E-LECTURE NOTE

COURSE TITLE: POWER SYSTEM ENGINEERING II

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UNIT: 3

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LECTURE1

POWER SYSTEM PROTECTION

1.1 Introduction

The protection of power system ensures that if any part of a system at fault is quickly detected and isolated so that the rest of the system equipment and personnel are safe and the remaining system operates satisfactorily.

1.2 Basic connection circuit

A typical circuit diagram is used to illustrate the basic components of the protection scheme. Some of these components include:

- The line being protected
- The current transformer
- The relays
- The trip coils
- The circuit breakers.

1.3 Protection System Attributes

Both appropriate earthing and fault studies are primarily necessary for the design and installation of a most appropriate protection arrangement for a given system. The protection system can be divided into three sub system namely:

(a) The circuit breakers

(b) The transducers - current transformer (CT) or voltage transformer (VT)

(c) The relays

For further discussion on the operation of the protection systems, a one line diagram of two transmission lines and the protection element is considered.

1.4 Relay Attributes

(a) It must be dependable and selective

(b) It must make its decision quickly and consistent with all requirements placed on it.

(c) Correctness of its selectivity.

(d) It's dependability for it to operate consistently for all the faults for which it is designed and set to operate and from operating for any other system conditions.

1.5 Types of Relays

A relay is an electromagnetic and mechanical device which makes measurement or receive a signal which causes it to operate and to effect the operation of another equipment.

There are many design of relay elements in use. The types of relay include:

(1) The attracted armature relay

(2) The balanced beam relay

(3) The thermal relay

(4) The timing relay

(5) The moving coil relay

(6) The buchholz relay

(7) The induction cup relay

(8) The induction disc time delay relay

(9) The electromagnetic plunger type relay

(10) The electronics relay.

The operational details and construction features as well as the area of applications of some of the above mention types of relay were considered.

1.6 Transformer Protection

A technique referred to as "differential protection" is used to protect a power transformer against damaging currents and voltages. This method is illustrated using a circuit diagram. A ***worked example*** is also used to illustrate the method.

Buchholz protection is also used in transformer protection to employ gas actuated relays for alarm and tripping.

1.7 Transmission line protection

A basic consideration with regard to line protection is proper coordination of circuit breakers and relay.

1.8 Motor and generator protection

The basic danger to a machine is excessive heating; this in turn may cause insulation and structural damage. Some of the hazard to rotating machines include: stator overload, stator overheating, loss excitation, over speed, etc.

1.9 Pilot relaying

Remote controlling of circuit breakers.

This scheme requires communication channels to carry system voltage and current information to the decision making location.

LECTURE II

POWER SYSTEM CONTROL

2.1 Introduction

A generator driven by a steam turbine can be represented by a large rotating machine with two opposing torques acting on the rotation – mechanical torque and electrical torque. The mechanical torque acts to increase the rotational speed while the electrical torque acts to slow it down.

The statutory limits for frequency control and voltage control is ±1% and ±6% respectively.

2.2 Frequency control

The main objective of frequency control is essentially the matching of the system active demand and generation at ‘all’ time. A typical schematic diagram is used to discuss frequency control of generation.

2.2.1 Turbine governor/speed governing system

Active power in a power system is controlled by controlling the driving torque of the individual turbines.

The governing system is made up of sensing device sensitive to change of speed i.e the centrifugal governor. A schematic diagram is used in illustration. The mathematical expression for governor characteristics (droop curve) is shown:

$$\text{Governor droop} = \tan\alpha = -\Delta f/\Delta p = -(f_e - f_o)/p_i \qquad \text{Hz/Mw}$$

A worked example is also used to describe the governor system.

2.2.2 Interconnected system

Interconnected system or tie lines join two separate power systems together. The change in power from a given change in the frequency in an interconnected system is known as stiffness of the system. The smaller the change in frequency for a given load changes the stiffer and more stable the system.

2.3 Voltage control

It is deserved to keep the terminal voltage of a generator constant irrespective of the stator current. Manual control of the excitation results in poor control or excitation and poor response of the terminal voltage. Any adjustment of the terminal voltage takes appreciable time. In modern generators, the output voltage is controlled by automatic devices referred to as automatic voltage regulator (AVR).

2.3.1 The Generation and Absorption of Reactive Power

In view of the findings in the previous section, the review of the characteristics of a power system from the viewpoint of reactive power is now appropriate.

2.3.1(a) Synchronous Generator

This can be used to generate or absorb reactive power. A figure would be used to show the limits of the capability of the synchronous generator.

2.3.1 (b) Overhead Lines and Transformer

When fully loaded, lines absorb reactive power. With the current I amp for a line of reactance per phase X ohms the VARs Absorbed are I^2X per phase. Transformers always absorb reactive power.\

2.3.1(c) Cables

Cables are generators of reactive power owing to their high shunt capacitance

2.3.1(d) Loads

In planning a network k, it is desirable to assess the reactive power require ment to generators are able to operate at the required power factors for the extremes of load to be expected. An example is given for further explanation.

2.4 Relation between Voltage, Power and Reactive power at a Node

The phase voltage V at a load is a function of P and Q at that node. The voltage is also dependent on adjacent nodes and the present treatment assumes that these are infinite buses.

2.5 Methods of Voltage Control

2.5.1 Injection of Reactive power

The background to this method has been discussed earlier. This is the most fundamental method, but in transmission system, it lacks the flexibility and economy of transformer tap-changing. Hence, it is only used in schemes when transformer alone will not suffice. Four methods of injection are available:

a. Shunt capacitors and reactors: Shunt capacitors are used for lagging power factor circuits, whereas reactors are used on those of leading power factor. In both cases, the effect is to supply the requisite reactive power to maintain the values of the voltage.

b. Series Capacitor: These are connected in series with the line conductors and are used to reduce the inductive reactance between the supply point and the load. The relative merits between shunt and series capacitors will be highlighted.

c. Synchronous Compensators: The synchronous compensator is a synchronous motor running without a mechanical load and depending on the value of excitation; it can absorb or generate reactive power. A great advantage is the flexibility of operation for all load conditions.

d. Series Injection: With the development of high power, high voltage semiconductor -controlled devices, including pulse turn-on and turn-off, inverters are now being designed and constructed that can inject a voltage in series with a line, whose angle can have any desired relation with the phase voltage.

2.5.2 Tap-changing Transformer

The basic operation of a tap-changing transformer involves changing the transformation ratio so that the voltage in a secondary circuit is varied and voltage control is obtained. This constitutes the most popular and widespread form of voltage control at all voltage levels.

2.6 Combined Use of Tap-Changing Transformer and Reactive-Power Injection

The usual practical arrangement involves the connection of a tertiary winding of a three-winding transformer to a compensator. For given load conditions, it is proposed to determine the necessary transformation ratio with certain output of the compensator.

2.7 Booster Transformer

It may be desirable on technical or economic grounds to increase the voltage at intermediate points in a line rather than at the ends as with tap-changing transformer, hence, booster transformers are used. Boosters are often used in distribution feeders where the cost of tap-changing transformers is not warranted

2.7.1 Phase- Shift Transformers

It is possible to achieve a quadrature phase shift using necessary connections. In a booster arrangement voltage is injected into one phase only; it is repeated for the other two phases.By the use of tappings on the energizing transformer, several values of phase shift may be obtained. Further illustration would be given by relevant examples.

LECTURE III

POWER SYSTEM STABILITY

3.1 Introduction

The stability of an interconnected power system is its ability to return to normal or stable operation after having been subjected to some form of disturbance.

The study of stability is one of the main concern of the control engineer whose methods may be applied to electrical power system.

Power system stability is classified into three, namely

3.2 Steady sate stability

This is primarily concerned with the ability of the system generators to remain in synchronism after minor disturbances such as gradual load changes, changes in excitation, line switching and so on.

3.3 Transient stability

This is concerned with generators synchronism after a large or sudden disturbance such as large load drop or addition, line switching, short circuit, sudden loss of big generating plant.

3.4 Long term stability

This forms the transition between transient and steady state stability.

3.5 Swing curves

The swing curve is a plot of the rotor angle against time, and is used to determine transient stability of a power system. A figure is used to illustrate the characteristics of a system subject to disturbance.

3.6 Equal area criterion

The equal area criterion is used to predict transient stability without solving the swing equation for simple system such as one machine supplying an infinite bus-bar or two machine systems.