TRANSFORMER PROTECTION FROM INRUSH CURRENT – USE AN NTC THERMISTOR

TRANSFORMER INRUSH CURRENT PROTECTION

- A transformer draws inrush current that can exceed saturation current at power up.
- The Inrush Current affects the magnetic property of the core.
- This happens even if the transformer has no load with its secondary open.
- The magnitude of the inrush current depends on the point on the AC wave the transformer is switched on.
- If turn-on occurs when the AC voltage wave is at its peak value, there will be no inrush current drawn by the transformer. The magnitude of the current in this case will be at normal no load value.
- If at turn-on, the AC wave is going through its zero value, then the current drawn will be very high and exceed the saturation current (see Figure 1). In figure 1., the transformer has to be protected from inrush current.

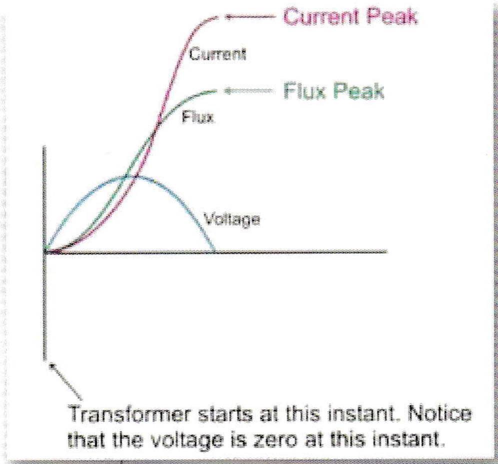

Figure 1

PROTECTION OF THE TRANSFORMER

This application note provides a convenient solution (see Figure 2) to deal with the problem of inrush current exceeding saturation current in transformers.
The solution uses an NTC Thermistor in series with the primary.
This NTC Thermistor offers high resistance at the beginning of switching and limits the inrush current.
After a short time, the NTC Thermistor resistance decreases to a low value due to self heating and does not affect normal operation.

Figure 2

Each transformer rating: 1000 VA, transformer step-down: 30 V
Total transformer rating: 2000 VA
Filter capacitors used: 30V, 2300 μF
Peak inrush Current occurs in one cycle = 564 A, as measured on the oscilloscope

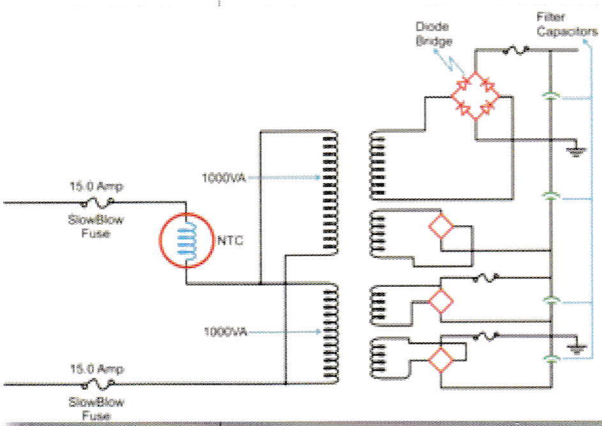

Figure 2

NTC SELECTION CRITERIA #1: ENERGY

Energy required for the NTC: Inductive reactance of the transformer

$$\frac{\textit{Peak Voltage}}{\textit{Inrush Current}} = \frac{120\text{ VAC} \times 1.414}{564\text{ A}} = 0.301\Omega$$

Note:

- Input Voltage = 120 VAC
- Frequency = 60 Hz

$X_L = 2\pi f L = 2 \times 3.14 \times 60 \times L$

So, $L = \frac{X_L}{2\pi F} = 798\ \mu H$

Energy rating for the NTC $= \frac{1}{2}(\text{Inductance})(\text{Inrush Current})^2 = \frac{1}{2} LI^2$

$\frac{1}{2} = (798 \times 10^{-6})(564\text{ A})^2 = \mathbf{127\ Joules}$

NTC SELECTION CRITERIA #2: STEADY STATE CURRENT

Assume, Efficiency of transformer: 70%, Ambient Temperature: 75°C, Minimum input voltage: 90 V

$$I_{steady} = \frac{\textit{KVA of Transformer}}{\textit{(Efficiency of Transformer)x(Minimum Input Voltage)}}$$

For this transformer, I_{steady} is calculated as $= \frac{(2.0\text{ KVA})}{(0.70) \times (90\text{ V})} = 31.75\text{ A}$

Normally Thermistors are rated up to 65°C for their operating current, and then a derating factor must be taken in to account.

Decision criteria: choose an NTC Thermistor that can provide at least the steady state current as calculated above:

Using the de-rating curve at 75°C , use corresponding 90% of max rated steady state current,
= 0.90 x 36 A = 32.40 A

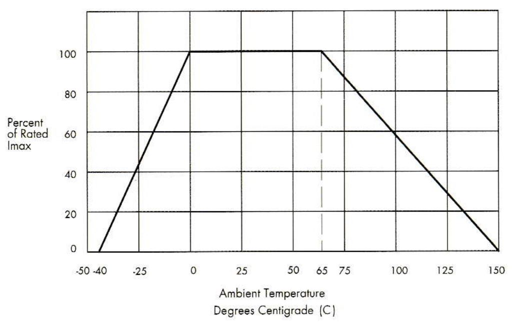

Figure 3

NTC SELECTION CRITERIA #3: CALCULATING MINIMUM RESISTANCE

$$\text{Minimum Resistance} = \frac{\textit{Peak Voltage}}{\textit{Reduce Inrush Current by 50\%}}$$

$$\text{Min R} = \frac{120\text{ VAC} \times 1.414}{0.50 \times 564\text{ A}} = \frac{170\text{ V}}{282\text{ A}} = 0.60\pi$$

So if we choose SL32IR036 it will meet all of the criteria.