A synchronous generator is an electrical machine that converts mechanical energy into alternating current (AC) electrical energy while operating at a constant speed that is synchronized with the grid frequency. It is called “synchronous” because the rotor speed is directly related to the electrical frequency of the output voltage. This relationship is given by:

$$ns = \frac{120f}{p}$$

where ns is the synchronous speed in revolutions per minute (rpm), f is the frequency in hertz, and P is the number of poles. In power systems operating at 50 Hz or 60 Hz, generators must rotate at precise speeds to maintain system stability and proper frequency.

The main components of a synchronous generator are the stator, rotor, excitation system, and cooling system. The stator contains the armature windings where the output voltage is induced. The rotor carries the field winding, which is supplied with direct current (DC) through an excitation system. When the rotor rotates, it creates a rotating magnetic field that cuts through the stator conductors, inducing a three-phase AC voltage according to Faraday’s law of electromagnetic induction. Depending on the application, rotors are typically designed as either salient-pole (used in low-speed hydro generators) or cylindrical (used in high-speed steam and gas turbines).

Synchronous generators are widely used in power plants because they provide stable voltage and frequency control. By adjusting the excitation current, operators can control the generator’s terminal voltage and reactive power output. This capability allows synchronous generators to support grid voltage regulation and maintain power factor. Unlike asynchronous (induction) generators, synchronous generators can operate at a wide range of power factors and are essential for large-scale power generation in thermal, hydroelectric, nuclear, and renewable power plants.

In modern power systems, synchronous generators also play a critical role in system stability and inertia support. Their large rotating masses provide mechanical inertia, which helps resist sudden frequency changes during disturbances. This inertia slows down frequency deviations and gives time for control systems to respond. With increasing integration of renewable energy sources that lack natural inertia, the role of synchronous generators—and technologies that replicate their behavior—remains central to maintaining reliable and secure power system operation.

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1. What is a synchronous generator, and why is it called “synchronous”?
2. Write the equation that relates synchronous speed, frequency, and the number of poles in a synchronous generator, and explain each term.
3. What are the main components of a synchronous generator, and what is the function of the excitation system?
4. How is the terminal voltage and reactive power of a synchronous generator controlled?

5. Why are synchronous generators important for grid stability and frequency regulation in modern power systems?

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Student A: Hey, have you heard about the power station tour next week? I'm thinking about going.

Student B: Yeah, I saw the announcement! I really want to visit. It would be cool to see how synchronous generators actually work in real life.

Student A: Exactly. We've studied all the theory—rotors, stators, excitation systems—but seeing them in operation is something else.

Student B: Do we need to sign up somewhere? I heard there's limited space.

Student A: I checked the flyer. We have to register with the electrical engineering department by Thursday.

Student B: Good to know. What time are we supposed to be there?

Student A: The bus leaves at 8:00 AM from the main gate. They said the tour will take about three hours.

Student B: Nice. I hope we get to see the control room. I'm curious how they regulate voltage and monitor frequency in real time.

Student A: Same here. It'll also be interesting to see how the generators handle reactive power and grid stability.

Student B: So, we're going together? Let's sign up today.

Student A: Definitely. I'll pass by the department office during the break.

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Important words

- Rotor
- Stator
- Excitation
- Frequency
- Voltage
- Magnetic field
- Synchronization
- Reactive power
- Inertia
- Power factor

A “flyer” is a printed sheet of paper or a card that typically contains information about an event, product, service, or anything else being advertised. It’s usually distributed for free to inform people about something and encourage them to attend an event or purchase a product.