Power System Stability

Course Notes

PART-1

Dr. A. Professor Mohammed Tawfeeq Al-Zuhairi

September 2012
Definition of stability

The stability of a power system is defined as the ability of the power system to return to normal or stable operation after having been subjected to some form of disturbance.

Disturbances threatening the stability of a system:

Small and large disturbances

A power system is subjected to a variety of disturbances. These are classified into two categories:

• Small disturbances (perturbations)
• Large disturbances (perturbations)

Small Perturbations

Perturbations are characterized as small if the changes in system states are small due to these perturbations. Random changes in load which occur in the system continuously are an example of small perturbation. Stability problem associated with small perturbation is known as dynamic stability.

Large perturbations

A power system may be subjected to large perturbations such as:

• Occurrence of faults on the line
• Loss of large generating units
• Loss of major transmission facilities
• Loss of large loads
Energy fluctuation as a result of disturbance:

- between capacitors and inductances
- between rotating masses (most important factor)
- boilers in power plants, or combustion chambers

Changes can be seen in the quantities \( P, Q, V, I \)

- time constants between 10 ms–10 s
- period of oscillations between 0.5–5 s

Categorization of stability in practice

1- **Rotor angle stability** (Loss of synchronism)
   
   Load angle differences of generators become too large causing tripping of generators

2- **Voltage stability**

   Voltage stability refers to the ability of a power system to maintain steady voltages at all buses in the system after being subjected to a disturbance. Collapse of voltage makes interconnected operation impossible

3- **Frequency stability**

   Frequency stability refers to the ability of a power system to maintain steady frequency at all buses in the system after being subjected to a disturbance. Collapse of frequency makes interconnected operation impossible

**Rotor angle stability (Synchronous operation)**

The stability of synchronous machines depends on the state of the network and the nature of the disturbance. In general, the rotor angle stability problems are classified into three types:

- steady-state stability
- transient stability
- dynamic stability
Steady state stability: The ability of the power system to remain in synchronism when subject to small disturbances (Small Perturbations due to random variation of loading).

Transient stability: The stability problem associated with large perturbations is known as transient stability. It concerns with the study of behavior of the power system when is subject to fast changes with large magnitudes. Transient stability studies are normally performed for a period of 1 second. The faults that are normally taken into consideration for the transient stability studies are: faults of heavily loaded lines, the tripping of a loaded generator or the dropping of a large load.

- The transient stability limit is generally lower than the steady state stability limit.
- In practice, transient stability is determined by computer calculation. Manual calculation is possible only in simple cases.

Dynamic stability: After a fault, an individual synchronous machine may remain in synchronism during the first swing. After this, strong electromechanical oscillations occur may cause the system to have natural oscillations. The system is said to be dynamically stable if the oscillations don’t exceed a certain magnitude and die out quickly (i.e., the system is well-damped). Dynamic stability of a given power system can be improved through the use of power system stabilizers. Dynamic stability study is normally carried out for a period of 5 to 10 second and sometimes to 30 seconds.

Rated faults on the grid

- a three-phase short circuit of any line, followed by a successful high speed automatic reclosing.
- a single-phase earth fault of any line, followed by a failed high-speed automatic reclosing.
- a three-phase short circuit of any bus bar, followed by a disconnection (switching off) of the bus.
The situation is acceptable, when:

- the synchronism of the network is not lost during the oscillation (swing) followed by the fault.
- sustained (undamping) oscillations do not occur after the fault has been cleared.
- voltages of the 400 kV network are at least 370 kV at all stations when the oscillation following the fault has damped out.
- network components are not exposed to permanent overload.
- single faults do not lead to an expanding disturbance.
- frequency does not fall below the frequency of 48.5 Hz that activates the automatic disconnection of loads.
- frequency does not exceed 51.5 Hz.

The power system normally has many interconnected generating stations, each with several generators. For the purpose of stability studies machines located at any generating station are normally considered as one large equivalent machine. This also applies for machines connected by low impedance lines. In this way a multi-machine system can be reduced to an equivalent few machine system. Normally, if the system falls out of step (synchronism lost) machines at any power station stay in synchronism although they go out of step with other machines located far away at other generating stations.
Typical swing curves in the loss of stability

1. At the power transfer limit (steady-state stability), the generator falls out of synchronism as a result of a small transient phenomenon on the network.

2. Transient stability is lost as a result of a fault on the network; the generator accelerates (speeds up) after the loss of synchronism.

3. Dynamic stability is lost as a result of sustained power angle oscillations caused by a fault.
4. Exceeding the limit of voltage stability as a result of a fault leads to an accelerated decrease in voltages and to a voltage collapse.

**Examples of stability**

1. Stable oscillation

**Rotor angle swing**

**Frequency Variation**
2. Loss of stability (Caused by a severe fault)

Rotor angle swing

[Graph of rotor angle swing]

Frequency Variation

[Graph of frequency variation]