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Technical requirements for connecting photovoltaic power station to power system

光伏发电站接入电力系统技术规定

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1 Scope

The document sets technical requirements for the connection of photovoltaic power stations to the power system covering active power, reactive power and voltage, fault ride-through, operational adaptability, power forecasting, power quality, simulation models and parameters and the secondary system, together with the content of testing and evaluation.

It applies to the construction, production and operation of new, rebuilt and extended photovoltaic power stations connected at voltage levels above 10 kV. Photovoltaic power stations fitted with storage follow it by reference.

3 Terms and definitions

3.3 The point of connection is, for a station with a step-up substation, the high voltage busbar or node of that substation, and for a station without one, the output collection point of the station.

3.5 to 3.7 Medium-term photovoltaic power forecasting is the forecast of active power from midnight of the following day to 240 h ahead at a time resolution of 15 min; short-term forecasting runs from midnight of the following day to 72 h ahead at the same resolution; ultra-short-term forecasting runs from 15 min to 4 h ahead, again at 15 min resolution.

3.8 to 3.10 Low voltage ride-through is the ability of the station to stay connected and running when a system fault or disturbance makes the voltage at the point of connection drop, within a given range of drop and a given time interval. High voltage ride-through is the same ability when the voltage rises, and low-high voltage ride-through when the voltage first drops and then rises.

3.11 and 3.12 The dynamic reactive current increment is the change in the reactive current injected into or absorbed from the system during low or high voltage ride-through relative to the value before the drop or rise, reactive current meaning capacitive reactive current. Its rise time runs from the moment the voltage at the point of connection reaches the trigger setting to the moment the increment reaches 90 % of its target value.

3.13 and 3.14 An island is a part of the grid containing load and source that stays running in isolation after separating from the main grid, planned or unplanned; anti-islanding is the prevention of unplanned islanding.

4 Active power

4.1 The station takes part in system frequency and peak regulation in accordance with GB 38755, GB/T 31464, GB/T 40594 and GB/T 40595, and is fitted with an active power control system able to adjust continuously and smoothly. The control modes include at least active power limit control, active power set point control, active power difference control and frequency regulation control, put into or out of service on the automation signals and dispatch instructions of the dispatching authority, with response time and control accuracy per GB/T 40289.

4.1.4 During connection, normal shutdown and rising irradiance the rate of change of active power meets the needs of safe and stable operation, its limit being fixed by the dispatching authority from the frequency regulation characteristics of the system and recommended at 10 % of rated capacity per minute. Where irradiance falls rapidly the rate of change is allowed to exceed the limit.

4.2 Under system fault or emergency the station reduces active power or disconnects on the instruction of the dispatching authority, and reconnects on its instruction once normal operation is restored.

4.3 Primary frequency regulation follows GB/T 40594 and GB/T 40595 and can be started and stopped on dispatch instruction. Where the frequency deviation leaves the dead band, the station adjusts its active power output according to formula (1). The formula as printed is broken and is not reproduced here; its symbols are the change in active power of the station in megawatts, the active frequency regulation coefficient, the system frequency and the rated system frequency in hertz, and the rated active power of the station in megawatts.

4.3.3 to 4.3.7 The frequency regulation coefficient and the dead band are fixed by the dispatching authority from the frequency regulation characteristics of the system; the coefficient is recommended to lie between 10 and 50 and the dead band at +/- 0.02 Hz to 0.06 Hz. Above 50 Hz the limit on the amplitude of the active power reduction is recommended to be not less than 10 % of rated active power, and below 50 Hz the limit on the increase not less than 6 %. The lag time of the active power response is not more than 1 s, the rise time not more than 5 s and the settling time not more than 15 s, and the steady-state regulation deviation not more than +/- 1 % of rated active power. Enabled and operated status signals are set and sent to the dispatching monitoring system, and the function can be enabled or disabled locally or remotely.

5 Reactive power and voltage

5.1 Inverters installed in the station are continuously adjustable at rated active output over a power factor range from 0.95 leading to 0.95 lagging and within the rectangle shown in Figure 1, whose axes are the per unit active power and per unit reactive power of the inverter. The reactive capacity and regulating ability of the inverters are used first; where they are not enough for the voltage regulation needs of the system, reactive compensation equipment is added, which may be shunt capacitors, shunt reactors, static var compensators, static var generators or synchronous condensers.

5.2 Reactive capacity is sized to meet the layered and zoned balance requirements of the system and to leave a maintenance margin. For a station connected to the public grid, the capacitive reactive capacity compensates the inductive reactive power of the internal collector lines and main transformer at full output plus half the inductive reactive power of the outgoing line, and the inductive reactive capacity compensates the station's own capacitive charging reactive power plus half the charging reactive power of the outgoing line. For a station collected at 220 kV or 330 kV and stepped up to 500 kV or 750 kV, the whole of the outgoing line is compensated instead of half. The type and rating of the compensation equipment may be settled by study of the reactive and voltage regulation characteristics of the system.

5.3 The station has reactive power regulation and voltage control capability per GB/T 31464 and GB/T 40594 and is fitted with a reactive and voltage control system offering constant voltage, constant power factor and constant reactive power modes with online switching between them. The main transformer is recommended to be an on-load tap changing transformer. The control system receives the voltage, power factor or reactive power value sent by the dispatching authority and controls the voltage at the point of connection by coordinating the inverters, the compensation equipment and the transformer tap position, with response time and accuracy per GB/T 29321.

5.3.5 and 5.3.6 With the grid voltage inside its normal range, a station connected at 35 kV to 110 kV can regulate the voltage at the point of connection to within 97 % to 107 % of nominal, and a station connected at 220 kV or above to within 100 % to 110 % of nominal.

6 Fault ride-through

6.1.1 Low voltage ride-through follows Figure 2. Where the voltage at the point of connection drops to zero, the inverters and compensation equipment stay connected and running for 150 ms; where it drops to 20 % of nominal, for 625 ms; and where it drops to between 20 % and 90 % of nominal, they stay connected inside the shaded area of the figure.

6.1.2 Table 1 fixes the assessed voltage by fault type: for a three-phase short circuit and for a two-phase short circuit it is the line voltage at the point of connection, and for a single-phase earth fault it is the phase voltage at the point of connection.

6.1.3 During a symmetrical fault, where the voltage falls below 90 % of nominal the reactive current injected is the sum of the pre-fault value and a dynamic increment that responds to the voltage and satisfies formula (2), valid for a per unit voltage from 0 to 0.9. The formula as printed is broken and is not reproduced here; its symbols are the dynamic reactive current increment injected by the station in amperes, the dynamic reactive current proportional coefficient, the per unit voltage at the point of connection, and the rated current of the station in amperes. The coefficient may be fixed from the actual system conditions and is recommended to lie between 1.5 and 3. The rise time of the dynamic reactive current is not more than 30 ms, the maximum reactive current output during the drop is not less than 1.05 times the rated current, and the increment is withdrawn within 30 ms of the voltage recovering above 90 % of nominal.

6.1.4 During an unsymmetrical fault the station supports both positive and negative sequence dynamic reactive current. Where the positive sequence component of the voltage lies between 60 % and 90 % of nominal, the positive sequence reactive current injected is the sum of the pre-fault positive sequence value and a positive sequence increment, and the negative sequence reactive current absorbed is the pre-fault negative sequence value less a negative sequence increment, both increments responding to the voltage and satisfying formula (3), valid for a per unit positive sequence voltage from 0.6 to 0.9. The formula as printed is broken and is not reproduced here; its symbols are the positive sequence increment injected and the negative sequence increment absorbed in amperes, the positive and negative sequence proportional coefficients, the per unit positive and negative sequence voltages at the point of connection, and the rated current of the station in amperes. Both coefficients may be fixed from actual system conditions and are recommended to be not less than 1.0, the rise time is not more than 30 ms and the maximum reactive current output not less than 1.05 times rated current. Below 60 % positive sequence voltage the station is recommended to inject positive sequence and absorb negative sequence dynamic reactive current according to the real control capability of its inverters and compensation equipment and the grid conditions, without aggravating the voltage unbalance at the point of connection.

6.1.5 For a station that has not disconnected during the fault, active power recovers quickly after clearance, the rate of recovery being recommended at not less than 30 % of installed