CASCADED TRANSFORMERS

For voltages higher than 400 KV, it is desired to cascade two or more transformers depending upon the voltage requirements. With this, the weight of the whole unit is subdivided into single units and, therefore, transport and erection becomes easier. Also, with this, the transformer cost for a given voltage may be reduced, since cascaded units need not individually possess the expensive and heavy insulation required in single stage transformers for high voltages exceeding 345 kV. It is found that the cost of insulation for such voltages for a single unit becomes proportional to square of operating voltage. Fig. 3.9 shows a basic scheme for cascading three transformers. The primary of the first stage transformer is connected to a low voltage supply. A voltage is available across the secondary of this transformer. The tertiary winding (excitation winding) of first stage has the same number of turns as the primary winding, and feeds the primary of the second stage transformer.

The secondary winding of the second stage transformer is connected in series with the secondary winding of the first stage transformer, so that a voltage of 2V is available between the ground and the terminal of secondary of the second stage transformer. Similarly, the stage-III transformer is connected in series with the second stage transformer. With this the output voltage between ground and the third stage transformer, secondary is 3V. it is to be noted that the individual stages except the upper most must have three-winding transformers. The upper most, however, will be a two winding transformer. Figure shows metal tank construction of transformers and the secondary winding is not divided. Here the low voltage terminal of the secondary winding is connected to the tank. The tank of stage-I transformer is earthed.

The tanks of stage-II and stage-III transformers have potentials of V and 2V, respectively above earth and, therefore, these must be insulated from the earth with suitable solid insulation. Through h.t. bushings, the leads from the tertiary winding and the h.v.

winding are brought out to be connected to the next stage transformer. However, if the high voltage windings are of mid-point potential type, the tanks are held at 0.5 V, 1.5 V and 2.5 V, respectively. This connection results in a cheaper construction and the high voltage insulation now needs to be designed for V/2 from its tank potential. The main disadvantage of cascading the transformers is that the lower stages of the primaries of the transformers are loaded more as compared with the upper stages. The loading of various windings is indicated by P in Figure 3.4.1 For the three-stage.

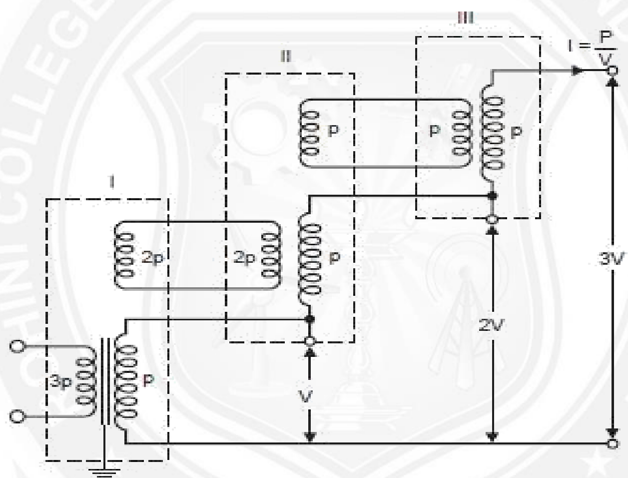

Figure 3.4.1 Basic 3 stage cascaded transform

[Source: "High Voltage Engineering" by C.L. Wadhwa , Page – 302]

The primary winding of stage-III transformer is loaded with P and so also the tertiary winding of second stage transformer. Therefore, the primary of the second stage transformer would be loaded with 2P.Extending the same logic; it is found that the first stage primary would be loaded with P. Therefore, while designing the primaries and tertiary's of these transformers, this factor must be taken into consideration. The total short circuit impedance of a cascaded transformer from data for individual stages can be obtained.

The equivalent circuit of an individual stage is shown in Figure 3.4.1.Here Zp, Zs, and Zt, are the impedances associated with each winding. The impedances are shown in series with an ideal 3-winding transformer with corresponding number of turns Np, Ns and Nt. The impedances are obtained either from calculated or experimentally-derived results of the three short circuit tests between any two windings taken at a time.

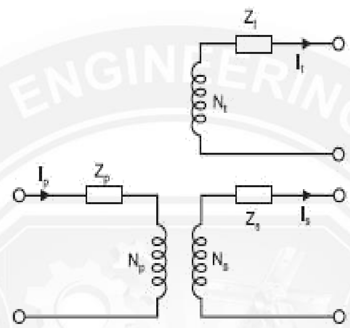

Figure 3.4.2 Equivalent circuit of one stage

[Source: "High Voltage Engineering" by C.L. Wadhwa , Page – 315]

- Let *Zps* = leakage impedance measured on primary side with secondary short circuited and tertiary open.
- *Zpt* = leakage impedance measured on primary side with tertiary short circuited and secondary open.
- *Zst* = leakage impedance on secondary side with tertiary short circuited and primary open.