

# Assessing the Stability of Regional Renewable Energy by the Grid Strength Index

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## 1. Introduction

To achieve the net-zero emission target, it is necessary to integrate a large amount of renewable energy and replace traditional generator units. However, the reduction of traditional generators will simultaneously decrease the short-circuit current and system inertia of the power grid, resulting in a weak-grid condition. Therefore, how to identify weak grids and address potential converter instability following fault disturbances needs to be explored in advance.

## 2. Research Content and Results

Grid strength can be defined as the ability of a power system to maintain and control voltage stability at any point, whether in a steady state or after a disturbance. This characteristic relates to the electrical strength contributed by the equipment connected to the network nodes. Generally speaking, a power system with higher strength is better able to tolerate disturbances caused by faults and restore normal operation; the opposite is true for lower strength. Grid strength is primarily provided by synchronous generators; however, the increase in renewable energy reduces the unit's net power generation, which in turn reduces the system strength. Because renewable energy converters, unlike

synchronous generators, are not driven by magnetic fields, they rely on internal Phase Lock Loops (PLL) to detect and respond properly to grid fluctuations. If the grid strength is low, the system may not respond in a stable manner, posing challenges to the power system in areas such as stability, protective relays, and power supply reliability.

The assessment of grid strength can be categorized into regional and system-wide levels:

- Regional assessment is primarily based on the short-circuit ratio, supplemented by the impedance ratio.
- Systemic assessment uses the rate of change of frequency and inertia as indicators, which is suitable for independent systems with a high proportion of renewable energy generation.

This study focuses on regional strength assessment. Currently, there is no universally defined short-circuit capacity threshold to identify weak-grid conditions; consequently, various methods exist to calculate the short-circuit capacity ratio, such as short circuit ratio (SCR), weighted short circuit ratio, composite short circuit ratio, and equivalent short circuit ratio.

To mitigate the instability brought by the

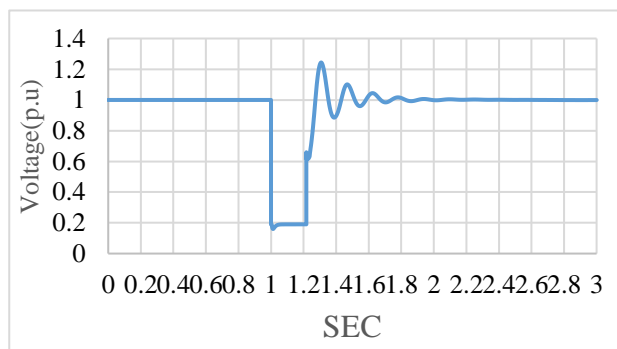
increase in Inverter-Based Resource (IBR) penetration, national grid codes require IBRs to have high/low voltage ride-through capabilities and high/low frequency ride-through capabilities to ensure stable operation under abnormal system conditions. If the IBR is connected at the end of the grid via a few transmission lines, the short-circuit ratio at the point of interconnection will decrease, forming a weak-grid situation, which may trigger oscillations after a fault. Initially, to meet the need for a generic dynamic model of wind turbines, the Western Electricity Coordinating Council (WECC) developed a generic positive-sequence wind turbine dynamic model suitable for grid planning studies. This study uses generic IBR models and RMS analysis software to evaluate post-fault stability under different grid conditions.

**(1) Weak Grid Scenario**

Taking the company's 2033 light-load scenario with high wind power generation in the central region as a case study, interconnection points with lower short-circuit ratios were first calculated to screen for areas with limited short-circuit capacities. Following this, various short-circuit ratio metrics were calculated. Bus 5832, which possesses a short-circuit ratio of approximately 2.8, was selected for analysis

using the REGC\_C model to observe the post-fault stability of renewable energy under low short-circuit ratio conditions.

In this study, the wind turbine at interconnection point Bus 5832 was first analyzed using REGC\_C and REEC\_A models with typical parameter values. When a three-phase-to-ground fault occurred at the interconnection point, the fault was cleared 13 cycles after the incident, resulting in one circuit tripping. The results, as shown in Figure 1, indicate that after the fault was cleared, the voltage at the wind turbine terminal oscillated and stabilized after 2 seconds.



Source: This study

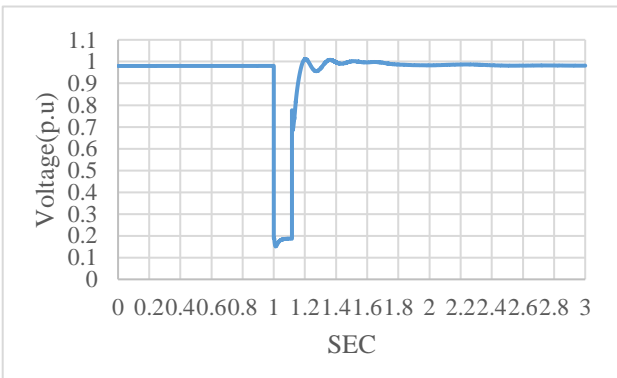
Figure 1. Weak Grid - Wind turbine terminal voltage 13 cycles after fault isolation

**(2) Strong Grid Scenario**

The strong grid scenario also uses the company's 2033 light-load scenario with high wind power generation in the central region as a case study. After evaluating the short-circuit ratios of various interconnection points, Bus 590, which possesses a

short-circuit ratio greater than 3, was selected. The REGC\_A and REGC\_C model parameters from the previous case were used to observe the post-fault stability of renewable energy under high short-circuit-ratio conditions.

The wind turbine at interconnection Bus 590 was analyzed using REGC\_C and REEC\_A models. When a three-phase-to-ground fault occurred at the interconnection point, the fault was cleared 7 cycles after the incident, followed by a single-circuit trip. The results, as shown in Figure 2, indicate that the wind turbine terminal voltage remained stable after the fault was cleared.



Source: This study

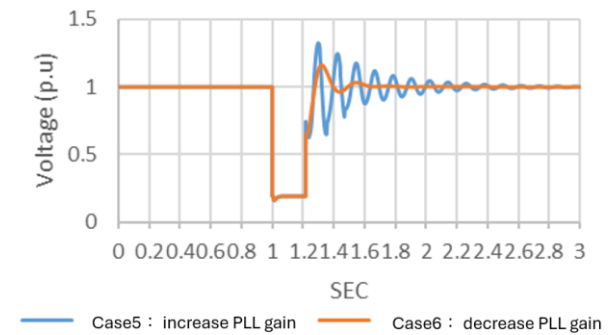
Figure 2. Strong Grid - Wind turbine terminal voltage 7 cycles after fault isolation

**(3) Impact of Different PLL Parameters**

As mentioned in this study, the oscillation behavior of the REGC\_C model after fault clearance can be mitigated by adjusting the PLL parameters and the internal current control loop parameters.

Therefore, this section modifies the PLL parameters to observe the resulting post-fault response.

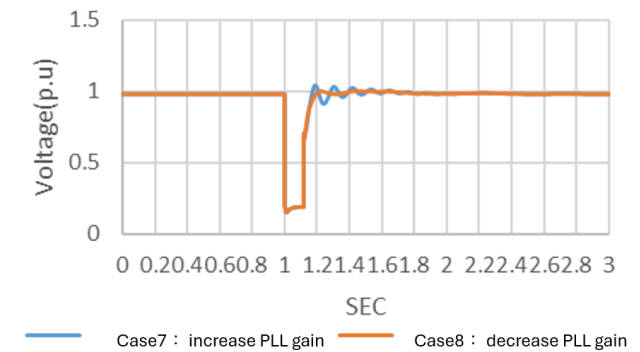
Figure 3 shows the response to increasing or decreasing the PLL gain in a weak grid scenario. It can be seen that reducing the PLL gain in a weak grid scenario can make the post-fault voltage more stable, while, conversely, increasing the PLL gain causes unstable voltage oscillation.



Source: This study

Figure 3. Response of different PLL parameter gains in a weak grid scenario

Figure 4 shows the scenario of increasing and decreasing the PLL parameter gain in a strong grid. The results indicate that reducing the PLL parameters can make the post-fault voltage more stable.



Source: This study

Figure 4. Response of different PLL parameter gains in a strong grid scenario

### **3. Conclusion**

The replacement of traditional generating units with renewable energy leads to a decrease in grid strength and inertia, making PLL-based equipment prone to voltage oscillation or even tripping in weak grids. To address this regional stability challenge, in addition to establishing grid strength assessment mechanisms based on international standards,

practical improvements can be achieved by deploying hardware such as synchronous condensers and combining dynamic simulation software to optimize equipment control parameters. Finally, technical specifications, system planning, and protection strategies must be simultaneously upgraded to ensure grid stability while moving toward the net-zero target.