Micro Hydro Power Plant

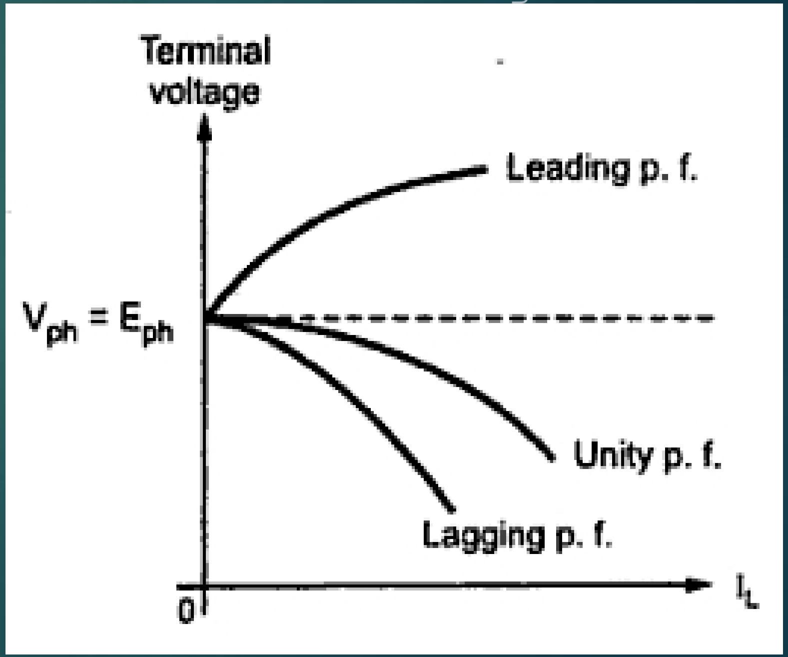
LECTURE 10 : VOLTAGE CONTROL

prepared by Er. Bibek Dahal

Voltage Regulation

- When the load on the generator changes from no-load to full load, assuming that the generator running constant speed and constant excitation , the terminal voltage across the load will change due to voltage drops in internal resistance and reactance of the stator winding.
- The magnitude and the nature of these voltage drops depends upon the power factor of the load
- Voltage regulation of a synchronous generator is defined as the percentage rise in terminal voltage as load is reduced from the rated full load current to zero, the speed and the excitation being constant.

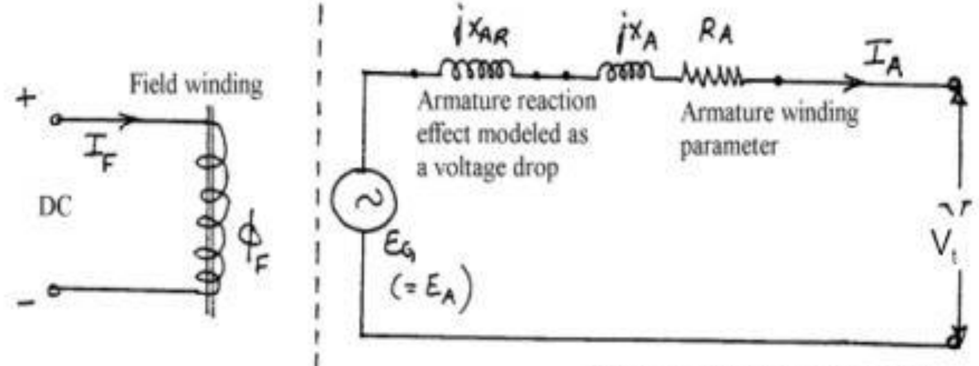
Voltage regulation = $\frac{NO\ Load\ voltage - Full\ load\ voltage}{Full\ Load\ VOltage}$



Voltage Regulation

Synchronous Generators Equivalent Circuit (round rotor)

1) DC current in the field winding produces the main flux, ϕ_f.
2) ϕ_f induces an emf, E_G, in the armature winding.
3) Depending on the load condition, the armature current I_A is established. In the following discussions, it is assumed to be a lagging power factor.
4) I_A produces its own flux due to armature reaction, E_{AR} is the induced emf by ϕ_{AR}.
5) The resulting phasor, $E_{resultant} = E_G + E_{AR}$ is the "true" induced emf that is available.



here n = n_s, the synchronous speed

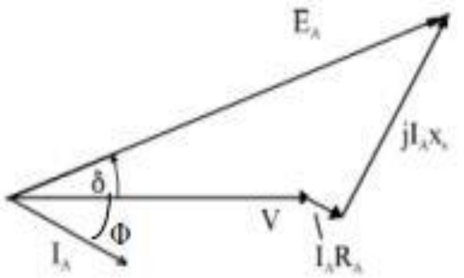
Phasor Diagrams (single phase):

$$V_t = E_A - I_A jX_A - I_A jX_{AR} - I_A R_A = E_A - jX_s I_A - I_A R_A$$

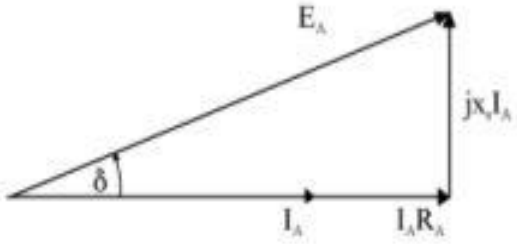
$$V_t = E_A - I_A(R_A + jX_s)$$

where, $(X_{AR} + X_A)$ = synchronous reactance, X_s.

Inductive Load



Resistive Load



δ= power angle

Automatic Voltage Regulator for Synchronous Generator

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- As the name implies, an automatic voltage regulator is a device which is used to control or regulate the voltage
- In power system voltage fluctuations usually occur due to varying loads
- In a synchronous generator an AVR is a part of the whole excitation system to ensure that a constant terminal voltage is maintained
- An AVR works on the principle of detection of errors
- The generators terminal voltage is first measured through PT and then rectified
- This is compared with the reference voltage after filtering and an error signal is obtained
- This error signal is then amplified and fed to the main or the pilot exciter
- Thus the output of the exciter is controlled which controls the alternators terminal voltage

Automatic Voltage Regulator for Synchronous Generator

- The automatic voltage regulator is used to regulate the voltage
- The fluctuation in voltage mainly occurs due to variation in load in the supply system
- Figure below shows schematic diagram of an automatic voltage regulator

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Automatic Voltage Regulator for Synchronous Generator

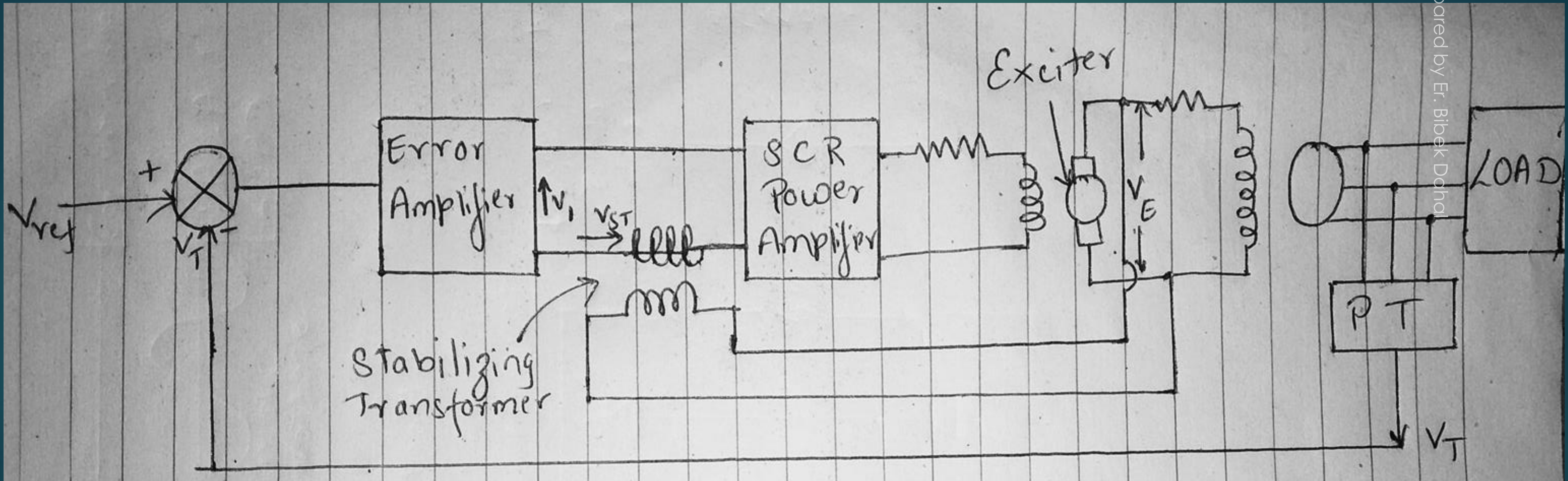

Fig: Schematic Diagram of Solid State Alternator Voltage Regulator.

Automatic Voltage Regulator for Synchronous Generator

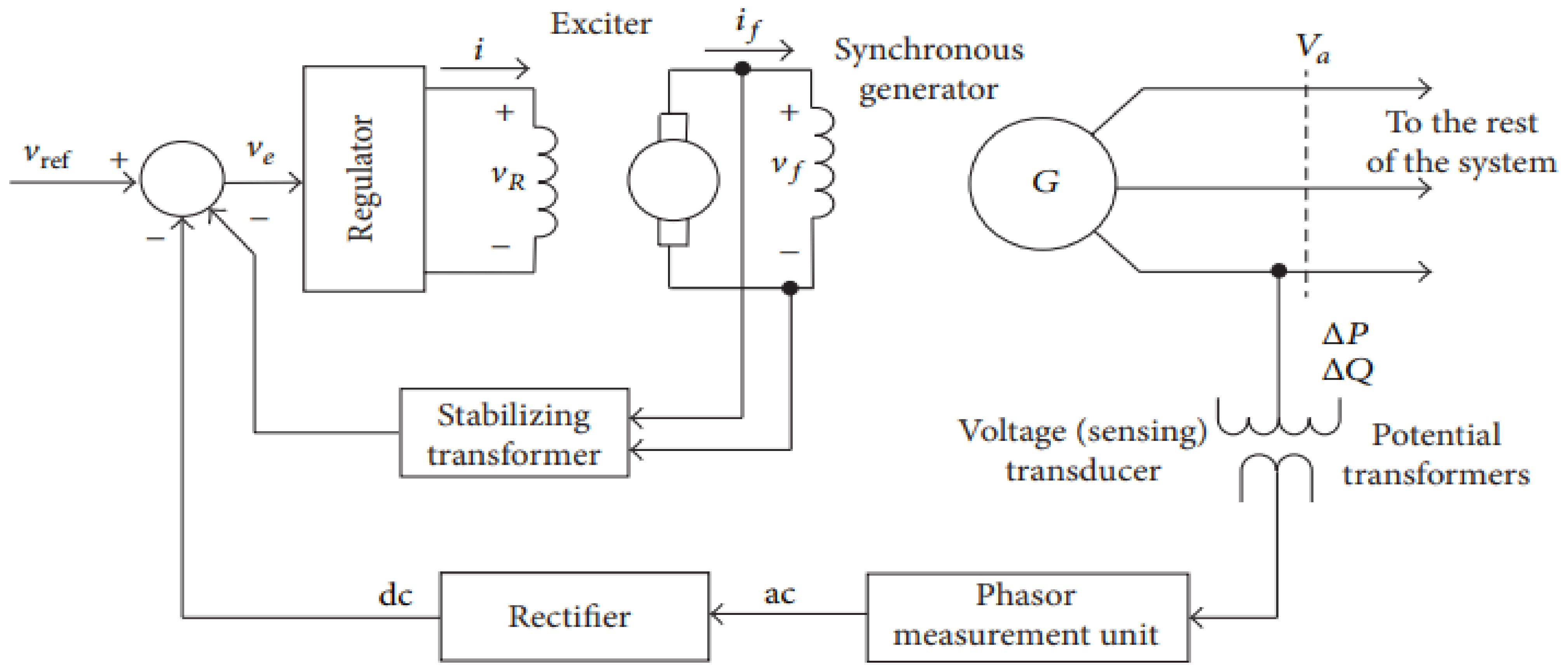

FIGURE 1: The schematic block diagram of the generator excitation control system.

Automatic Voltage Regulator for Synchronous Generator

- It basically consists of a main exciter which excites the alternator field to control the output voltage
- The exciter field is automatically controlled through error e= $V_{ref} - V_T$ suitably amplified through voltage and power amplifier
- Function of important components are:
  1. **Potential Transformer** : it gives a sample of terminal voltage V_T
  2. **Error amplifier**: It demodulates and amplifies the error signal
  3. **SCR power amplifier and exciter field**:
     1. It provides the necessary power amplification to the signal for controlling the exciter field
  4. **Alternator**: Its filed is excited by the main exciter voltage V_E. Under no load it produces a voltage proportional to filed current
  5. **Stabilizing transformer:** it is included in AVR system to improve the dynamic response of a control system. It is excited by the exciter output voltage V_E . The output of the stabilizing transformer is fed negatively at the input terminals of the SCR power amplifier

VAR Compensator

- Static VAR compensators (SVC) are system or a set of devices that creates voltage stability in high voltage electrical system
- It is connected parallel with load to be compensated
- The system provide reactive power in proportion to the system supply voltage

Need for Reactive power compensation.

The main reason for reactive power compensation in a system is: 1) the voltage regulation;2) increased system stability; 3) better utilization of machines connected to the system; 4) reducing losses associated with the system; and 5) to prevent voltage collapse as well as voltage sag. The impedance of transmission lines and the need for lagging VAR by most machines in a generating system results in the consumption of reactive power, thus affecting the stability limits of the system as well as transmission lines. Unnecessary voltage drops lead to increased losses which needs to be supplied by the source and in turn leading to outages in the line due to increased stress on the system to carry this imaginary power. Thus we can infer that the compensation of reactive power not only mitigates all these effects but also helps in better transient response to faults and disturbances. In recent times there has been an increased focus on the techniques used for the compensation and with better devices included in the technology, the compensation is made more effective. It is very much required that the lines be relieved of the obligation to carry the reactive power, which is better provided near the generators or the loads. Shunt compensation can be installed near the load, in a distribution substation or transmission substation.

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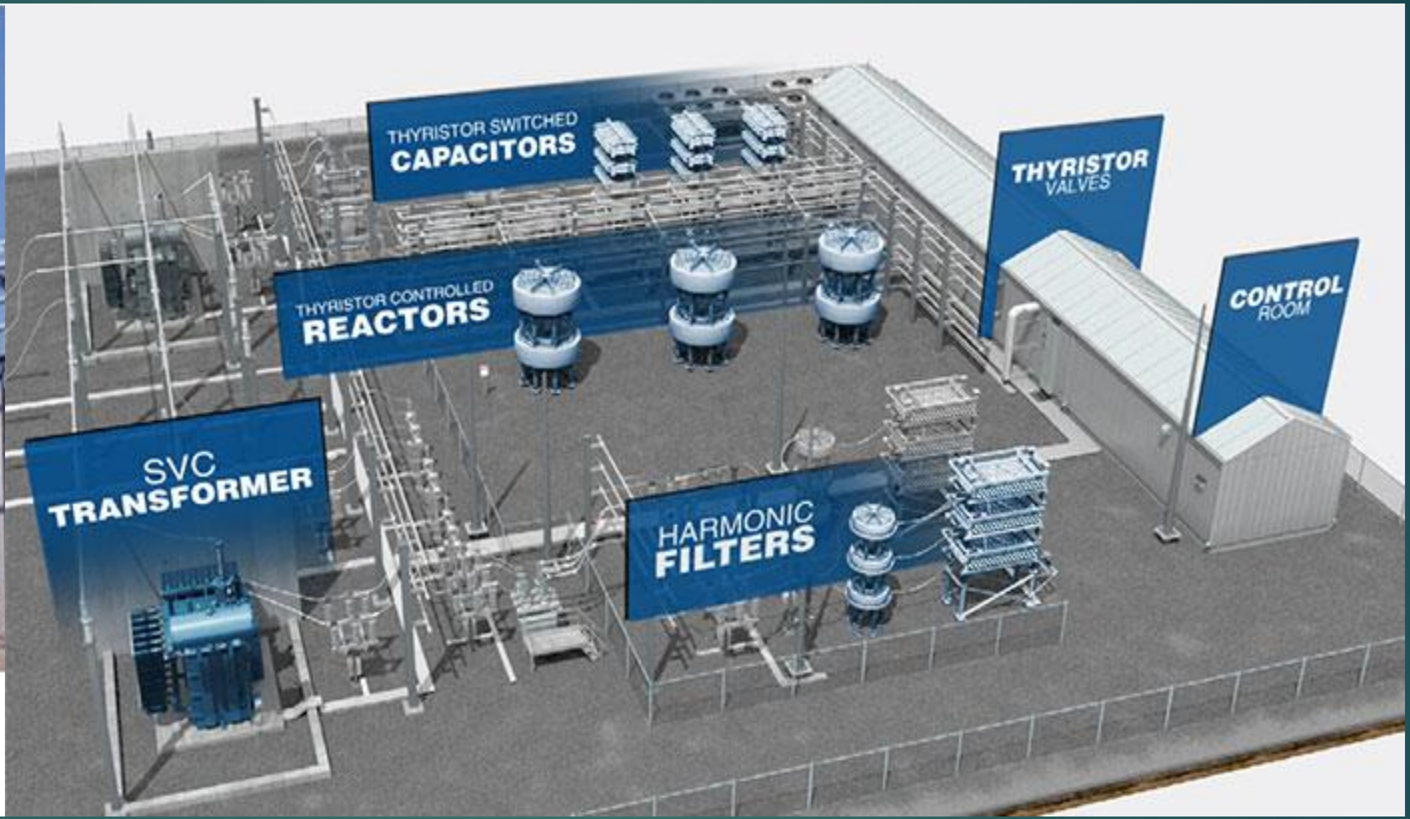
VAR Compensator

Static Var Generator (SVG) & Static Var Compensator (SVC) Market



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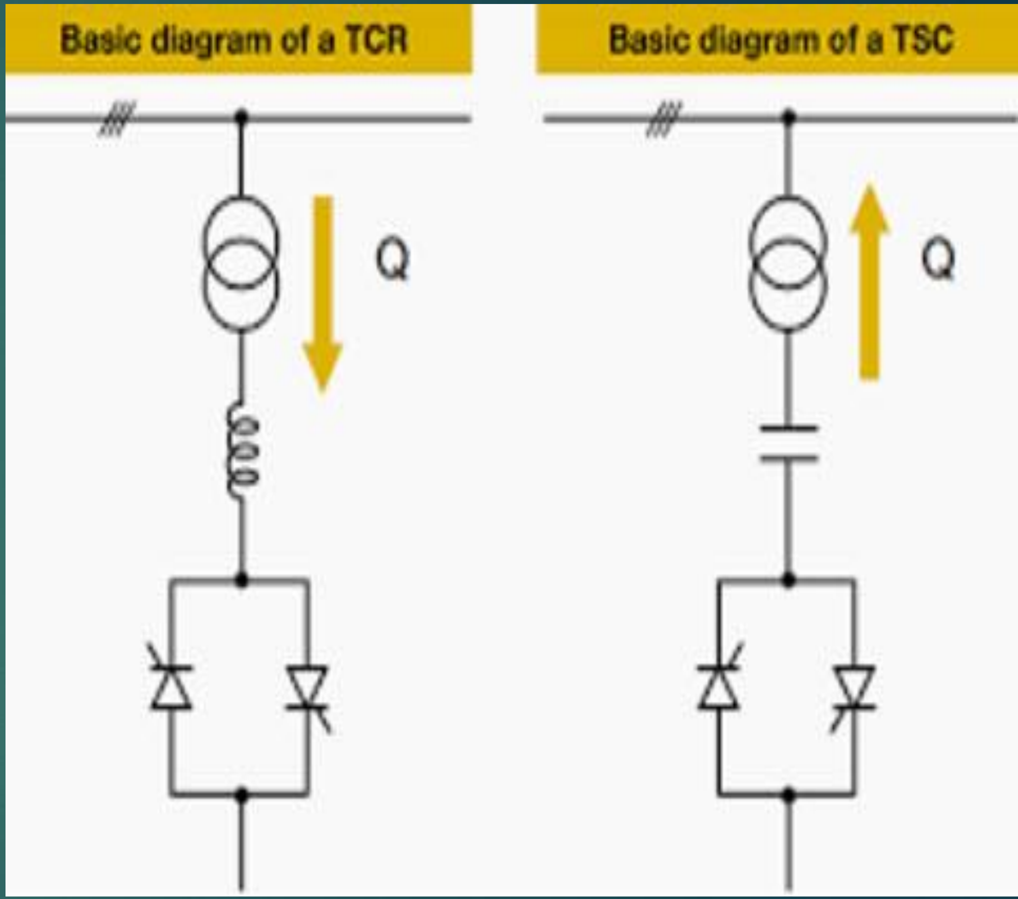
Thyristor switched capacitor

- The Thyristor switched capacitor is used in extra high voltage lines for providing leading VAR's during heavy loads
- The current through the capacitor can be varied by controlling the firing angle of the back to back Thyristor connected in series with capacitor
- When the voltage at a bus reduces below the reference value, the static VAR compensation used Thyristor switch capacitor for injecting capacitive volt amperes
- when the voltage at the Bus rises above the reference value inductive VAR are injected to lower the bus voltage by using **Thyristor switched Reactor**
- Generally, static VAR compensation is not done at line voltage; a bank of transformers steps the transmission voltage (for example, 230 kV) down to a much lower level (for example, 9.0 kV)
- This reduces the size and number of components needed in the SVC, although the conductors must be very large to handle the high currents associated with the lower voltage
- In some static VAR compensators for industrial applications such as electric arc furnaces, where there may be an existing medium-voltage busbar present (for example at 33 kV or 34.5 kV), the static VAR compensator may be directly connected in order to save the cost of the transformer.



Fixed capacitor Thyristor control reactor (FC-TCR)

- Thyristor control reactors are shunt compensators that they can absorbs the reactive power
- In FC-TCR fixed capacitor injects reactive power into the system whereas Thyristor controlled reactor absorbs the reactive power from the system so depending upon the system requirements by adjusting
- The reactive power injection and absorption, we can vary the system voltage
- The reactor is in series with two antiparallel Thyristor defined as Thyristor controlled reactor i.e. TCR branch
- This branch is a parallel with a big shunt capacitor
- Then the two oppositely placed Thyristor are gated symmetrically
- They control the timing for which the reactor conducts and thus control the fundamental component o f reactor current

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Fixed capacitor Thyristor control reactor (FC-TCR)

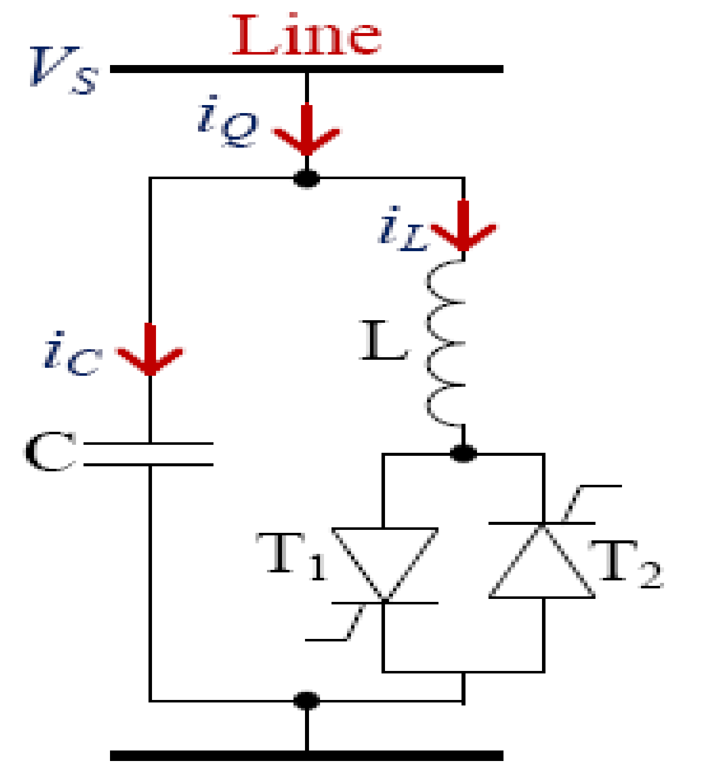
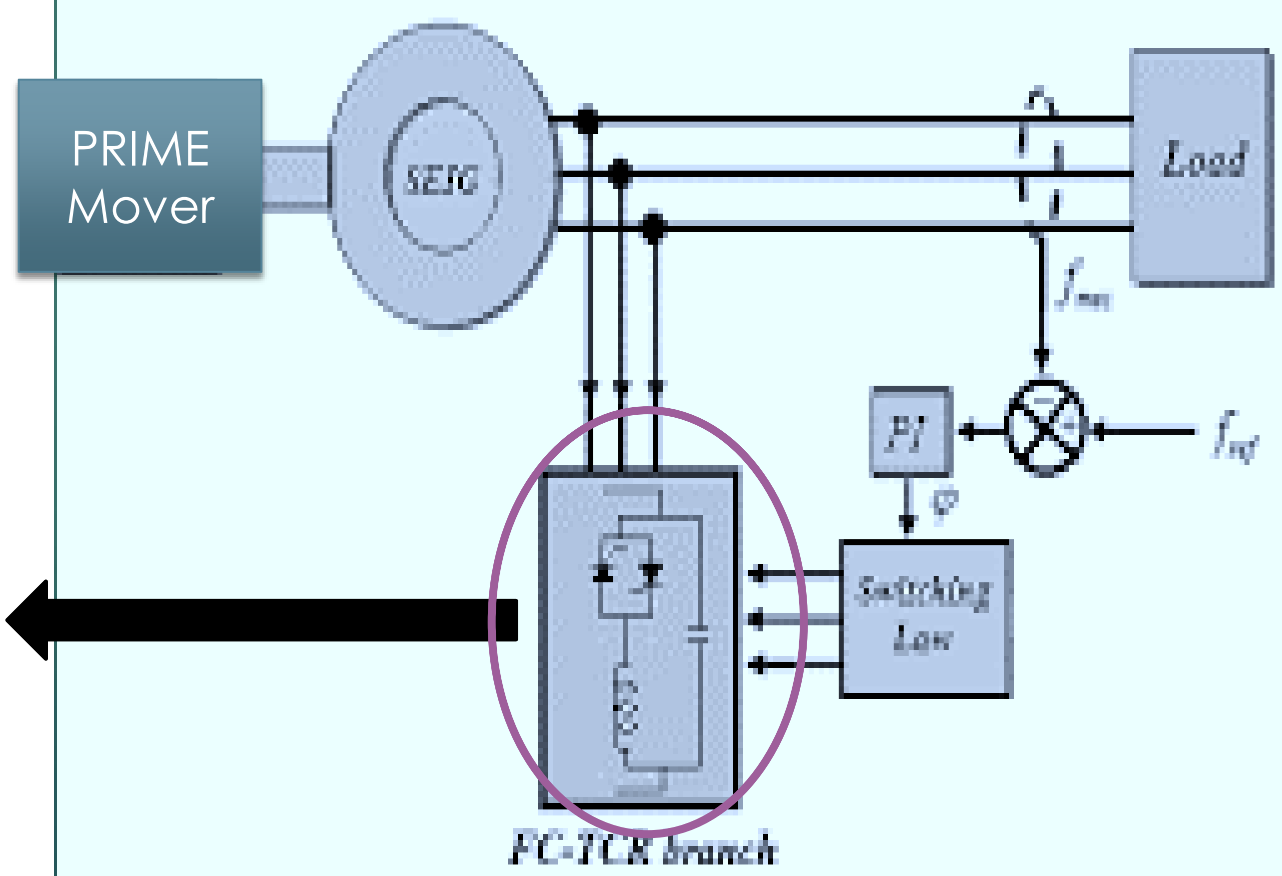


Fig. 6.8. Circuit diagram of a FC-TCR



Fixed capacitor Thyristor control reactor (FC-TCR)

- in FC-TCR fixed capacitor injects reactive power into the system whereas the TCR absorbs the reactive power
- The value of capacitor is fixed so reactive power injection into the system is constant whereas the effect of reactor can be controlled by controlling Thyristor firing angle and hence reactive power absorption can be controlled
- The control of firing angles of the Thyristor connected antiparallel and switching logic is done by designing control circuit for it
- Depending upon conduction period of each Thyristor the current through the reactor depends
- It the conduction period of Thyristor is maximum then it allows maximum current to pass through it whereas if it is minimum then it allows less current that is less reactive power injective through FC-TCR

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THANK YOU