Enhancing grid stability: the vital role of inverters in renewable energy integration

In the context of sustainable development, addressing the widespread integration and consumption of new energy is crucial for achieving carbon peak and neutrality goals. Integrating new energy sources into the power grid is a key focus of the power industry. However, the intermittent nature of new energy poses challenges, potentially impacting the stability of regional power grids. To ensure safe and stable grid operations, new energy equipment must actively regulate grid conditions. This article explores how inverters, from the perspective of grid adjustment, play a vital role in ensuring the stable operation of power grids.

The main function of an inverter is to convert the variable DC voltage generated by the photovoltaic (PV) solar panel to the municipal electric frequency AC power (AC) and feed it back to the commercial transmission system, or for the off-grid power grid. The interaction between the inverter and the grid is mainly through active power and reactive power. The information that the inverter detects from the grid is mainly the grid voltage and frequency.

According to the analysis of the basic principles of the power system, for an ideal grid system with a line impedance of 0, the excess energy will be converted into kinetic energy to increase or decrease the generator speed, affecting the grid frequency when the active power of the load does not match the output power of the generator.

When the reactive power of the load does not match the reactive power of the generator, it will affect the excitation current of the generator set, changing the magnetic field and affecting the induced electromotive force which is the grid voltage. In actual working conditions, the line impedance of the grid cannot be zero.

Due to the line impedance, the greater the grid current, the greater the voltage drop of the line impedance. In other words, the grid active power will also affect the magnitude of the grid voltage.

In summary, the effects of active power and reactive power on the grid voltage and frequency can be described as follows: The grid frequency increases as active power increases, while it decreases as active power decreases. Additionally, the grid voltage rises with an increase in capacitive reactive power and falls with an increase in inductive reactive power. Furthermore, the grid voltage increases with an increase in active power due to line impedance, but decreases with a decrease in active power for the same reason.

Solutions

In view of the above situation, the safety regulations of many countries clearly require the inverter to have the following functions for adjusting the grid voltage and frequency, so as to ensure the stability of the power grid and the stable operation of other equipment on the power grid.

Voltage active power curve (P-V)

According to the relationship between the active power and the grid voltage, the change of the grid voltage is detected during the rise of active power, and the active power output is reduced before the grid over-voltage protection is triggered, which can effectively avoid the over-voltage fault of the machine caused by the power rise.

To effectively meet the evolving demands of PV applications regarding inverter functionality and performance, we have focused on safety, intelligence, and modularity.

Many manufacturers unlimitedly increase the protection threshold of the grid voltage to avoid the over-voltage problem of the inverter due to the power rise which we think is not advisable.

As more and more inverters enter thousands of households, the safety of the entire power system is very important. Long-term operation of the grid voltage at a high level may cause damage to other equipment on the line, or even burn out and cause a fire. For example, the Australian safety regulations AS4777.2 standard requires the inverter to start to reduce the active power output when the grid voltage is greater than 250 V, and reduce it to 20% of the rated power when the grid voltage is greater than 250 V.

Voltage and reactive power curve (Q-V)

The load of the power grid is diversified, including resistive load, inductive load and capacitive load. In order to ensure the stability of the grid voltage, when the load change causes the fluctuation of the grid voltage, the inverter needs to actively send out reactive power to compensate the grid.

When the grid voltage is lower than the expected value, the inverter needs to actively generate corresponding capacitive reactive power to support the grid according to its own capacity.

When the grid voltage is higher than the expected value, the inverter needs to actively generate corresponding inductive reactive power to pull down the grid according to its own capacity.

For example, the German VDE4105 standard requires that when the grid voltage is lower than 0.97 times the rated voltage, the inverter starts to generate capacitive reactive power, and when the grid voltage is lower than 0.93 times the rated voltage, the maximum capacitive reactive power output, 60% of the rated power, is reached.

When the grid voltage is greater than 1.03 times the rated voltage, the inverter begins to actively generate inductive reactive power and when the grid voltage is greater than 1.07 times the rated voltage, the maximum inductive reactive output, 60% of the rated power, is reached.

Power factor power curve (cosɸ-P)

For a grid system, the more active power generated by the inverter, the higher the grid voltage will be lifted. When the inverter generates active power, a certain inductive reactive power can also be generated to actively attenuate the voltage rise caused by the increase in active power. This is the cosɸ-P curve.

For example, the Brazilian NBR 16149 standard stipulates that when the grid voltage is greater than 1.05 times the rated voltage, the photovoltaic inverter needs to enter the cosɸ-P function curve. The curve requires the inverter to start actively adjusting the power factor when the power is greater than 0.5 times the rated power.

Frequency active power curve (F-P)

Frequency is the cornerstone of stability for the grid system, and its importance is self-evident. When the frequency of the grid system fluctuates greatly, it means that the grid system is on the verge of collapse. As the proportion of new energy grid-connected capacity increases, this situation will happen more often. So the ability to actively maintain the stability of the grid system frequency has become one of the main performance parameters of the inverter.

In principle, inverters need to actively reduce active power output as the grid frequency increases, and inverters need to actively increase active power output as the grid frequency decreases.

For example, the European EN-50549 standard requires that when the grid frequency is greater than 50.2 Hz, the inverter needs to reduce the active power output. When the grid frequency is greater than 51.2 Hz, the active power output of the inverter needs to be reduced to 60% of the power before the load reduction.

Sunways, a German inverter manufacturer established in 1993, has consistently aimed to offer cutting-edge solutions for the PV industry. To effectively meet the evolving demands of PV applications regarding inverter functionality and performance, we have focused on safety, intelligence, and modularity.

Our extensive range of models features configurable function modules encompassing parameters, modes, and activation conditions, catering to diverse application scenarios and ensuring the provision of the safest, most intelligent, and highly efficient services to our customers.

Our modules currently comply with regulatory requirements in nearly all countries, prioritising not only customer benefits but also grid stability to ensure safe and efficient energy utilisation.

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