape” network has traditionally been a SSR susceptible network with its series compensated lines.

9. Conclusion

Steady state simulations together with power quality analysis should be conducted upfront and this will give the network provider and the developer a worthy idea on the impact of the RE farm on the network. Besides the wide range of studies that need to be conducted further aspects such as variances in the network topology, loading, generating patterns in the network also need to be considered, in order to fully assess the impact of the farm on the network and vice versa. Detailed dynamic studies are required prior to commissioning and connection and the results must be presented as part of the connection procedure.

10. References

[1] “GRID CODE REQUIREMENTS FOR WIND TURBINES CONNECTED TO DISTRIBUTION OR TRANSMISSION SYSTEMS IN SOUTH AFRICA”, Draft rev. 4.4

[2] “ELECTRICITY SUPPLY – QUALITY OF SUPPLY, Part 4: Application practices for licensees”, NRS 048-4:2009 Edition 2, ISBN 978-0-626-22829-3

[3] “GRID CODE COMPLIANCE TEST FOR WIND ENERGY FACILITY CONNECTED TO TRANSMISSION OR DISTRIBUTION GRIDS IN SOUTH AFRICA”