Inrush Current Control in Transformers

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Abstract

The paper deals with the problem of magnetizing inrush current phenomenon in transformers and describes the design of a robust time delay relay which can be used to control the inrush current into transformers. Test results are presented on the performance of the time delay relay to demonstrate the effectiveness of the relay in reducing the switch on inrush current into a small laboratory transformer.

Keywords: *Inrush current, time delay relay, bridge rectifier, current source, thermistor*.

Introduction

When a transformer is switched on to line, at times the circuit breaker trips or their fuse blows. This happens even if the transformer is on no load with its secondary open. This is due to the heavy magnetizing current drawn by the transformer. This current may reach a level exceeding the full load current. However, this heavy inrush current magnitude depends on the instant on the a.c wave at which the transformer is switched on. If the instant happens to be such that the a.c voltage wave is going through its peak value, then 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 the instant happens to be such that the a.c wave is going through its zero value, then the current drawn will be very high leading to breaker tripping. Hence to avoid inrush current, the transformer is to be connected to the line when the voltage is going through its peak. This requires a point on wave switch (Panthala 1999) which makes the switching equipment costly and is not adopted in practice. A mechanical or electro-mechanical contactor is used to connect the transformer to the line in practice and there is no control on the instant of switching. Inrush current does occur occasionally leading to nuisance tripping of the breaker. One simple way to reduce inrush current is to insert a resistor in series with the transformer at the beginning of switching and then cut this resistor out after a short time to allow normal operation. Another way is to use NTC thermistor (AMETHERM 2001) in series with primary. This NTC thermistor will offer high resistance at the beginning of switching and limit the inrush current. After a short time thermistor resistance decreases to a low value due to self heating and does not affect normal operation. The NTC thermistor solution is practicable for small transformers. In this paper a time delay relay solution is presented which will physically insert a resistor in the primary circuit and then cut this resistor completely out of the circuit automatically after a predetermined time delay. First a brief theory is presented to explain the reason for the inrush current in transformers and then the time delay relay circuit is described. Finally some test results are presented.

Refer to Fig.1, the switch SW is closed at time t =0. Neglecting the resistance of the primary winding the equation for the primary loop will be $v = N d\varphi/dt$ where $v = V_m \sin(wt + \theta)$, $d\varphi/dt = (V_m/N)\sin(wt + \theta)$. Integrating this equation we get $\varphi = -\varphi_m \cos(wt + \theta) + k$. The value of k is evaluated by applying the initial condition that at t =0, $\varphi = 0$. The final equation for the flux in the core is given by $\varphi = \varphi_m \{\cos\theta - \cos(wt + \theta)\}$ where $\varphi_m = V_m/wN$. It should be noted that this is a simplified analysis. In a real case when resistance is taken into account $\varphi_m \cos\theta$ term dies down