Power System Stability

Overview of power system stability phenomena

Series of 8 seminars

Simulation exercises

Information at http://www.iea.lth.se/~ielolof/stability/

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Needs

Original need – transmission of electric power over large distances, distribution of electric power to consumers in urban and rural areas.

Current need – connection of remote wind turbines to the existing power system

Demands – technology must be available, cost effective long-term investments, simple expansion for new needs, high reliability.

AC or DC?

AC solution – transformers,

meshed 3-Φ HV (sub)transmission system,

radial MV and LV distribution,

synchronous generation

DC solution – converters,

unmeshed system,

synchronous or asynchronous generation

Sweden

1952 Pioneering with HVAC transmission, Harsprånget-Hallsberg 380 kV highest voltage

1954 Pioneering with HVDC transmission, Gotland first commercial HVDC link

1996 New generator – PowerFormer

2000 New system concept – WindFormer

2000 New transformer – DryFormer

Success of AC

The synchronous generator – simple load sharing.

The transmission line – series reactance has natural current limiting ability.

The AC transformer – voltage level can be freely selected anywhere. *Extremely robust compared to an HVDC converter*.

Three-phase system – no return conductor, constant power and torque.

Downside of AC

Synchronous generators → angle stability

Series reactance → voltage stability

Why is it important now?

Stability phenomena limit transfer capability.

Systems grow more complex as they are interconnected (to increase reliability and profit)

Stagnation in line constructions and increased use of electricity increases the load level.

Power System Stability and Industrial Automation

Stability is a system property

System analysis

Model simplifications – resolution or overview

Stability phenomena I

… leading to loss of stable operating point

Name, cause and effect:

Transient (angle) **stability**, large disturbance angle stability

> imbalance between accelerating torque and load torque on (groups of) generators caused by outage of major generator, line, transformer, busbar, load
>
> loss of synchronism, frequency instability, system separation and/or blackout

Small signal (angle) **stability**, small disturbance angle stability

> insufficient damping of electromechanical dynamics cause oscillations with low or negative damping
>
> transient instability, loss of synchronism, system separation and/or blackout

Stability phenomena II

… leading to loss of stable operating point

Name, cause and effect:

Voltage stability, load stability, transient VS, small signal VS

> insufficient reactive power supply due to system overload
>
> voltage collapse, excessive currents, system separation and/or blackout

Subsynchronous resonance

> interaction between electrical network resonance and torsional dynamics of thermal plants or electrical generator dynamics (self excitation)
>
> generator tripping

Frequency stability

> turbine controllers do not manage to stabilize system frequency
>
> system separation and/or blackout

Stability criteria

N-1 with normal fault clearing

- Permanent three-phase fault anywhere
- Loss of any element without a fault
- Phase-to-ground fault on a circuit breaker or stuck breaker
- Loss of DC line
- Two simultaneous single-phase faults on different phases of adjacent transmission line circuits on the same tower (N-2?)

Contradiction in protection

To save equipment, lines, transformers, generators are taken **out of** service

To save system operation, a heavily loaded system needs all its components **in** service

System protection schemes

or Wide Area Protection System

- Aims at saving system operation
- Can extend transfer limits beyond N-1
- Wide Area Protection Against Voltage Collapse in Southern Sweden