

Module 1 : Fundamentals of Power System Protection

Lecture 3 : Protection Paradigms - System Protection

Objectives

In this lecture we will:

- Overview dynamics in power systems.
- Introduce system protection relays like underfrequency relays, rate of change of frequency relays, reverse - power flow relays etc.
- Give a brief introduction to lightning protection.

3.1 Overview of Power System Dynamics

Usually, system protection requires study of the system dynamics and control. To understand issues in system protection, we overview dynamical nature of the power system. Power system behavior can be described in terms of differential and algebraic system of equations. Differential equations can be written to describe behaviour of generators, transmission lines, motors, transformers etc. The detailing depends upon the time scale of investigation.

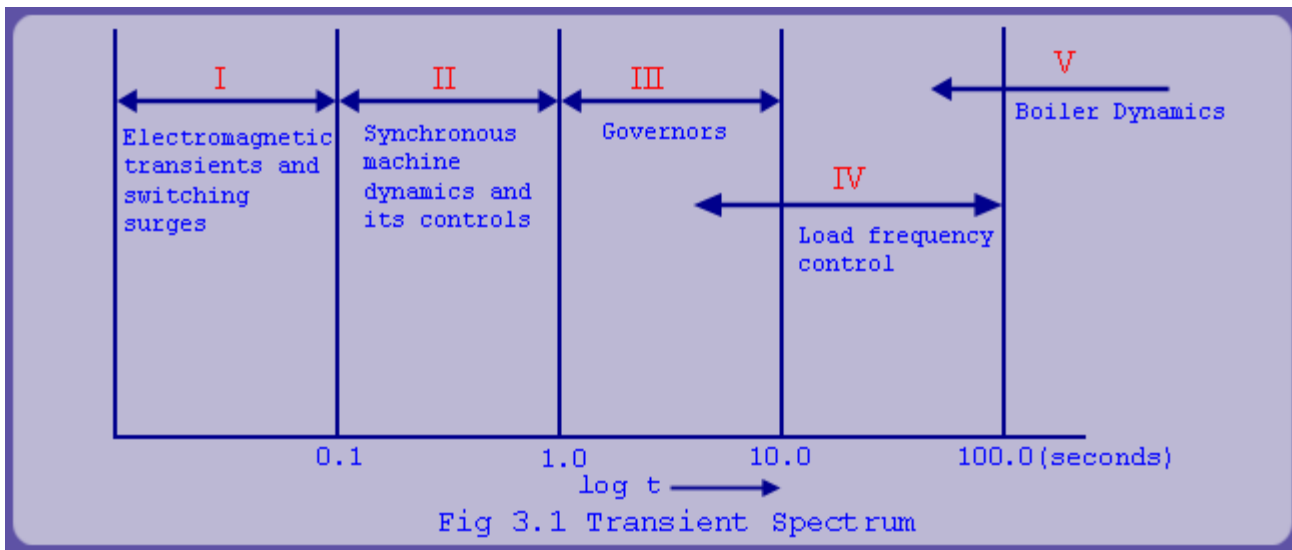


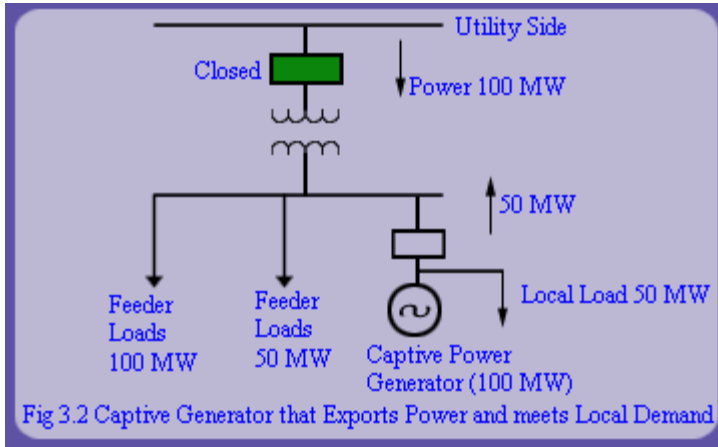
Figure 3.1 shows the various time scales involved in modelling system dynamics. The dynamics involved in switching, lightning, load rejection etc have a high frequency component which die down quickly. In analysis of such dynamics, differential equations associated with inductances and capacitances of transmission lines have to be modelled. Such analysis is restricted to a few cycles. It is done by Electromagnetic Transient Program (EMTP).

At a larger time scale (order of seconds), response of the electromechanical elements is perceived. These transients are typically excited by faults which disturb the system equilibrium by upsetting the generator-load balance in the system. As a consequence of fault, electrical power output reduces instantaneously while the mechanical input does not change instantaneously. The resulting imbalance in power (and torque) excites the electromechanical transients which are essentially slow because of the inertia of the mechanical elements (rotor etc).

Detection and removal of fault is the task of the protection system (apparatus protection). Post-fault, the system may or may not return to an equilibrium position. Transient stability studies are required to determine the post fault system stability. In practice, out-of-step relaying, under frequency load shedding,

islanding etc are the measures used to enhance system stability and prevent blackouts. The distinction between system protection and control (e.g. damping of power swings) is a finer one. In the today's world of Integrated Control and Protection Systems (ICPS), this distinction does not make much sense. In this lecture, we discuss these issues from distribution system perspective. In the next lecture, a transmission system perspective will be discussed.

3.2 System Protection Relays

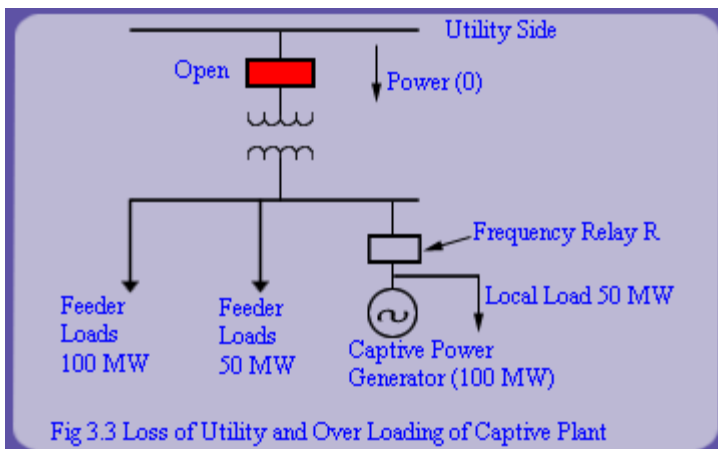


Consider a medium voltage distribution system having local generation (e.g., captive power generation) as shown in fig 3.2 which is also synchronized with the grid. During grid disturbance, if plant generators are not successfully isolated from the grid, they also sink with the grid, resulting in significant loss in production and damage to process equipments. The following relays are used to detect such disturbances, its severity and isolate the inplant system from the grid.

- Underfrequency and over frequency relays.
- Rate of change of frequency relays.
- Under voltage relays.
- Reverse power flow relays.
- Vector shift relays.

3.2 System Protection Relays

3.2.1 Underfrequency Relay and Rate of Change of Frequency Relay

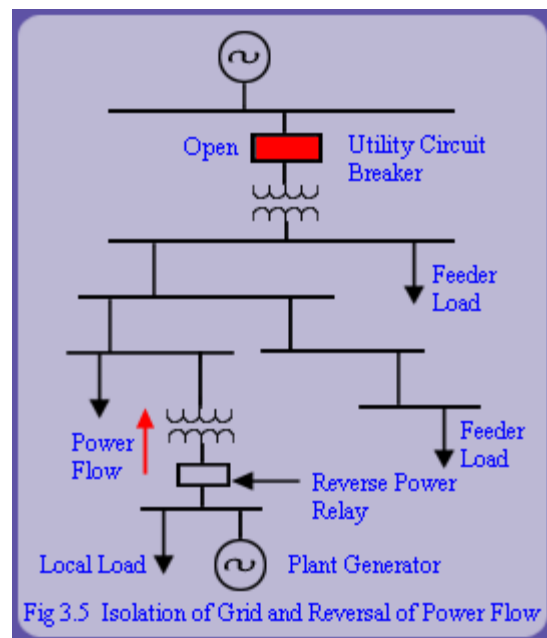
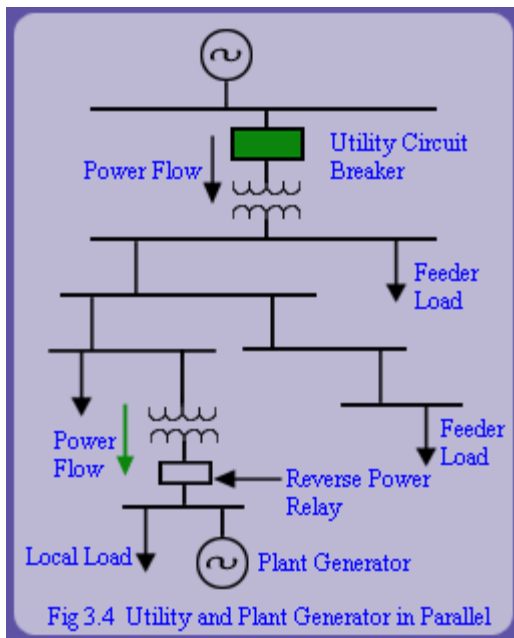


In case of a grid failure (fig. 3.3), captive generators tend to supply power to other consumers connected to the substation. The load-generation imbalance leads to fall in frequency. The underfrequency relay R detects this drop and isolates local generation from the grid by tripping breaker at the point of common coupling. After disconnection from the grid, it has to be ascertained that there is load-generation balance in the islanded system. Because of the inertia of the machines, frequency drops gradually. To speed up the islanding decision, rate of change of frequency relays are used.

3.2.2 Undervoltage Relay

Whenever there is an uncleared fault on the grid close to the plant, the plant generators tend to feed the fault, and the voltages at the supply point drops. This can be used as a signal for isolating from the grid.

3.2.3 Reverse Power Relay



Distribution systems are radial in nature. This holds true for both utility and plant distribution systems. If there is a fault on the utility's distribution system, it may trip a breaker thereby isolating plant from the grid. This plant may still remain connected with downstream loads as shown in fig 3.4 and 3.5. Consequently, power will flow from the plant generator to these loads.

If in the prefault state, power was being fed to the plant, then this reversal of power flow can be used to island the plant generation and load from the remaining system. This approach is useful to detect loss of grid supply whenever the difference between load and available generation is not sufficient to obtain an appreciable rate of change of frequency but the active power continues to flow into the grid to feed the external loads.

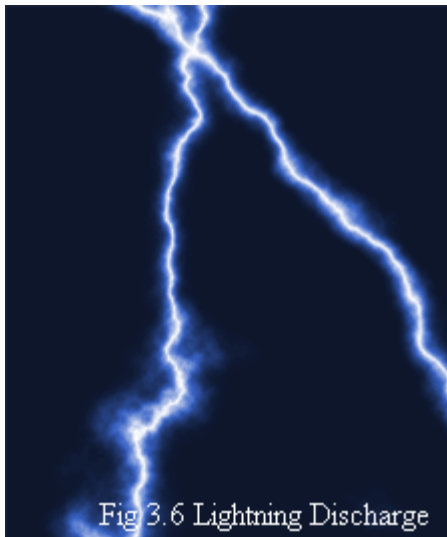
Example

In fig 3.4, consider that the plant imports at all times a minimum power of 5 MW. Studies indicate that for various faults in utility side, minimum power export from the plant generator is 0.5 MW. Deduce the setting of reverse power relay. If the plant generator is of 50 MW capacity, what is likelihood of underfrequency or rate of change of frequency relay picking up on such faults?

Ans: Reverse power flow relay can be set to 0.4 MW. Since minimum reverse power flow is 1% of plant capacity, it is quite likely, that utility disconnection may not be noticed by underfrequency or the rate of change of frequency relays.

Vector shift relays and system protection schemes in transmission systems will be discussed in more details in later lectures.

3.3 Lightning Protection



Many line outages result from lightning strokes that hit overhead transmission lines. Lightning discharges normally produce overvoltage surges which may last for a fraction of second and are extremely harmful. The line outages can be reduced to an acceptable level by protection schemes like installation of earth wires and earthing of the towers.

Lightning overvoltages can be classified as follows:

- Induced overvoltages which occur when lightning strokes reach the ground near the line.
- Overvoltages due to shielding failures that occur when lightning strokes reach the phase conductors.
- Overvoltages by back flashovers that occur when lightning stroke reaches the tower or the shield wire.
- The most commonly used devices for protection against lightning surges are the following:
 - Shielding by earth wires: Normally, transmission lines are equipped with earth wires to shield against lightning discharges. The earthwires are placed above the line conductor at such a position that the lightning strokes are intercepted by them. In addition to this, earthing of tower is also essential.
 - Lightning Arrestors: An alternative to the use of earthwire for protection of conductors against direct lightning strokes is to use lightning arrestors in parallel to insulator strings. Use of lightning arrestors is more economical also. ZnO varistor is commonly used as lightning arrester because of its peculiar resistance characteristic. Its resistance varies with applied voltage, i.e, its resistance is a nonlinear inverse function of applied voltage. At normal voltage its resistance is high. But when high voltage surges like lightning strokes appear across the varistor, its resistance decreases drastically to a very low value and the energy is dissipated in it, giving protection against lightning.

Review Questions

1. Describe various system protection relays in use.
2. What are the functions of an underfrequency relay?
3. Explain the functioning of reverse power flow relay.
4. How transmission lines are protected against lightning?
5. Explain the functioning of ZnO varistor.

Recap

In this lecture we have learnt the following:

- Dynamics in power systems.
- Various system protection relays like underfrequency relays, rate of change of frequency relays, reverse power flow

relay, under voltage relay etc.

Lightning protection.