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Renewables and power system stability

The transition from fossil fuels to renewable energy sources also entails a fundamental transformation of the transmission and distribution grids. The electric power system is shifting from a rotating mass-dominated system to a power converter-dominated system. Without the appropriate measures, this will have a negative impact on power system stability.

Over the past 20 years, the global share of renewable energy in new generation plant additions increased from 15% in 2002 to 83% in 2022. This growth is primarily driven by photovoltaics and wind power, and both depend on the instantaneous supply currently available (solar irradiation and wind). They are therefore referred to as Variable Renewable Energy (VRE).

"Synchronous condensers are an effective solution for the new requirements of the grid."

As soon as renewable energy sources feed into the grid, they supersede conventional thermal power plants due to common regulatory framework conditions. As a result, the rotating mass in the system decreases as the proportion of wind and solar increases, which are coupled via inverters.

Grid-connected inverter-coupled generation equipment does not provide an instantaneous reserve, so-called inertia, which is inherently provided by the rotating masses of synchronous generators. Inverter-coupled generation equipment also provides no or very little, short circuit power. High penetration of inverter-coupled generation equipment therefore leads to lower stability of the electric power system, manifesting itself in reduced frequency stability, voltage stability, rotor displacement angle stability, resonance stability, and inverter-based stability.

Possible consequences include wide-scale, undamped voltage and power oscillations, degradation of generator performance during faults, malfunctions or failures of protective equipment, Fault Induced Delayed Voltage Recovery (FIDVR), greater voltage jumps after capacitor banks are connected or disconnected, increased harmonics, deeper voltage sags, and higher voltage transients. Furthermore, due to higher frequency gradients, i.e., RoCoF (rate of change of frequency), increased frequency instability occurs, which leads to a deterioration of the system protection fault detection. All of these impacts result in limited power system hosting capacity for new renewable wind and photovoltaic units.

In light of these challenges and new regulatory requirements the electricity grid operators' main task is maintaining a stable energy supply at all times. For this, the synchronous condenser is a reliable, proven, and cost-effective solution.

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MAIN FUNCTIONS OF SYNCHRONOUS CONDENSERS

Synchronous condensers are extremely valuable grid-serving systems whose main functions are:

- Improved frequency stability
- Improved transient stability
- Improved steady-state voltage support

Frequency stability and transient stability are necessary whenever faults occur in the synchronous grid. These can be events like shedding large loads or the failure of a large power plant leading to an abrupt change of frequency, or short circuits on a transmission line leading to an abrupt change of voltage.

Instantaneous reserve and short-circuit power are essential system services when there is a high penetration of wind and photostatic generation. Previously common compensation devices such as SVCs and STATCOMs cannot supply both. They do little, or nothing to improve either frequency stability or transient stability.

As a consequence, synchronous condensers are continuously gaining importance in managing grid stability in the face of the accelerating energy transition.

For more than 120 years ANDRITZ has supplied numerous synchronous and non-synchronous machines for generation purposes. Today, approximately 5,000 units are still in service all over the world, relying on decades of experience in plant and system integration in the renewable energy business.

The ANDRITZ Synchronous Condenser portfolio covers a range of standardized air-cooled systems from 50 to 330 MVAr.

Independent power producers (IPPs) and project developers for wind and photovoltaic plants are generally operating smaller rated systems. Strict grid regulations require them to use a modern synchronous condenser to gain grid access. These cylindrical rotor solutions are very cost-efficient and offer the shortest delivery times due to a high degree of standardization.

The higher rated systems with salient pole design are intended for transmission grids where high inertia, low losses, and dynamic behavior are crucial. With its high robustness, the salient pole design is best suited for transmission grid applications.

Engineering excellence from ANDRITZ is focused on the entire power train, from the synchronous condenser unit with its mechanical and electrical auxiliaries right up to the defined Point of Common Coupling (PCC) with the high voltage transmission system.

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