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# PSCAD Studies Demonstrate Grid Forming Inverters Can Improve Weak Grid of Australia

## 1. Background

With the increase of the proportion of new energy resources access, the operation mode of traditional power system that mainly based on thermal synchronous generators is changing. In the past, when the proportion of new energy resources was relatively low, its grid-connected performance had a limited impact on the grid, and its impact capacity was limited by its small capacity scale. Even if it fluctuated, it would not have a great impact on the strong grid. But now, with the rapid increase of new energy resources penetration, its grid-connected performance will directly affect the safe operation of the grid. Therefore, issues related to grid friendliness have been put on the agenda.

The short circuit ratio (SCR) of grid is an important index to measure the strength of grid. In the case of low SCR, any disturbance injected by inverter will be amplified by weak grid. Therefore, it becomes more difficult for power stations to maintain steady-state operation, complete transient fault through and maintain power quality under weak power grid. However, if the performance of any aspect is not up to standard, it may lead to problems or accidents such as off-grid, vibration, harmonic increase and even equipment damage.

$$SCR\downarrow = \frac{\text{Grid short-circuit capacity}\downarrow}{\text{Renew energy capacity}\uparrow}$$

Currently, the traditional grid-following (GFLI) inverter has been widely used in grid-connected photovoltaic applications, but it is easy to be unstable because of the low grid strength. Although the inverter manufacturers continue to optimize the grid-connected algorithm to adapt to the weak grid, with the increase of new energy resources access ratio, the grid strength continues to decline, blindly adapting to the weak grid cannot solve the fundamental problem, and how to increase the grid strength becomes particularly important.

Although grid-forming (GFMI) technology originated from off-grid applications, with the gradual promotion and use of this technology in grid-connected applications, it has become a potential solution for unstable and low-strength systems. Through PSCAD model, this paper verifies how GFMI converter + energy storage battery can strengthen the system strength and improve the inertia of the system, and promote the system to be more stable.

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# 2. Research overview

## 2.1 Modeling method

PSCAD stands for Computer Aided Design of Power System and is the graphical user interface of EMTDC. The successful development of PSCAD makes it easier for users to use EMTDC for power system analysis, and makes it possible to visualize complex parts of power system. This report uses PSCAD tool to model and simulate, and verifies how the solution of energy storage converter + energy storage battery with GFMI (grid-forming) technology can effectively enhance the strength of power grid and improve the inertia of power grid system.

## 2.2 Introduction of Inverter

Inverter is a kind of power electronic equipment that converts direct current (DC) or variable frequency electricity into alternating current (AC), which can be used in photovoltaic power generation, wind power generation and other new energy power resources generation scenarios. But now a key problem is that although the standard grid frequency is 50Hz, the instantaneous mismatch between supply and demand balance will occur at any time in the power system, so in fact the frequency is constantly changing. Inverter must adapt to the fluctuation and change of power grid through grid-connected algorithm. GFLI inverter and GFMI inverter have different influences on power grid due to different control schemes.

### 2.2.1 Grid following inverter

GFLI inverter is a new energy grid-connected photovoltaic inverter widely used at present. Its output voltage will track the frequency and phase of the voltage waveform of the power grid, and its output alternating current will keep synchronized with the power grid, so it is fundamentally a current source system.

When multiple GFLIs run in parallel, if the power grid strength is low, the output of each inverter will cause the fluctuation of the power grid voltage, and other inverters in this region will find this voltage disturbance. This may cause the subsequent response of other inverters, which will lead to further fluctuation of grid voltage, and then form oscillation, resulting in the collapse of grid system.

### 2.2.2 Grid forming inverter

The operation mode of GFMI inverter is more similar to that of synchronous generator. GFMI does not generate its control reference parameters according to the grid voltage, but creates its own internal reference values, which are constantly adjusted according to the output power of the inverter. The inverter does not directly control the power output itself, but controls the voltage angle between the inverter and the power system, and determines the actual output power according to the actual situation.

During the stable operation of the system, the power will flow to the power grid under control, similar to GFLI inverter. However, when the voltage phase angle of the power system changes sharply during the system fluctuation, for GFLI inverter, the power output will change only after the inverter control system detects the fluctuation and calculates the appropriate response. However, for GFMI inverter, the sudden change of voltage phase angle will automatically change the output power of the inverter. This instantaneous response to system interference is closer to the response mode of synchronous generator, so the solution of GFMI inverter with energy storage battery has the ability to support and strengthen the power grid compared with the traditional GFLI inverter.

# 3. Power system analysis

In this study, PSCAD simulation software is used for modeling and simulation. The circuit diagram of the simulation case is shown in Figure 1. The system has a double-circuit 275kV line (purple) and a double-circuit 132kV line (orange) in parallel with each other. Grid-connected inverter PV power station is connected to bus Bus1. In the dotted box of Bus1 is GFMI energy storage converter + energy storage battery, and its influence on the whole system is verified by adding this energy storage part. Add a load on the Bus5 side, and observe the inertia of the system by switching the load.

The total capacity of PV power station (GFLI inverter) is about 100MW. The capacity of ESS energy storage power station (GFMI converter + energy storage battery) is 20MW/20MWh. The simulation scenario of battery system is as follows: when the transmission circuit fault occurs in loop 1 and the relay protection trips, the transmission is carried out by loop 2 alone, and the short-circuit capacity of the transmission line decreases at this time. Observe the voltage status of the system grid under different grid strengths.

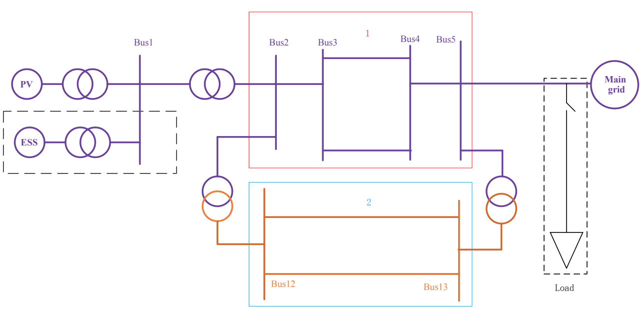


Fig.1 - Topological Graph

## 3.1 Enhance the power grid strength verification of the system

In order to verify the power grid strength of the system, the circuit 2 power grid parameters in the model were set differently to obtain SCR=10 and SCR=3 working conditions, and the voltage waveform at Bus1 and Bus5 was observed. The simulated output results are shown as follows.

**Condition 1: Strong power grid (SCR=10)**

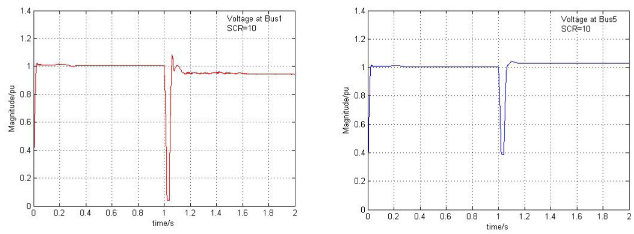


Fig.2 - Bus1 and Bus5 side voltages in a strong grid

As can be seen from Fig.2, when the fault relay protection of transmission loop 1 trips, transmission is carried out by loop 2 alone, and the parameters of loop 2 are set so that the system impedance SCR=10. At this time, although the transmission capacity of the circuit decreases, the system impedance of loop 2 is still at a high level, so the bus voltage in Bus1 and Bus5 remains stable and the system runs stably.

**Condition 2: Weak grid (SCR=2)**

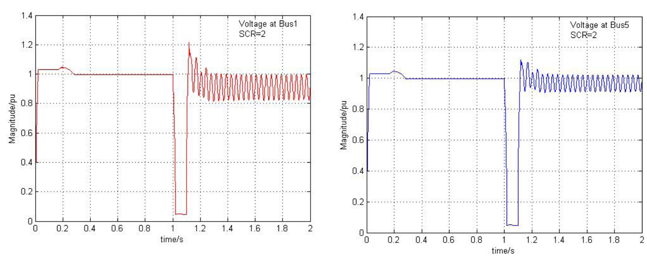


Fig.3 - Bus1 and Bus5 Side Voltages in Weak Grid

It can be seen from Fig.3 that when the fault relay protection of transmission loop 1 trips, the transmission is carried out by loop 2 alone, and the system impedance parameter is set so that SCR=3. Because the power grid system strength is low, GFLI inverter is used to connect to the grid, so it can be seen that the bus voltage of Bus1 and Bus5 has obvious fluctuation, and the system begins to be unstable. If the system impedance is continuously reduced, the system may oscillate and collapse.

**Condition 3: Weak power grid (SCR=2 with 20MW/20MWh GMFI energy storage system added)**

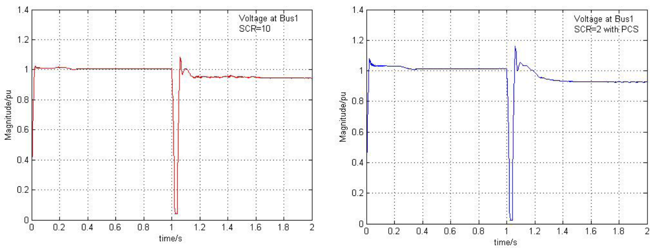


Fig.4 - Increasing Bus Voltage of Grid Forming Energy Storage System

Fig.4 shows the addition of 20% energy storage system on the basis of working.The simulation results show that the voltage waveform of the system is more stable when the energy storage system is added by comparing the voltage waveform of the system under three working conditions. This is because the energy storage system scheme of Grid-forming energy storage inverter is added, which enhances the short-circuit capacity of parallel nodes. Therefore, for new energy power stations such as photovoltaics, the grid strength is effectively enhanced by adding GFMI energy storage solution.

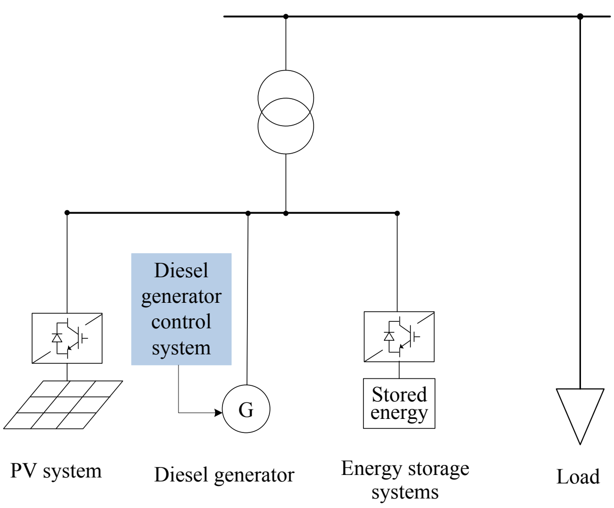


Fig.5 - Topology Graph

## 3.2 Verification of System Inertia Increasing

Condition: GFMI inverter is grid-formed with diesel generator and other energy sources

The GFMI inverter group operates in microgrid by setting the inertia time constant of the inverter.

(1) Tj=0s, the system has no inertia (2) Tj=0.5s

The frequency changes of the system under two different time constants are observed when the load is switched on and off.

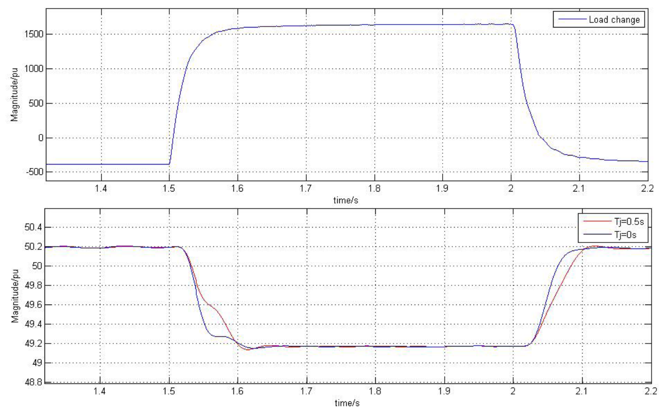


Fig.6 - Off-grid Load Waveform (Top) & Off-grid Load Frequency Waveform (Bottom)

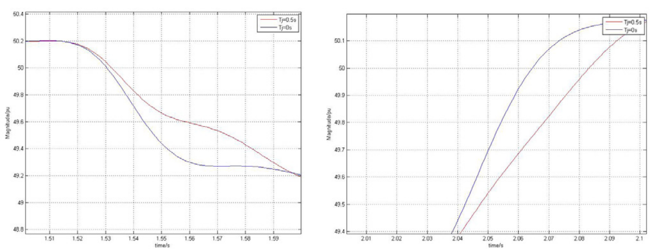

Fig.7 - Amplification Comparison of Off-grid Switching Load Frequency Waveform

As can be seen from the above fig.5, the load is put into 1.5 s and the load is cut off in 2s. Observing the frequency change of the system, we can see that when the system has no inertia, the frequency drops or rises faster. With the increase of virtual inertia, the frequency change rate of the system decreases significantly and the system is more stable.

**Condition 2: GFMI Inverter Connected to Utility Power Grid**

The GFMI inverter is connected to utility power network, and the inertia time constant of the inverter is set.

(1) Tj=0s, that is, the system has no inertia (2) Tj=0.5s The power changes of the system under two different time constants are observed when the load is switched on and off.

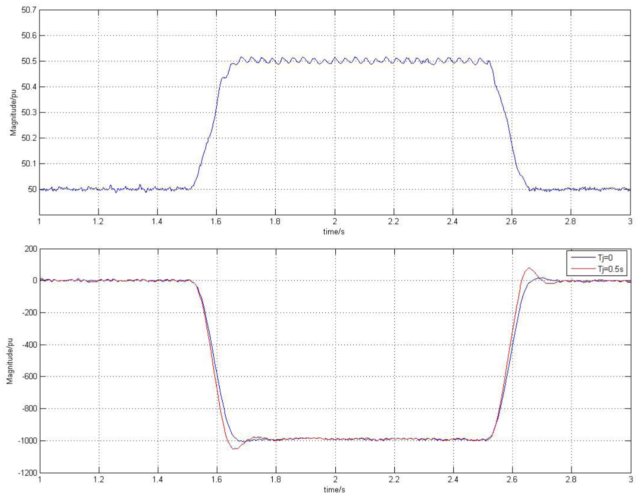


Fig.8 - Grid-connected frequency change diagram (Top) & Power change waveforms when grid-connected frequency changes (Bottom)

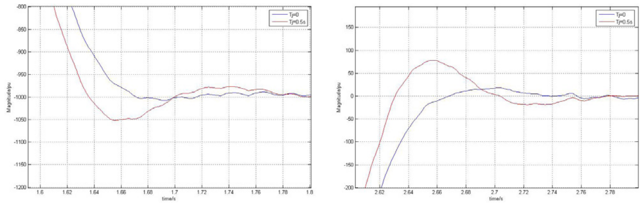

Fig.9 - Amplification comparison of power change waveform when grid- connected frequency changes

Different from microgrid system, utility grid has higher strength and no obvious change in system frequency. Therefore, the effect of system inertia can be observed by the active power response of converter in frequency change. It can be seen from the figure that when Tj=0.5s inertia is added to GFMI converter, the converter can support active power faster during the dynamic frequency change of grid. When the frequency drops, like the rotor characteristics of synchronous machine, compared with the system without inertia, it can inject power spontaneously faster and suppress the change of power grid frequency.

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# 4. Conclusion

Based on PSCAD model, this report verifies the influence of GFMI inverter + battery energy storage solution on power grid system through three modeling cases. Through simulation results, the following two conclusions can be drawn:

· GFMI inverter + battery energy storage solution can increase the strength (SCR) of the grid system. Under the background that the proportion of new energy access may reach 80% in the future, this is particularly important for remote areas or areas with weak grid strength. It can enhance power quality and reduce the influence of power grid fluctuation.

· GFMI inverter is similar to synchronous generator operation mode, which can add inertia link in inverter control system and improve inertia of new energy resources grid-connected system. When the grid load suddenly changes, it can make active response faster and slow down the frequency decline speed, and play a role in stabilizing the grid frequency and relieving the grid congestion.

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