Research on Coordinated Control Technology Among Inverters in Distributed Voltage Regulation Control Mode of Photovoltaic Power Station

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Abstract. Photovoltaic and other renewable energy power generation systems are connected to the grid through power electronic converters. Normally, they do not participate in grid voltage regulation when they are running in the mode of tracking the maximum power point. However, when their grid-connected capacity exceeds a certain scale, photovoltaic needs to participate in grid voltage regulation.

Keywords: Photovoltaic; coordinated control; voltage regulation; maximum power point.

1. Optimal distribution of reactive power output in photovoltaic power station

The reactive power optimization control for photovoltaic power station, is refers to in the design and operation stages of photovoltaic power station, by adjusting the reactive power output of photovoltaic inverter, adjust parallel compensating capacity of reactive power compensation device and the main transformer tap position adjustment means, make the photovoltaic power station in order to achieve the minimum network loss, voltage is allowed within the scope and economic benefit. The purpose of optimal in actual operation, the reactive power regulation ability of grid-connected inverter of photovoltaic power station should be given full play and the reactive power output instruction of photovoltaic power station should be given priority. Secondly, the reactive power instruction is distributed to the reactive power compensation device to adjust the compensation capacity. This distribution method can reduce the input times of reactive power compensation device, give play to the reactive power regulation ability of inverter, and achieve the purpose of optimal distribution of reactive power output and voltage stability control of photovoltaic power station. Reactive power instruction has a variety of methods for inverter allocation:

(1) Equal power factor

According to the obtained reactive power adjustment amount of the new energy power station and the current active power of the unit, the power factor of the new energy power station after adjustment is calculated and the reference value of the specific unit's reactive power is determined according to the power factor. The specific realization is as follows:
\[ P_{F_{plant}} = \frac{\sum P_{meas_i}}{\sqrt{Q_{cma}^2 + \sum P_{meas_i}^2}} \]  
\[ Q_{ref,i} = P_{meas,i} \times \frac{\sqrt{1-P_{F_{plant}}^2}}{P_{F_{plant}}} \]  

Where, \( P_{F_{plant}} \) is the power factor of the new energy power station, \( \sum P_{meas,i} \) is the sum of the active power of the new energy generating set, and \( Q_{ref,i} \) is the reference value of the reactive power distributed to the ith new energy generating set.

2) Distributed according to rated capacity and other reactive power proportion

According to the proportional relationship of the unit's reactive power capacity, the distribution is implemented as follows:

\[ Q_{ref,i} = Q_{meas,i} + \frac{Q_{i_{max}}}{\sum Q_{i_{max}}^{\text{adj}}} \times Q_{adj} \]  

Where, \( Q_{i_{max}} \) is the maximum reactive power capacity of unit i participating in reactive power control.

3) Allocation based on reactive power margin

According to the size of the reactive power margin distribution, as far as possible to ensure that each new energy unit has a similar reactive power margin, that is, the unit with more reactive power left provides more reactive power, and the unit with less reactive power left provides less reactive power.

4) Priority adjustment for some units

According to the merits and disadvantages of reactive power regulation performance of the generating sets in the new energy power station, the units with excellent regulating performance bear more reactive power regulation amount, while the units with poor regulating performance bear little or no reactive power regulation amount. The above four reactive power adjustment quantity distribution methods: the first method (average distribution) is simple, but some units may have insufficient regulation capacity, resulting in repeated adjustment of reactive power control system, increasing the system regulation time; the second method (equal reactive power proportional distribution) has similar problems. The third method (based on reactive power margin allocation) can solve the above problems, but it needs to calculate the adjustable reactive power margin of each unit. The fourth method (priority regulation of some units) can avoid repeated regulation of the active power control system and reduce the regulation time of the control system, but it is necessary to determine the priority regulation sequence of units according to the historical running state of each unit in the power station.

2. Simulation verification of decentralized voltage regulation control strategy

2.1. Photovoltaic power generation model modeling based on powerfactory platform

The photovoltaic power generation unit model published by wecc is adopted. The model uses the controlled current source as the grid-connected interface, including photovoltaic cell array, converter and control system. Its structure is shown in figure 1. it is shown in the model of photovoltaic power generation system based on the controlled current source interface, the dynamic characteristics of photovoltaic system equipment itself have been simplified enough, especially associated with inverter control of some of the fast approximate relationship between the dynamic characteristics of the algebra reflects its response characteristics, usually used in analyzing the characteristic of photovoltaic power generation system response grid disturbance.
Figure 1. ge photovoltaic power generation system model

(1) Converter
The converter model receives and responds to the active and reactive control instructions of the control module and injects active and reactive power into the grid. The system fault control and protection function is also reflected in this module. The initialization of the active current is obtained from the power output calculated by the power flow. Figure 2 is the structural block diagram of the converter module.

Figure 2. ge part structure diagram of converter of photovoltaic power generation system

In figure 2, ipcmd and iqcmd instructions are provided by the electrical control module, lvpl is the dynamic limit value of active current, which is calculated by the terminal bus voltage through the low-voltage power logic module, and rrpwr is the limit value of active current instruction change rate. The reactive current management module at high voltage/active current management module at low voltage should cooperate with the protection part.

Low voltage power logic (lvpl) reduces the damage and impact to the system by limiting the upper limit and rising rate of active current instruction ipcmd when the terminal voltage vterm is lower than brkpt due to network fault. Under normal operation, the filtered terminal voltage vterm is higher than the user-defined breakpoint (brkpt), in which case lvpl has no upper limit (it can also be set manually). When the power grid fails, the terminal voltage vterm is lower than brkpt, lvpl output has a certain linear relationship with the terminal voltage vterm, that is, the upper limit is adopted for ipcmd. This linear relationship is the user-defined upward rate limit (rrpwr). According to experience, the recovery rate of active power after fault recovery is very important, which can be said to be the key to the normal recovery of active power output after fault recovery. When the voltage continues to drop below the user-defined zero cross point (zerox), the upper limit of ipcmd is set to zero, that is, the active power emitted by the photovoltaic power generation system is 0, that is, it is in the state of shutdown.
(2) Control system

Photovoltaic power generation system model based on the controlled current source interface module in the control system including the active and reactive power control, its effect is according to the active orders and reactive power demand, after a certain computation, sent the generator/converter modules active reference iqcmd ipcmd and reactive reference current, among them, the active control reference pord generated by the mechanical part, reactive power control reference qord by reactive power control module according to the and node voltage vreg modulation. The structure of the electrical control module is shown in figure 3, where the limiter of active current ipcmd and reactive current iqcm is calculated by the converter limiter current calculation module.

\[
\begin{align*}
I_{q_{\text{mn}}} &\leq I_{q_{\text{mx}}} \\
I_{p_{\text{ord}}} &\leq I_{p_{\text{cmd}}} \\
Q_{\text{min}} &\leq Q_{\text{qi}} + K_i (v_i - v_{\text{reg}}) \\
Q_{\text{max}} &\leq Q_{\text{qi}} + K_i (v_i - v_{\text{reg}})
\end{align*}
\]

**Figure 3.** Control system module structure diagram

Based on powerfactory platform implementation of photovoltaic power generation system model as shown above, the model is mainly composed of measuring system, the converter control model and grid interface model of three main parts, among them, the inverter control model of the main active/reactive power decoupling control, through the outer loop and current inner loop power control of photovoltaic power generation system output current reference value to meet the demand of power grid.

**Figure 4.** A model of photovoltaic power generation control system based on powerfactory platform
2.2. The simulation verification
Set up \( t = 3 \) s, about the connection in bus07 load 17 reactive power exploding 1000 mvar, system voltage drop. To verify the active voltage regulation control performance of photovoltaic power station, simulation analysis was carried out under the two modes of photovoltaic power station not participating in voltage regulation control and photovoltaic power station active voltage regulation control. The 35kv bus voltage, terminal voltage of photovoltaic power station and reactive power output of photovoltaic power station are shown in figure 5.

![Simulation Results](image)

(a) 35kv bus voltage

(b) photovoltaic unit terminal voltage

(c) photovoltaic unit reactive power

Figure 5. the simulation results

3. Conclusion
This paper mainly studies the coordinated control technology among the inverters under the distributed voltage regulation control mode of photovoltaic power station, the voltage coordinated control strategy of multi-group photovoltaic inverter is proposed to realize benefits from investors and power grid of photovoltaic power station and improve the friendliness of photovoltaic power station access to power grid.
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