

## **Unit-5**

### **Voltage Control**

#### **5.1 PROBLEMS AT POWER FREQUENCY**

Power-frequency voltage is impressed on a system continuously as compared to transients caused by faults, lightning, and switching operations. Certain abnormal conditions arise when over voltages of a sustained nature can exist in systems which have to be guarded against. Insulation levels will be governed by these, and it is very important to know all the factors which contribute to such over voltages. E.H.V. lines are longer than and their surge impedance lower than lines at 345 kV and lower voltages. Also, e.h.v. lines are used more for point-to point transmission so that when load is dropped, a large portion of the system is unloaded and voltage rise could be more severe than when there is a vast interconnected network. Due also to the high capacitance of e.h.v. lines possibility of self-excitation of generators is quite serious.

Shunt reactors are employed to compensate the high charging current, which not only prevent over voltages during load dropping but also improve conditions for load flow, and the risk of self excitation can also be counteracted. In order to improve conditions, variable static VAR systems can also be employed as well as switched capacitors which introduce harmonics into the system. Finally, the use of series capacitors to increase line loading in long lines might bring about the danger of subsynchronous resonance in which electrical conditions in generators can produce torques which correspond to the torsional frequencies of the shaft and result in mechanical damage. The system at power frequency consists of lumped-parameter network elements connected to distributed-parameter transmission lines, and the calculations are best handled through generalized constants in matrix form.

#### **5.2 Sub-Synchronous Resonance Problem and Counter Measures**

As pointed out before, electrical resonance frequencies lower than synchronous frequency  $f_0$  exist when series-capacitor compensation is used. The frequency  $f_0$  corresponds to the steady state speed of the rotor in large power stations. With steam-turbine-driven generating units (designated T.G. units), the shaft or shaft portions connecting the HP, IP, LP stages of the turbine and the generator-exciter are very long, with their own characteristic torsional mechanical resonant frequencies. When the electrical system operates in such a manner that the rotating fields in the generator due to sub-synchronous currents produce torques of the same frequency as one of the mechanical torsional frequencies of the shaft and of

the correct phase, torques up to 10 times the break away or ultimate strength of the shaft can be reached resulting in shaft damage. This phenomenon of electromechanical interaction between electrical resonant circuits of the transmission system and the torsional natural frequencies of the T-G rotor is known as "Sub-Synchronous Resonance", and designated SSR.

The phenomenon of SSR has been studied very extensively since 1970 when a major transmission network in the U.S. experienced shaft failure to its T-G unit with series compensation in the 500 kV lines. This has now gone into technical literature as a classic problem and known as Project Navajo. The phenomenon, however, had been known to exist for a few years according to many experts who predicted such a phenomenon in series compensated lines connected to T-G units. As a result of extensive study of Project Navajo, countermeasures to combat the SSR problem have been designed and are operating successfully.

The SSR failure must therefore be considered as one of the governing factors in design of series compensated lines when they are used for evacuating power from large thermal power stations. The combined cost of series-capacitor installation and the countermeasures is lower than the cost of additional transmission lines required when no series-compensation is used. Three distinct problems have been identified in SSR problem which are called

1. Induction Generator Effect,
2. Torsional Interaction, and
3. Transient Torque Problem.

The first two are known as steady-state problems while the last one occurs when system conditions change due to short-circuits and switching operations.

### **5.3 STATIC REACTIVE COMPENSATING SYSTEMS (STATIC VAR)**

One type of reactor compensation for countering SSR was mentioned as a Dynamic Filter which uses thyristors to modulate the current through a parallel-connected reactor in response to rotor speed variation. The advent of high-speed high-current switching made possible by thyristors (silicon-controlled-rectifiers) has brought a new concept in providing reactive compensation for optimum system performance. Improvements obtained by the use of these static var compensators (SVC) or generators (SVG) or simply static var systems (SVS) are numerous, some of which are listed below:

1. When used at intermediate buses on long lines, the steady-state power-handling capacity is improved.
2. Transient stability is improved.
3. Due to increased damping provided, dynamic system stability is improved.
4. Steady-state and temporary voltages can be controlled.

5. Load power factor can be improved thereby increasing efficiency of transmission and lowering of line losses.
6. Damping is provided for SSR oscillations.
7. Overall improvement is obtained in power-transfer capability and in increased economy.
8. The fast dynamic response of SVC's have offered a replacement to synchronous condensers having fast excitation response.