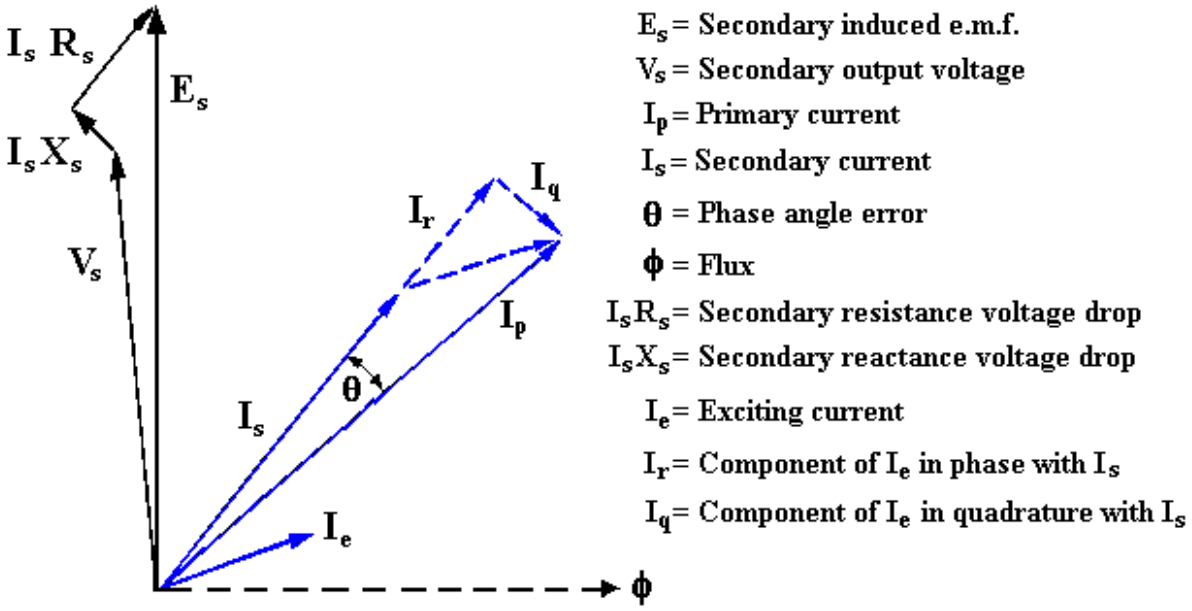
Current Measurement Fundamentals

May 2010

Introduction

In current transformer design, the core characteristics must be carefully selected because excitation current I_e essentially subtracts from the metered current and affects the ratio and phase angle of the output current.



The higher the exciting current or core loss the larger the error

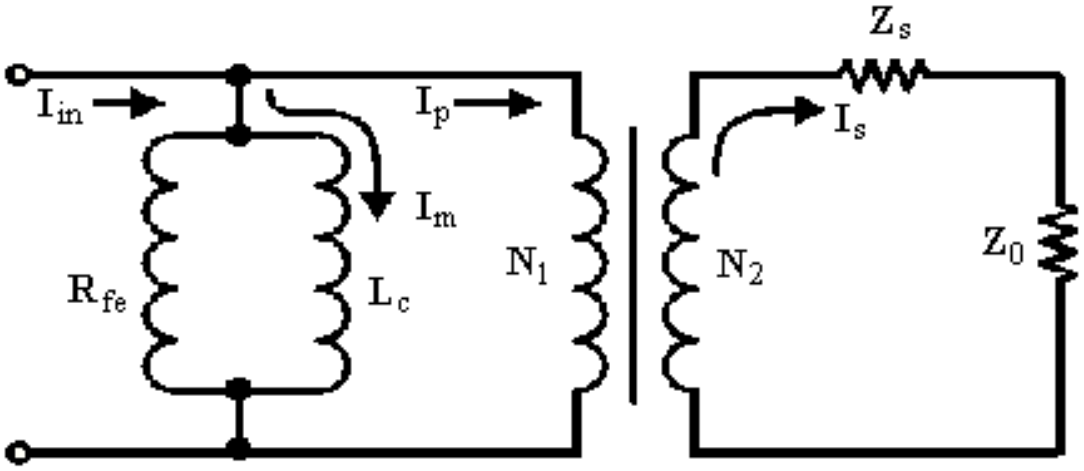
Measuring or protective current transformers?

Measuring current transformer
Permeability of the core material high and core loss low => exciting current small (I_{fe}<<) => current error small. The exciting current determines the maximum accuracy that can be achieved with a current transformer => Study accuracy classes
Protective current transformer
Permeability of the core material is low => When remanence is reduced to a lower level (increase the useful flux density,gapping), the voltage spikes produced

by the leakage inductance due to the transformer saturation will be eliminated. Inlinear current transformersthere are generally air gaps in the iron core to reduce the time constantand remanence. Such current transformers are used only to protect objects of major importance that require a short tripping time.

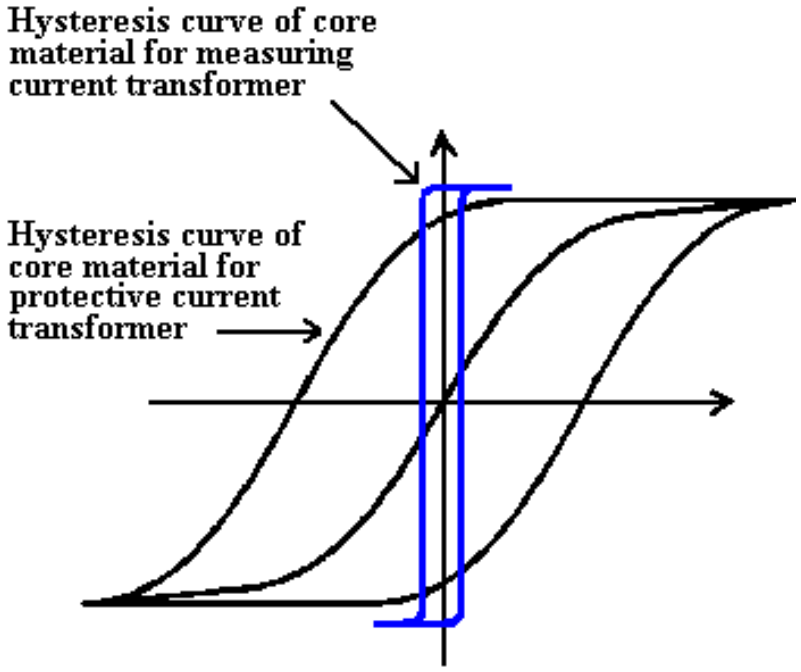
Selecting core material

When choosing a core material a reasonable value for B_m (0,2 ... 0,3 T) typically results in L_c and R_{fe} values large enough to reduce the current flowing in these elements so as to satisfy the ratio and phase requirements.



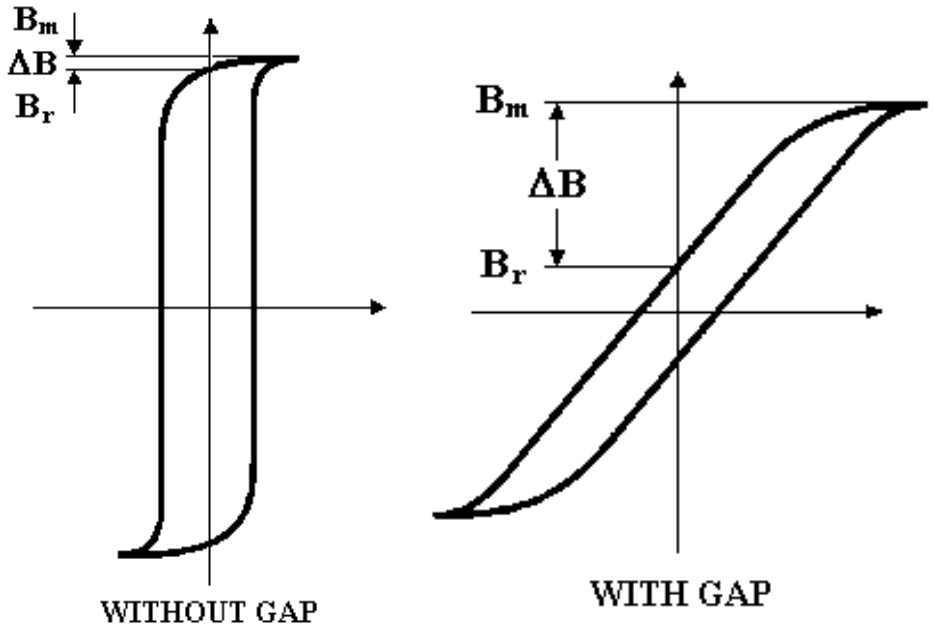
Window utilization factor

The window utilization factor ($K_u = S_1 \times S_2 \times S_3 \times S_4$) is the amount of copper that appears in the window area or transformer of inductor. The window utilization factor is influenced by four different factors: (1) wire insulation, (2) wire lay (fill factor), (3) bobbin areaand (4) insulation required for multilayer windings or between windings. In the design of high-current of low-current transformers, the ratio of conductor area over total wire area can vary from 0,941 to 0,673 depending on the wire size. The wire lay or fill factor can vary from 0,7 to 0,5, depending on the winding technique. The amount and the type of insulation are dependent on the voltage. [McLyman.]



A transformer intended to supply measuring instruments, meters, relays and other similar apparatus

Effect of Gapping



[McLyman.]

Air gap increases the effective length of the magnetic path

Air-gapped current transformers
These are auxiliary current transformers in which a small air gap is included in the core to produce a secondary voltage output proportional in magnitude to current in the primary winding. Sometimes termed ´transactors´ or ´quadrature current transformers´, this form of current transformer has been used as an auxiliary component of unit protection schemes in which the outputs into multiple secondary circuits must remain linear for and proportioned to the widest practical range of input currents.
[Protective Relays Application Guide.]

Anti-remanence current transformers
A variation in the over-dimensioned class of current transformer has small gap(s) in the core magnetic circuit, thus reducing the possible remnant flux from approximately 90% of saturation value to some 10% only. These gap(s) are quite small, for example 0.12mm total, and so within the core saturation limits. Errors in current transformation are thereby significantly reduced when compared with those with the gapless type of core.
[Protective Relays Application Guide.]

Linear current transformers
The ´linear´ current transformer constitutes an even more radial departure from the normal solid core CT in that it incorporates an appreciable air cap, for example 7.5-10mm. As its name implies the magnetic behavior tends to linearization by the inclusion of this gap in the magnetic circuit. However, the purpose of introducing more reluctance into the magnetic circuit is to reduce the value of magnetizing reactance, this in turn reduces the secondary time-constant of the CT thereby reducing the over-dimensioning factor necessary for faithful transformation.
[Protective Relays Application Guide.]

The time constant τ_c of the circuit depends on the inductance of the coil and on the resistance in the circuit in accordance to the following simple formula:

$$\tau_c = \frac{L}{R}$$