Unit 3.4: Ferroresonance

Ferroresonance refers to a series resonance involving a nonlinear inductance and capacitance. This can occur in practice due to the interaction between a transformer saturable magnetizing inductance and a highly capacitive distribution cable.

In a linear circuit we can have a resonant situation for the circuit shown below when the capacitive reactance and the inductive reactance cancel each other out. This occurs when

$$j\omega L + \frac{1}{j\omega C} = 0 \tag{3.25}$$

which would occur at a frequency of

$$\omega = \frac{1}{\sqrt{LC}} \tag{3.26}$$

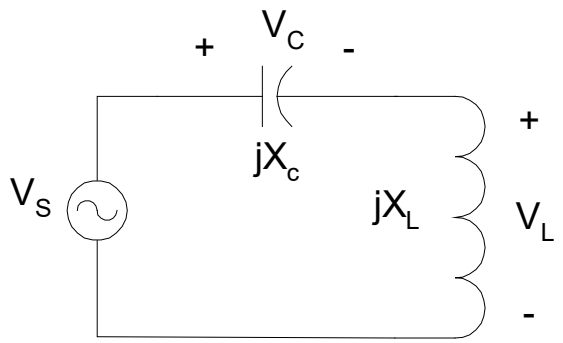

Fig. 3.7 Linear Circuit

A linear circuit would only have one operating point associated with it. We can illustrate this graphically. Suppose that we have the following relationships for the voltages in the circuit shown in above figure:

$$\begin{aligned} V_S &= E \\ V_C &= \frac{1}{j\omega C}\left(I\angle -90\right) = -\frac{I}{\omega C} \end{aligned} \tag{3.27}$$

These relationships are based on the assumption that the inductance dominates the circuit and that the current lags the voltage by 90 degrees. The inductance voltage will be related to the source and capacitor voltages by:

$$V_L = V_S - V_C = E + \frac{1}{\omega C} I \tag{3.28}$$

where for a linear circuit

$$V_L = j\omega L\left(I\angle -90^o\right) = \omega L I \tag{3.29}$$

The operating point for this circuit can be determined graphically by plotting (3.28) and (3.29) on the same graph and determining the intersection as shown below.

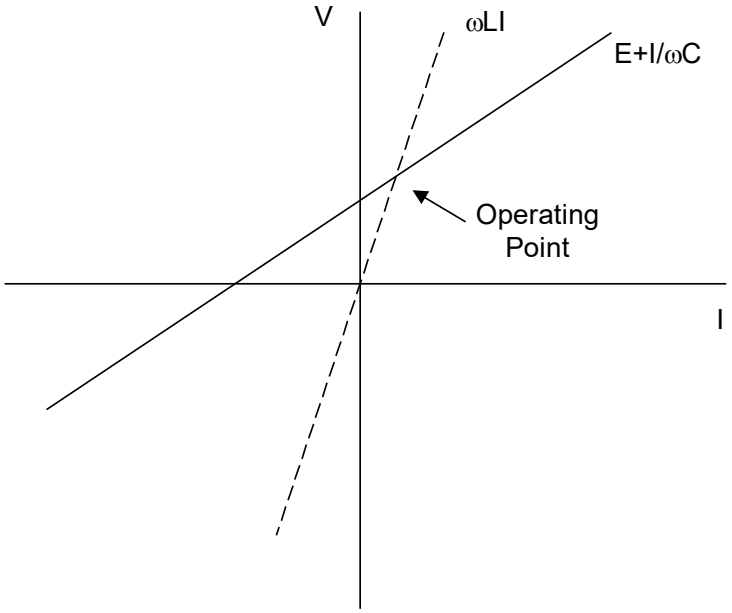

Fig. 3.8 Operating Point for a Linear Circuit

Now what happens when we have an inductance that is nonlinear? The inductance is actually a function of current. As the current increases so does the magnetic field intensity, H. If the current gets too large this can drive the magnetic circuit into the saturation region. If we superimpose a saturable inductance instead of a linear inductance in Fig. 3.8, we get the plot shown in Fig. 3.9. For current lagging voltage there are two possible operating points due to the nonlinear inductance. Hence the current can jump rapidly between these two points, resulting in erratic voltage waveforms.

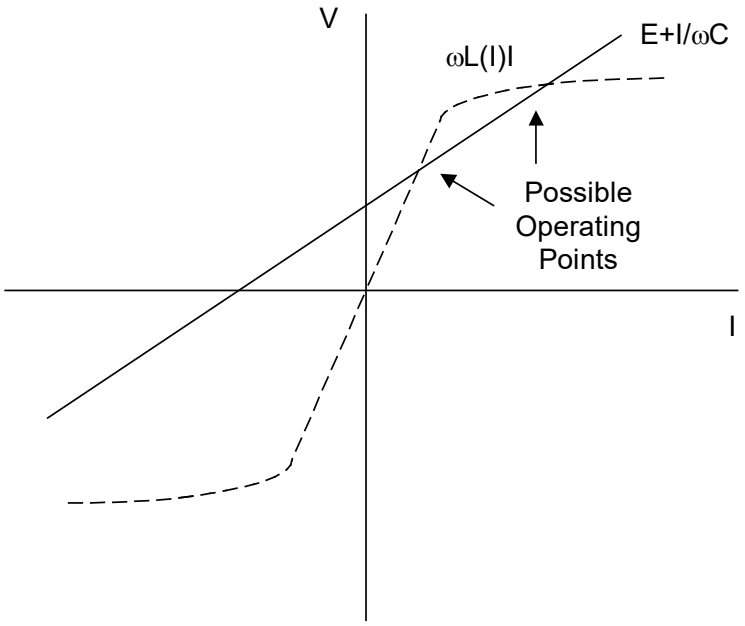

Fig. 3.9 Operating Point for a Saturable Inductor

Resonant conditions normally occur when a three-phase system is inadvertently operated in a single-phase mode. This can happen if as single pole of a circuit breaker operates too fast or too slow, or if fuse blowing results in a single phase condition. A typical scenario where ferroresonance could occur is shown in Fig. 3.10. This shows a pad mounted delta to wye transformer being fed by a cable. If a phase is left closed in by itself, then there are two LC paths, which could result in ferroresonance.

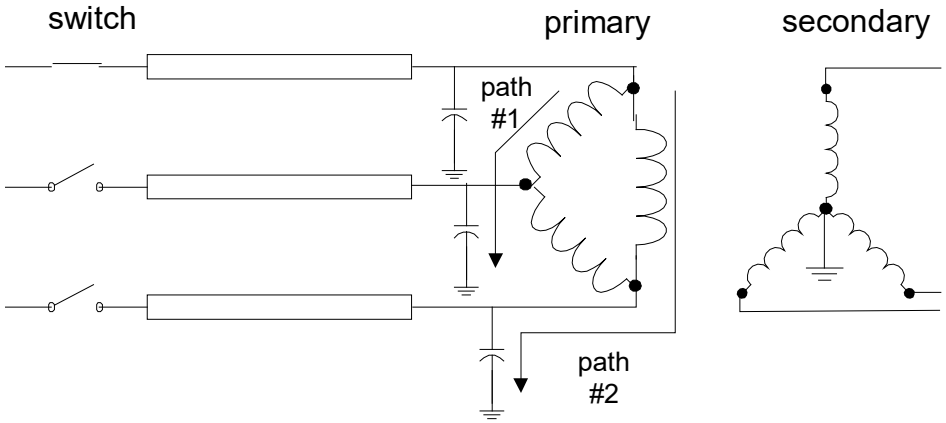

Fig. 3.10 Ferroresonance Scenario