itance. Tests by the Southern California Edison Company on three-phase transformers with ungrounded primary connections found that ferroresonance occurred when the capacitive power per phase exceeded the transformer's no-load losses per phase by the following relationship (Jufer, 1994):

$$B_C \geq 1.27 P_{NL}$$

The phase-to-ground capacitance of overhead transformers is primarily due to the capacitance between the primary and secondary windings (the secondary windings are almost at zero potential). A typical 25-kVA transformer has a phase-to-ground capacitance of about 2 nF (Walling et al., 1995). For a 7.2-kV line-to-ground voltage, 0.002 µF is 39 vars. So, if the no-load losses are less than 39 vars/1.27 = 30.7 W per phase, the transformer may ferroresonate under single-pole switching.

Normally, ferroresonance occurs on three-phase transformers, but ferroresonance can occur on single-phase transformers if they are connected phase to phase, and one of the phases is opened either remotely or at the transformer. Jufer (1994) found that small single-phase padmounted transformers connected phase to phase ferroresonate when remotely switched with relatively short cable lengths. Their tests of silicon-steel core transformers found that a 25-kVA transformer resonated with 50 ft (15 m) of 1/0 XLPE cable at 12 kV. A 50-kVA transformer resonated with 100 ft of cable, and a 75-kVA unit resonated with 150 ft of the cable. Peak primary voltages reached 3 to 4 per unit. Secondary-side peaks were all under 2 per unit. Longer cables produced slightly higher voltages during ferroresonance. Jufer found that ferroresonance didn't occur if the resistive load in watts per phase (including the transformer's no-load losses and the resistive load on the secondary) exceeded 1.15 times the capacitive vars per phase ($P_{NL} + P_L > 1.15 B_C$). Bohmann et al. (1991) describes a feeder where single-phase loads were switched to a phase-to-phase configuration, and the reconfiguration caused a higher-than-normal arrester failure rate that was attributed to ferroresonant conditions on the circuit.

It is widely believed that a grounded-wye primary connection eliminates ferroresonance. This is not true if the three-phase transformer has windings on a common core. The most common underground three-phase distribution transformer has a five-legged wound core. The common core couples the phases. With the center phase energized and the outer phases open, the coupling induces 50% voltage in the outer phases. Any load on the outer two phases is effectively in series with the voltage induced on the center phase. Because the coupling is indirect and the open phase capacitance is in parallel with a transformer winding to ground, this type of ferroresonance is not as severe as ferroresonance on configurations with an ungrounded primary winding. Overvoltages rarely exceed 2.5 per unit.

Five-legged core ferroresonance also depends on the core losses of the transformer and the phase-to-ground capacitance. If the capacitive vars exceed the resistive load in watts, ferroresonance may occur. Higher capac-