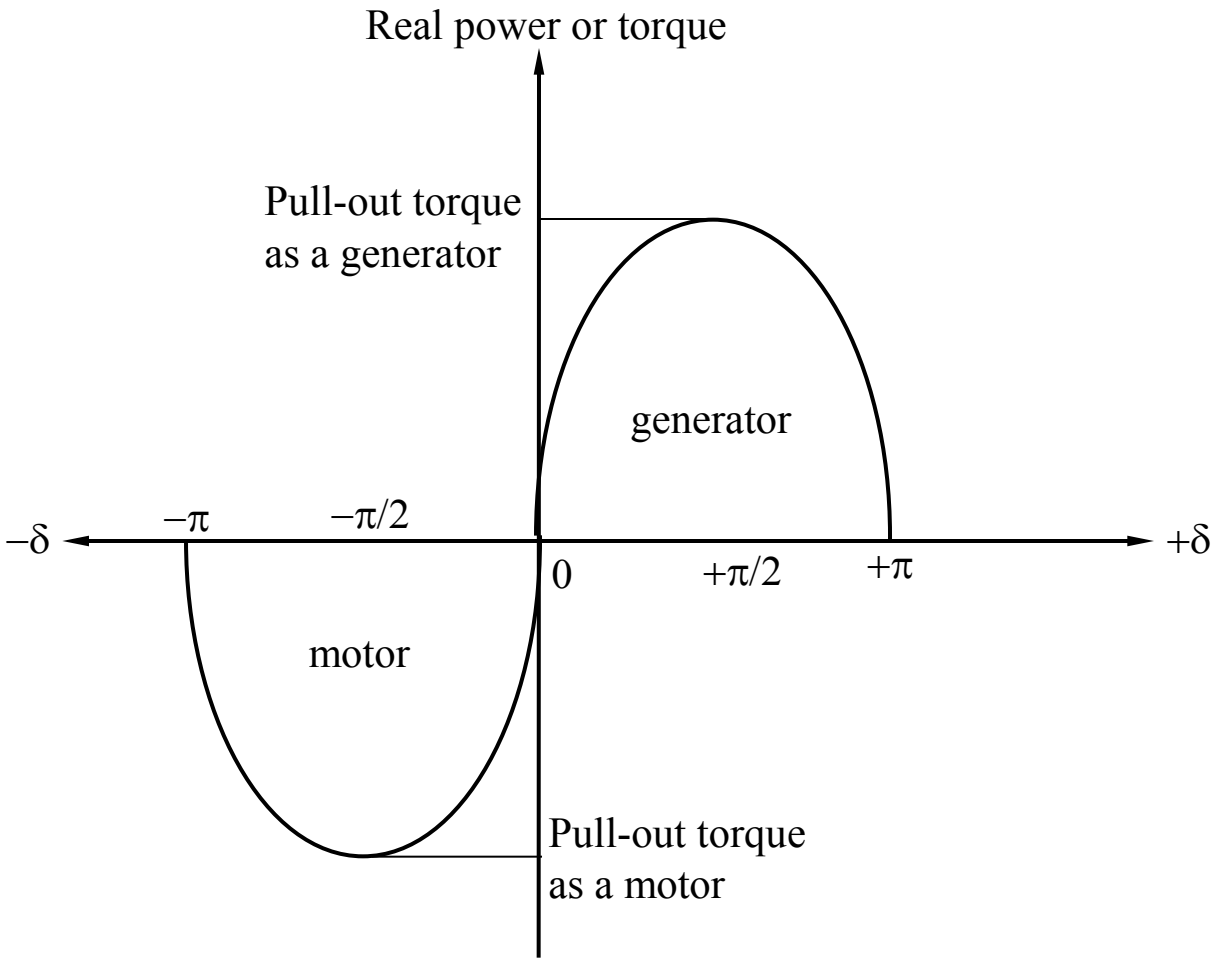
LECTURE 7

Steady-state power-angle or torque-angle characteristic of a cylindrical-rotor synchronous machine (with negligible armature resistance).



Steady-state stability limit

Total three-phase power: $P = \frac{3V_t E_f}{X_s} \sin\delta$

The above equation shows that the power produced by a synchronous generator depends on the angle δ between the V_t and E_f. The maximum power that the generator can supply occurs when δ=90°.

$$P = \frac{3V_t E_f}{X_s}$$

The maximum power indicated by this equation is called *steady-state stability limit* of the generator. If we try to exceed this limit (such as by admitting more steam to the turbine), the rotor will accelerate and lose synchronism with the infinite bus. In practice, this condition is never reached because the circuit breakers trip as soon as synchronism is lost. We have to resynchronize the generator before it can again pick up the load. Normally, real generators never even come close to the limit. Full-load torque angle of 15° to 20° are more typical of real machines.

Pull-out torque

The maximum torque or *pull-out torque* per phase that a two-pole round-rotor synchronous motor can develop is

$$T_{max} = \frac{P_{max}}{\omega_m} = \frac{P_{max}}{2\pi\left(n_s / 60\right)}$$

where n_s is the synchronous speed of the motor in rpm

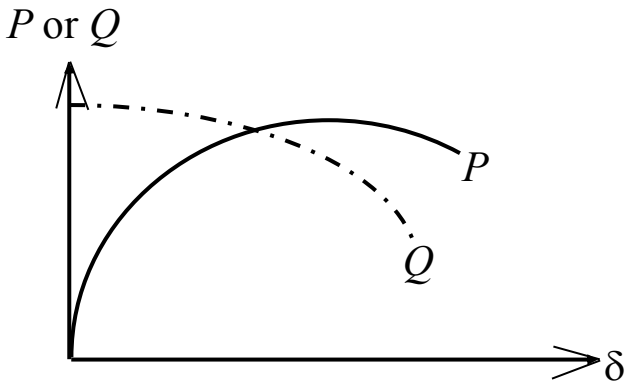


Fig. Active and reactive power as a function of the internal angle

Operation Principle

- The field current of a synchronous motor produces a steady-state magnetic field B_R
- A three-phase set of voltages is applied to the stator windings of the motor, which produces a three-phase current flow in the windings. This three-phase set of currents in the armature winding produces a uniform rotating magnetic field of B_s
- Therefore, there are two magnetic fields present in the machine, and *the rotor field will tend to line up with the stator field*, just as two bar magnets will tend to line up if placed near each other.
- Since the stator magnetic field is rotating, the rotor magnetic field (and the rotor itself) will try to catch up
- The larger the angle between the two magnetic fields (up to certain maximum), the greater the torque on the rotor of the machine