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PHASE SHIFT

General

Lenze's law states: "An induced electromotive force (EMF) always has such a direction as to oppose the action that produces it." Re-stated: "When a current in an inductive circuit is increasing, the induced EMF opposes the applied voltage and tends to keep the current from increasing, and when the current is decreasing, the induced EMF aids the line voltage and tends to keep the current from decreasing."

In order for this phenomena to exist there must be a special relationship between the voltage and current in inductive circuits. This relationship is a phase difference; or a "phase shift". When applying a voltage to an inductor (coil), the voltage develops across the coil instantaneously. The developing EMF opposes the voltage and suppresses the current. Thus a condition is observed when all the applied voltage is present across the coil and no current is flowing.

The EMF diminishes exponentially and the current conducts inversely (Figure 1). This phase relationship between the voltage and current is 90°with the current always lagging the voltage. At the extremes, there will be all current and no voltage, or all voltage and no current (Figures 2a and 2b).

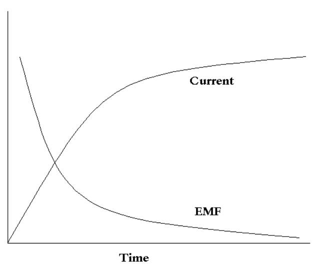

Figure 1

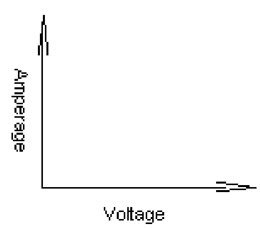

Figure 2a

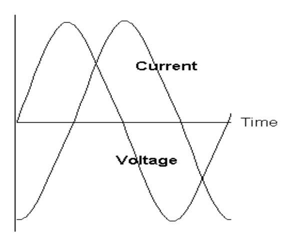

Figure 2b

Ferroresonant Transformers

Ferroresonant transformers use magnetic shunts in their design to obtain substantial values of leakage inductance between the primary and secondary circuits. The leakage inductance isolates the primary from secondary load variations, providing excellent regulation. The magnetic shunts also represent a parallel path for the power to pass from primary to secondary, producing a means to saturate the secondary winding and offer absolute immunity to input line distortion.

Putting it all together. Imagine the ferroresonant transformer passing input power to the load through an inductor, the magnetic shunts (Figure 3). As the load increases, the effects of leakage inductance becomes progressively more predominant within the overall circuit. The reaction of the circuit can be analyzed as a simple R/L circuit The resultant phase shift is dependent upon the ratio of the load and the leakage inductance. $\varnothing = \mathrm{Tan}^{-1}$ (leakage inductance/load). As the load increases the phase shift becomes greater. The result is seen in a ferroresonant transformer as a phase shift between the input voltage and the output voltage. A no load condition produces a 0° phase shift. As the load increases, the output voltage begins to lag the input voltage. At full load the phase shift typically reaches 35° to 40° (output voltage lagging the input voltage).

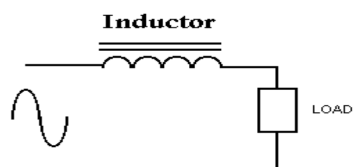

Figure 3

Single Phase vs. Three Phase

In single phase derived circuits the phase shift is of no concern. The load sees one regulated source (the output), it could care less what the phase relation is. In three phase wye derived circuits, the line-to-line voltages are the vector sum of the phase (line-to-neutral) voltages. The vectors are assum-ed to remain constant at 120° apart. But in the application of the ferroresonant transformer the vectors will shift with the load, re-sulting in line-to-line voltages out of published specifications while maintaining regulated phase voltages (Figure 4).

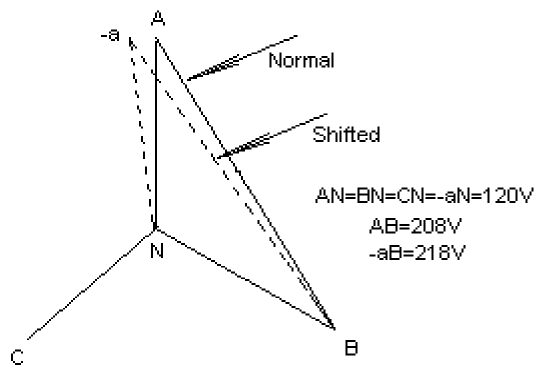

Figure 4

Summary of the Power Purifier

Controlled Power Company's *Power Purifier* uses advanced ferroresonant technology to pro-vide the utmost protection from electrical anomalies. The *Power Purifier* is intended for single phase applications. It performs Buck-Boost functions and is well suited for three phase applications when the loads are reasonably balanced or all loading is from line-to-neutral. The phase shift is only a concern when dealing with synchronization circuits or in wide-ly unbalanced three phase config-urations.

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