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Ingenuity for life

Dynamics of the transmission system

System stability criteria

At a glance

Loads are increasing in many electricity systems today, often leading to system instabilities. To avoid severe instability issues, it is important to determine which factors are involved and to analyze how the system can be improved.

Siemens Power Technologies International (Siemens PTI) can help you acquire a profound knowledge of your system:

- in determining and analyzing the relevant stability aspects for your individual power system
- with powerful simulation tools from the PSS® product suite which model the dynamic behavior of the system

A safe and reliable operation can be achieved, even at high load.

The challenge

Simply having the knowledge of the static safety limits of a system is not sufficient in ensuring safe and reliable operation of the power system with increasing load. It is of utmost importance to know and understand system dynamics and stability. Not only should generator stability be tested, but voltage stability criteria must be taken into consideration.

Our solution

We have extensive and powerful tools to facilitate the gathering of information on all aspects regarding system stability, therefore helping to ensure stable power systems. The following issues must be analyzed in detail:

- stability criteria
- transient stability
- rotor angle swing
- oscillation damping power system stabilizers
- voltage stability
- small signal stability
- frequency stability criteria

Stability criteria

A power system is stable if it returns to a steady-state, or equilibrium operating condition, following a disturbance. This criterion holds true for loading conditions and generation schedules under normal operating conditions; following the loss of any power plant, or for the most severe network faults. In the planning and operation of a power system, it is important to consider the potential emergence of a variety of stability problems.

Two broad categories of stability are considered:

- Angle stability involves the dynamics of generators and their associated control systems. Angle stability can be further categorized into transient stability and small-signal or steady-state stability. Frequency stability is closely related to angle stability.
- Voltage stability involves the dynamic characteristics of loads and reactive power compensation. Voltage collapse is perhaps the most widely recognized form of voltage instability.

Transient Stability

Transient stability is the inherent ability of a system to remain stable and maintain network synchronism when subjected to severe disturbances such as three-phase faults on power lines, loss of generation, and loss of a large load or other failures. Such large disturbances need to be cleared within a reasonable time span in order to prevent network instability and physical damage to a plant.

Transient stability is assessed based on the first angular swing following a solid three-phase fault on one circuit at the most critical location cleared by the faster of the two protection schemes with all inter-trips assumed in service.

Rotor angle swing

In general, an initial generator rotor angle swing which does not exceed 160° is considered stable (practical limit). A rotor angle swing exceeding 160° only has a small margin before pole slipping (180°), and an initial rotor swing angle higher than 160° may result in a pole slip or repeated pole slipping, which is considered unstable.

The relative rotor angle concept of synchronous instability is based on the rotor angle between two synchronous machines. In the case of two or more generation groups containing various generators, a correlated effect on the network, such as transient voltage dip limits, shall be used to prevent synchronous instability.

Oscillation damping

All electromechanical oscillations resulting from any small or large disturbance in the power system can be well damped and the system can return to a stable operating state. The damping ratio of the oscillations should be at least 5%. For inter-area oscillation modes, lower damping ratios may

be acceptable; the halving time of such oscillations should not exceed five seconds.

Power system stabilizers

Power system simulation studies may indicate the possibility of insufficient damping on the system, where the best solution to this problem would be the installation of power system stabilizers. These are to be installed on generating units where they will be most effective in improving the overall system damping. Eigenvalue analysis will define the most suitable location for a power system stabilizer. The stabilizing circuits can be responsive and adjustable over a wide frequency range, including frequencies from 0.7 Hz to 1.3 Hz. The power system stabilizer settings can be optimized to provide maximum damping using eigenvalue analysis.

Voltage stability

Voltage stability is a function of the dynamic characteristics of system loads. A power system at a given operating state, subject to a given disturbance, is voltage stable if post-disturbance voltages at every point on the system reach equilibrium within satisfactory limits. Disturbances may be small or large, and time frames may vary from tenths of a second to several hours.

Voltage instability most commonly results in voltage collapse, but may give rise to excessively high voltage levels under some conditions. Adequate and appropriate reactive power compensation can be provided to ensure that the power system is protected against voltage instability. This can include the use of shunt and series capacitors and/or reactors, SVCs, synchronous condensers, etc.

Small signal stability (eigenvalue analysis)

Following any small disturbance, a power system is small signal stable for a particular steady-state operating condition if it reaches an equilibrium condition which is identical or close to the pre-disturbance condition. Small disturbances include the continuously changing system load and minor switching operations. Small signal instability may be oscillatory where undamped rotor angle oscillations grow to dangerous magnitudes, or monotonic where rotor angle differences increase in one direction. In either case, generating units can fall out of synchronism with each other and pole slipping can occur.

Small signal stability is assessed based on the damping design criteria, stating that system damping is considered adequate if simulations indicate that the damping coefficient is at least 5%.

Frequency stability criteria

The frequency stability criteria relate to recovery times for derivations of the system frequency from steady state limits. To cover for a loss of generation capacities there are two measures applied to restore the frequency:

- spinning reserve
- under-frequency load shedding (UFLS)

Application example

Figure 1 shows the inter-area oscillation of the European grid after a variation of load flow in France and Spain.

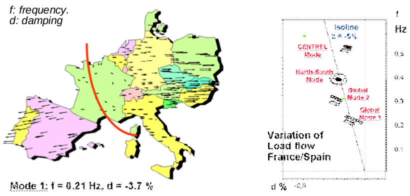

Figure 1: Inter-area oscillation after variation of load flow in France / Spain.

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