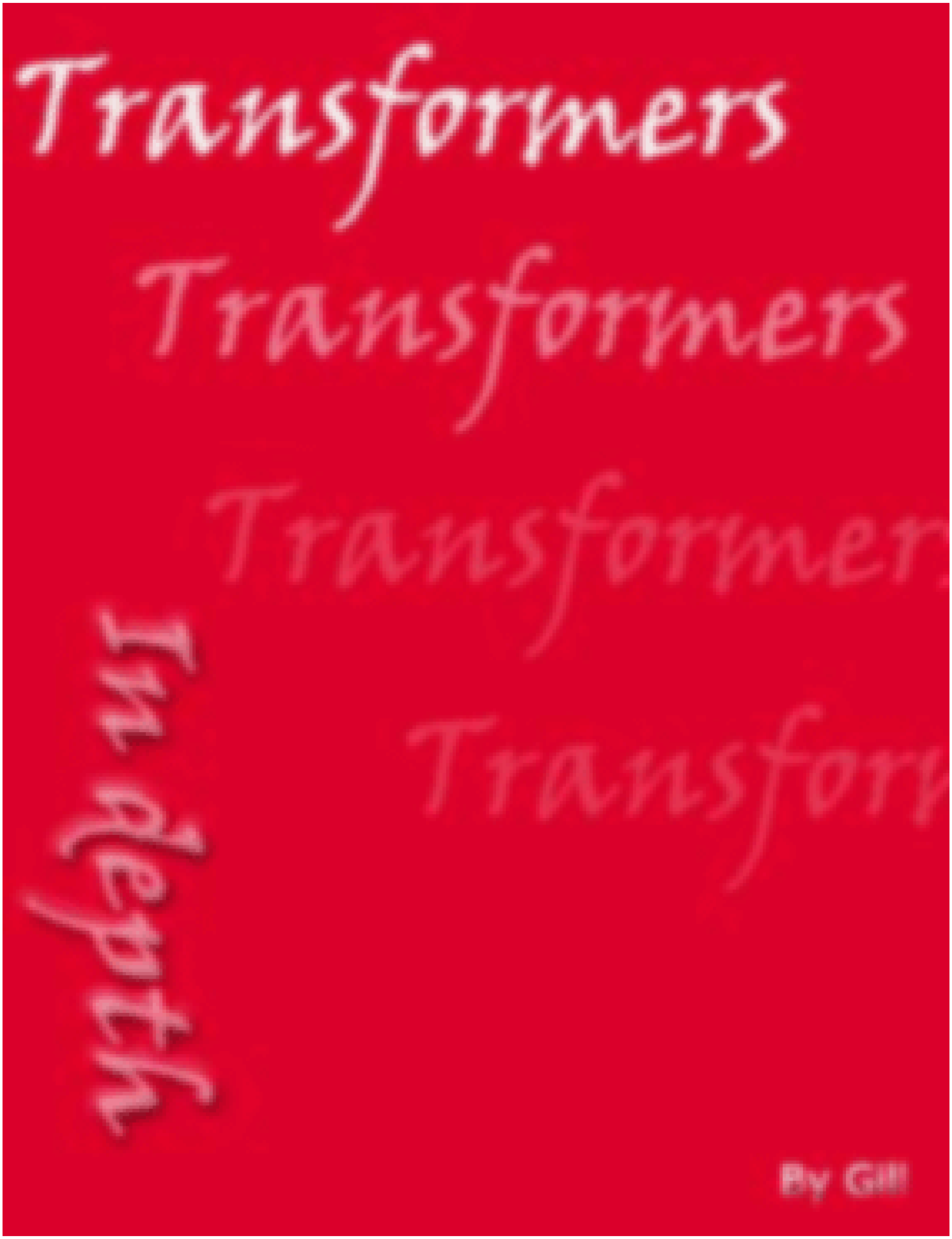


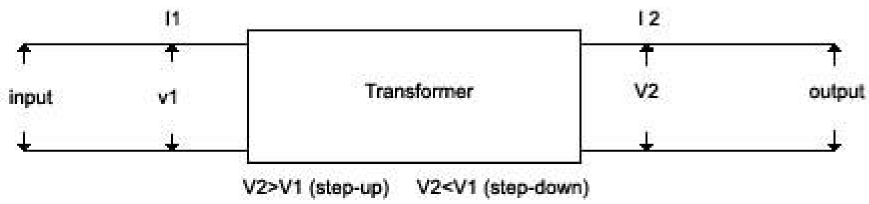
By Gill (www.angelfire.com/al4/gill)

Introduction

One of the main reasons of adopting a.c. system instead of d.c. for generation, transmission and distribution of electrical power is that alternating voltage can be increased or decreased conveniently by means of a transformer. In fact, for economical reasons, electrical power is required to be transmitted at high voltages whereas it has to be utilized at low voltages for safety point of view. This increase and decrease in voltage can only be obtained by using a ***transformer.***

Transformer

A transformer is a static device which transforms a.c. power supply from one circuit to another at the same frequency but the voltage level is changed usually



(fig. 1)

When the voltage is raised on the output side (V2 > V1), the tranformer is called *step-up transformer*, whereas when the voltages is lowered at the output side (V2 < V1), the transformer is called *step-down transformer.*

Necessity

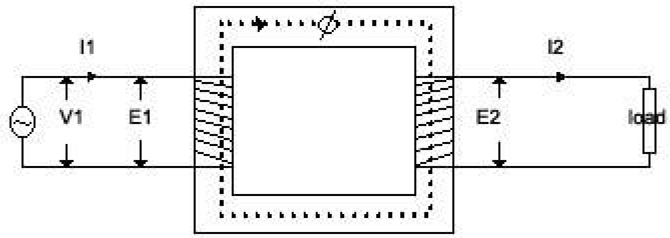
The electrical power is usually generated at 11KV. For economical reasons electrical power is transmitted at very high voltages (220 KV to 400 KV) over long distances, therefore a step-up transformer is applied at the generation station. Then to feed different areas, voltage is stepped-down to different levels by transformers at various substations. Ultimately for utilization of electrical power, the voltage is stepped-down to 400/230 V for safety reasons.

Thus transformer plays an important role in the power system.

Working Principle of a Transformer

The basic principle of transformer is **Electromagnet Induction.**

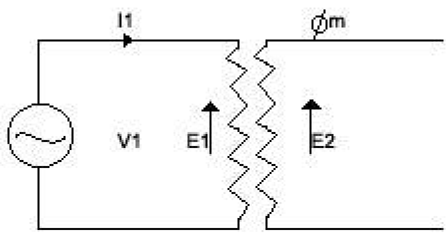
A simple form of a transformer is shown in Fig.2.



(*fig. 2)*

It essentially consists of two separate windings placed over a laminated silicon steel core. The winding to which a.c. is supplied is connected is called *primary winding* and the to which load is connected is called *secondary winding*.

When a,c, supply of voltage V1 is connected to the primary winding an alternating flux is set up in the core. This alternating flux when links with the secondary winding an e.m.f. in induced in it called mutually induced e.m.f.. The direction of induced e.m.f. is opposite to the applied voltage V1, according to Lenz's law as shown in Fig.3.



(fig. 3)

The same alternating flux also links with the primary winding and produces self induced e.m.f. E1 also acts in the opposite direction to the applied voltage V1 according to the Lenz's law.

Although, there is no electrical connection between primary and secondary winding, but electrical power is transformed from the primary circuit to the secondary circuit through mutual flux.

The induced e.m.f. in the primary and secondary depends upon the rate of change of flux linkages (………………a). the rate of change of flux (***d ø / dt)*** is the same for both primary and secondary. Therefore the induced e.m.f. in primary is proportional to the no. of turns of the primary winding (E1 ∞ N1) and in secondary is no. of turns in the secondary winding (E2 ∞ N2).

In case, N2 > N1, the transformer is step-up transformer.

And if, N2 < N1, the transformer is step-down transformer.

Turn ratio

The ratio of primary to the secondary turns is called the turn ratio, i.e. turn ratio = N1/N2

Transformer ratio The ratio of secondary voltage to the primary voltage is called voltage transformer ratio of the transformer. It is presented by K. (…………………b).

Transformer Construction

The main elements of a transformer are two coils and a laminated steel core. The two coils are insulated from each other as well as from the core. The core of the transformer is constructed from sheet steel or sheet silicon steel assembled to provide a constant magnet path. At usual flux densities of the silicon steel material has low hystersis losses. The core is laminated to minimum eddy current loss. The thickness of lamination varies from .35 to .5 mm for a frequency of 50Hz.

According to core construction and the manner in which the primary and secondary coils are placed around it, the transformer are named as (1) core-type transformer (2) shell-type transformer. For more about both types, mail me (agill19@hotmail.com)

An Ideal Transformer

An ideal transformer is one which has no Ohmic resistance and no mannet leakage flux i.e. all the flux produced in the core links with primary as well as secondary. Hence, transformer has no copper losses and core losses It means an ideal transformer consists of two purely inductive coils wounded on a loss free sore. Although in actual practice, it is impossible to realize such a transformer, yet for convenience, it is batter to start with an ideal transformer and then extend it to an actual transformer.

In an ideal transformer there is no power loss, therefore, output must be equal to the input.

i.e.

$$E2\ I2 \cos \o = E1\ I1 \cos \o$$

Or $E2\ I2 = E1\ I1$

Or $E2/E1 = I1/I2$

Since $E2 \propto N2$; $E1 \propto N1$ and $E1 \equiv V1$; $E2 \equiv V2$

$$V2/V1 = E2/E1 = N2/N1 = I1/I2 = K \text{ (transformer ratio)}$$

Hence, primary and secondary currents are inversely proportional to there respective turns.

The ratio of secondary turns t = o primary turns is called transformer ratio of the transformer and is represented by K.

Transformer on D.C.

A transformer cannot work on d.c. supply. If a rated d.c. voltage is applied across the primary, a flux of constant magnitude will be set up in the core. Hence, there will be not any self induced e.m.f. in the primary voltage to oppose the applied voltage. The resistance of primary winding will be very low and the primary current will be quite high as given by Ohm's law.

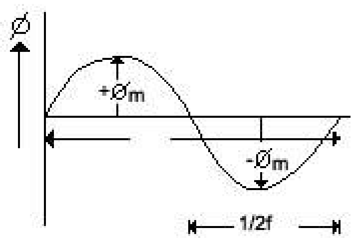
primary current = d.c. applied voltage / resistance of primary winding

This current is moch more than the rated full load current of the primary winding. This will produce high heat(I^2R Loss) and burn the insulation of the primary winding, and transformer will be damaged. This is why, d.c. is never applied to a transformer.

E.M.F. Equation

When sinusoidal voltage is applied to the primary winding of a transformer, a sinusoidal flux is set up in the core which links with the primary and secondary winding.

Let $ø_m$ = maximum value of flux in wb ;
f = supply frequency in Hz ;
N1 = no. of turns in primary ;
N2 = no. of turns in secondary ;



As shown in Fig.4. (*fig. 4)*,
flux changes from +øm to –øm in a half cycle i.e. 1/2f seconds,

Average rate of change of flux = øm – (-øm)/ (1/2f)

= 4f øm wb/s

now, the rate of change of flux per turn is average induced e.m.f. per turm in volts,

average e.m.f. induced /per turn = 4 føm volts
for a sinusoidal wave, R.M.S. value/Average value = form factor = 1.11
R.M.F. value of e.m.f. induced / turn = E= 1.11 * 4føm = 4.44 føm volts
Since, primary and secondary have N1 and N2 turns respectively.

R.M.S. value of induced e.m.f. in primary,

E1 = (e.m.f. induces/turn) * no. of primary turns = 4.44 N1 føm volts……(i)

Similarly, r.m.s. value of e.m.f. induced in secondary,

E2 = 4.44 N2 føm volts ……………..(ii)

Again, we can find the voltage ratio,

E2/E1 = 4.44 N2 føm / 4.44 N1 føm

Or

$E_2/E_1 = N_2/N_1 = K$ (transformar ratio)

Equation (i) and (ii) can be written in the form of maximum flux density Bm using relation,

$Øm = Bm * Ai$ (where Ai is iron area)

$E_1 = 4.44\ N_1\ fBmAi$ volts

And

$E_2 = 4.44\ N_2\ fBmAi$ volts.

Three phase Transformer

Three phase system is invariably adopted for generation, transformation and distribution of electrical energy. Usually power is generated at 11Kv or 33Kv, whereas it is transmitted at 400, 220 132 or 66Kv. At the receiving stations, thr voltage level is decreased and power is transmitted through shorter distances and distributed at lower voltages. While delivering to customer voltage level in decreased to 400V (line voltage) for safety reasons.

To increase the voltage level at the generating station and to decrease the voltage at the receiving station, step-up and step-down transformers are used respectively.

The voltage level in three phase system at the generating station and at the receiving station can be changed by employing three phase transformers (inter connecting them in star or delta) or by employing one three phase transformer. Generally three phase transformer are employed because of the following reasons:

1. It requires smaller quantity of iron and copper.
2. It has smaller size and can be accommodated in smaller tank and hence needs smaller quantity of oil for cooling.
3. It has less weight ant occupies less space.
4. It needs fewer no of bushings.
5. Over and above, it costs nearly 15% lesser than the a bank of three single phase transformers of equal rating.
6. It operates at slightly better efficiency and regulation.

   Hence three phase transformers are invariably employed in the power stations to step-up and step-down the voltage. Although, these transformers suffer from the following disadvantages.

   1. It is difficult to repair three phase transformer.
   1. It is difficult to transport transformer from one place to the another due to larger size.