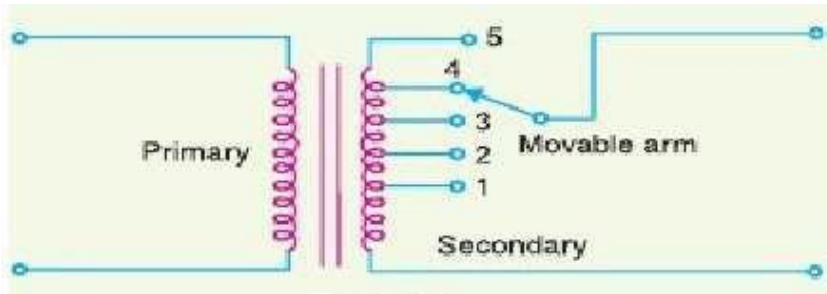
Tap changing transformer:

- when the movable arm makes contact with lower positions such as 1, the secondary voltage is minimum, during the period of light inductive load
- When the movable arm contact with higher position such as 5 ,the secondary voltage is maximum, during the period of high inductive load



Advantage of tap changing transformer

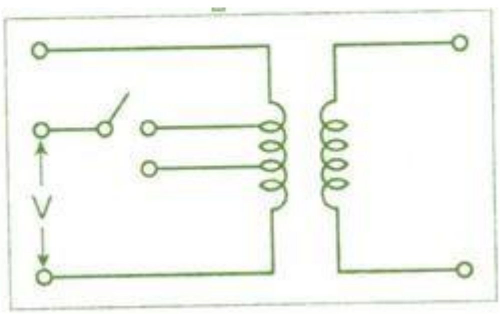
- During high system load conditions, network voltages arekept At highest practical level to minimize reactive power requirements increase effectiveness of shunt capacitors to compensated reactive power
- During light load conditions, it is usually required to lower network voltages avoid under excited operation of generators
- All power transformers on transmission lines are provided with taps for control of secondary voltage. The tap changing transformers do not control voltage by regulating the flow of reactive VARs but by changing transformation ratio.

There are two types of tap changing transformers.

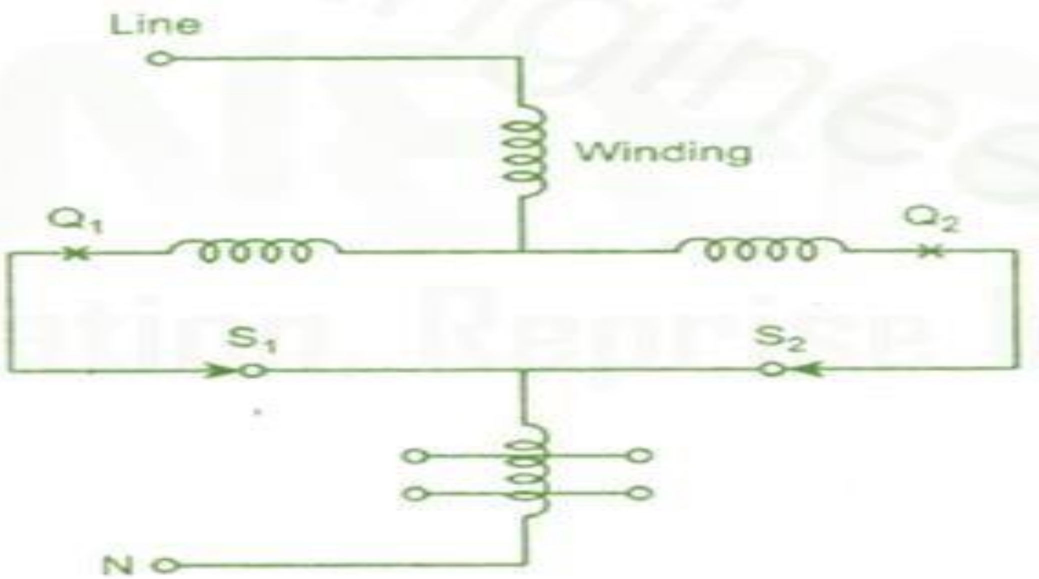
- Off-load tap changing transformers.
- On-load (Under-load) tap changing transformers (OLTC).

Off-load tap changing transformers:

The off-load tap changing transformer as shown in figure which requires the disconnection of the transformer when the tap setting is to be changed. Off-load tap changers are used when it is to be operated in frequently due to load growth or some seasonal change.



- On-load tap changing transformer is used when changes in transformer ratio to be needed frequently, and no need to switch off the transformer to change the tap of transformer.
- It is used on power transformers, auto transformers and bulk distribution transformers and at other points of load service.
- The modern practice is to use on-load tap changing transformer which is shown in figure.
- In the position shown, the voltage is maximum and since the currents divide equally and flow in opposition through the coil between Q1 and Q2, the resultant flux is zero and hence minimum impedance.



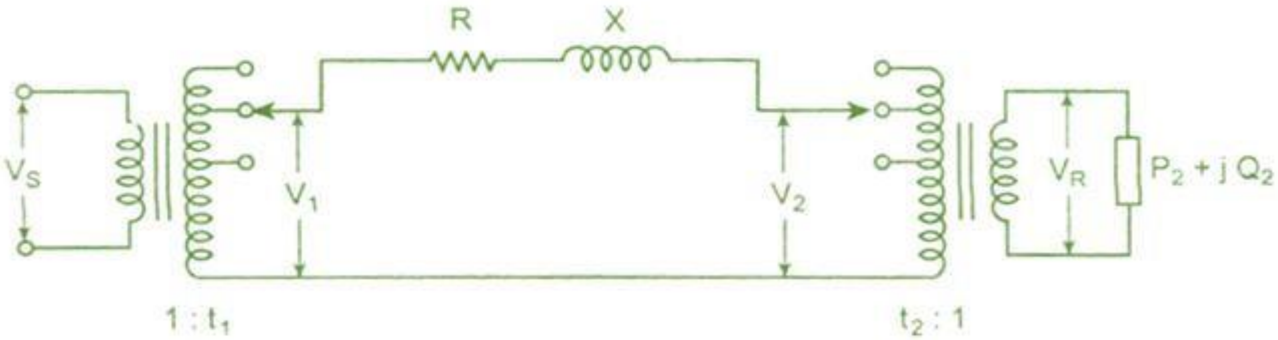
On-load tap changing transformers (OLTC):

- To reduce the voltage, the following operations are required in sequence:
- Open Q1.
- Move selector switch S1 to the next contact. Close Q1.
- Open Q2.
- Move selector switch S2 to the next contact. Close Q2.
- Thus, six operations are required for one change in tap position. The voltage change between taps is often 1.25 % of the nominal voltage.

System Level Control using Generator Voltage Magnitude Setting:

- Transformers transfer the reactive power from one side to another side by altering the inphase component of the system voltage. Let us consider the tap changing transformer at both ends of a line is shown in figure.
- Let t1, t2 be the functions of nominal transformation ratio. i.e., tap ratio/nominal voltage

- The actual voltage will be t1V1 and t2V2. Let V1, V2 be the nominal voltage at the ends of the line. Since, the line has impedance, it is necessary to compensate the voltage drop in the line so that the voltage at the receiving end is maintained at a desired level.



$$t_1|V_1| = t_2|V_2| + \left||P_2R + Q_2X|/t_2|V_2|\right|$$

$$t_1|V_1| = \frac{|V_2|}{t_1} + \frac{(P_2R + Q_2X)t_1}{|V_2|}$$

$$t_1|V_1| = \frac{|V_2|^2 + (P_2R + Q_2X)(t_1)^2}{t_1|V_2|}$$

$$(t_1)^2\left[|V_1||V_2| - (P_2R + Q_2X)\right] = |V_2|^2$$

Dividing by we get

$$(t_1)^2\left[1 - \frac{(P_2R + Q_2X)}{|V_1||V_2|}\right] = \frac{|V_2|}{|V_1|}$$

$$(t_1) = \sqrt{\frac{\frac{|V_2|}{|V_1|}}{\left[1 - \frac{(P_2R + Q_2X)}{|V_1||V_2|}\right]}}$$

For complete line drop compensation

$$|V_1| = |V_2|$$

$$(t_1) = \sqrt{\frac{1}{\left[1 - \frac{(P_2R + Q_2X)}{|V_1|^2}\right]}}$$

Sending end voltage,

$$t_1 V_1 = V_S$$

Now ,

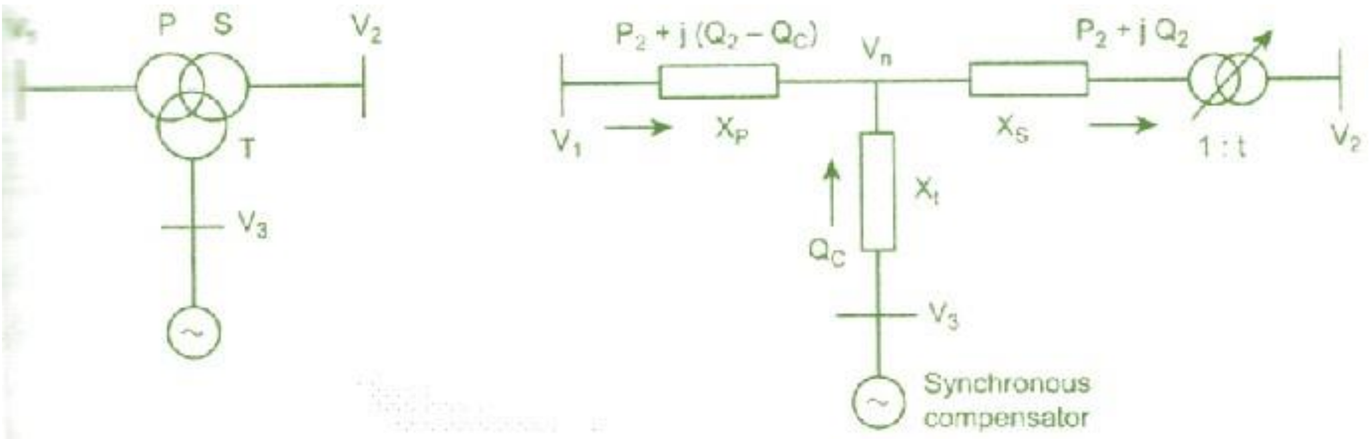
$$t_2 = \frac{1}{t_1}$$

Sending end voltage $V_S = t_1 V_1$

- For a given load, given the nominal voltages, we can find t1 and t2 as to keep V2 constant at a specific value.
- For high line drops, the tap changing transformers do not improve voltage profile because it does not have any reactive power generation capability.
- For small voltage variation or line drop, tap changing transformer is used to improve voltage magnitude of the system.

Combined use of Tap changing Transformers and Reactive Power Injection:

- Normally tap setting are provided in steps for the range of ± 20 %. If the setting exceeds this range, it is necessary to inject VARs at the load end to maintain the voltage profile and to minimize transmission loss.
- A synchronous compensator is connected to the tertiary winding of a three winding transformer as shown in figure.
- The equivalent circuit is shown in figure.



Quadrature voltage drop, $\delta V = \frac{P_2(X_P)}{|V_n|}$

$$|V_1|^2 = \left(|V_n| + \triangle V\right)^2 + \delta V^2$$

$$|V_1|^2 = \left[|V_n| + \frac{(Q_2 - Q_C)X_P}{|V_n|}\right]^2 + \left[\frac{P_2 X_P}{|V_n|}\right]$$

$$|V_1|^2 = \left[\frac{|V_n|^2 + (Q_2 - Q_C)X_P}{|V_n|}\right]^2 + \left[\frac{P_2 X_P}{|V_n|}\right]^2$$

$$|V_1|^2|V_n|^2 = |V_n|^4 + 2|V_n|^2(Q_2 - Q_C)X_P + \left[(Q_2 - Q_C)X_P\right]^2 + (P_2)^2(X_P)^2$$

$$|V_n|^4 + 2|V_n|^2\left[2(Q_2 - Q_C)X_P - |V_1|^2\right] + \left[(Q_2 - Q_C)X_P\right]^2 + (P_2)^2(X_P)^2 = 0$$

Solving the above equation, we get $|V_n|$

We can find out off nominal tap setting t,

$$t = \frac{|V_2|}{|V_n|}$$