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Reduction of Single Phase Transformer Magnetizing Inrush Current by using Point on Wave Switching

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Abstract -When transformer is energization by supply voltage, a high current will be drawn by the transformer. The mentioned current is called transient inrush current and it may rise to ten times the nominal full load current of transformer during operation. Energization transients can produce mechanical stress to the transformer, causes protection system malfunction and it often affect the power system quality and may disrupt the operation of sensitive electrical loads such as computers and medical equipment connected to the system. Reduction and the way to control of energization transients currents have become important concerns to the power industry for engineers. One of the methods to reduce inrush current is switching technique. This paper discusses the experimental results on a single phase transformer for reduction of inrush currents. An electronic single phase switching controller has been designed.

Keywords: Inrush current; transformer; solid state relay; microcontroller.

1. INTRODUCTION

When a power transformer is switch on from primary side, with keeping its secondary circuit open, it acts as a simple inductance. When electrical power transformer runs normally, the flux produced in the core is in quadrature with applied voltage as shown in the figure below. That means, flux wave will reach its maximum value, ¼ cycle or π/2 angle after, reaching maximum value of voltage wave. Hence as per the waves shown in the figure, at the instant when, the voltage is zero; the corresponding steady state value of flux should be negative maximum. But practically it is not possible to have flux at the instant of switching on the supply of transformer. This is because, there will be no flux linked to the core prior to switch on the supply. The steady state value of flux will only reach after a finite time, depending upon how fast the circuit can take energy. This is because the rate of energy transfer to a circuit cannot be infinity. So the flux in the core also will start from its zero value at the time of switching on the transformer [1].

The transformer cores are generally saturated just above the maximum steady state value of flux. But in our example, during switching on the transformer the maximum value of flux will jump to double of its steady state maximum value. As, after steady state maximum value of flux, the core becomes saturated, the current required to produced rest of flux will be very high. So, transformer primary will draw a very high peak current from the source, which is called magnetizing inrush current in transformer or simply inrush current in transformer.

Magnetizing inrush current in transformer is the current which is drown by a transformer at the time of energizing the transformer. This current is transient in nature and exists for few milliseconds.

The inrush current may be up to 5-10 times higher than normal rated current of transformer. Inrush current in power transformer is a problem, because it interferes with the operation of circuits as they have been designed to function. Some effects of high inrush include nuisance fuse or breaker interruptions, as well as arcing and failure of primary circuit components, such as switches. High magnetizing inrush current in transformer also necessitate over sizing of fuses or breakers. Another side effect of high inrush is the injection of noise and distortion back into the mains.

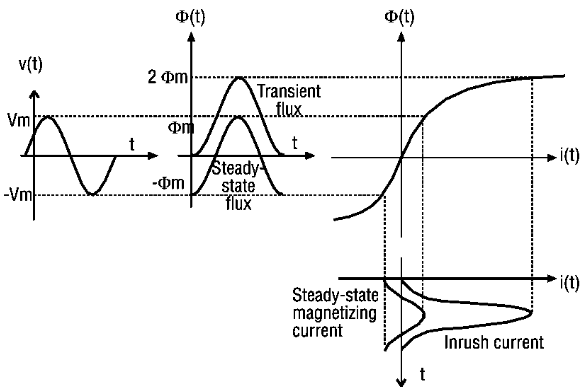


Fig. 1. Nature of inrush current

In a transformer circuit the voltage and the current waveform are 90° apart from each other. Transformer current and flux are normally in phase so the voltage and flux are 90° apart as well. Without point on wave closing, energizing a transformer may result in core saturation, where, a small increase of flux leads to a large increase in current [4]. Therefore, minimizing the flux will minimize the inrush current. Closing at peak voltage by point on wave will minimize the transient flux generated by the transformer, and results on reducing inrush current to a lower value from its initial value.

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 switching technique. In a transformer circuit, the voltage and the current waveform are 90° apart from each other; the transformer current and flux are normally in phase so that the voltage and flux are 90° apart as well. With the point-on-wave device closing on the supply voltage, energizing a transformer does not result in core saturation, where; a small increase of flux may lead to a large increase in current. Therefore, minimizing the flux will minimize the inrush current [5].

2. BLOCK DIAGRAM

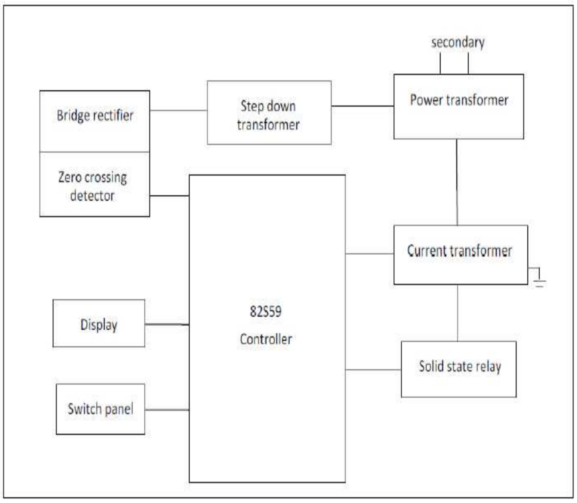
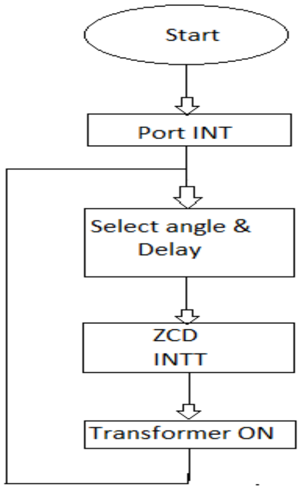


Fig. 2. Block diagram of inrush current reduction technique

In this project there are different electrical and electronics parameters to design the assembly for reduction of inrush current by point on wave switching technique. Like current transformer, solid state relay, step down transformer, bridge rectifier, ZCD, microcontroller, 7-segment display, power transformer, switch panel. In our project we are using power transformer as a load, this transformer has specifications 1kVA, 230/15V 50Hz power transformer. At primary side of power transformer the current transformer and Solid state relay are connected, the power supply is connected power transformer through SSR and the CT. The step down transformer has output voltage of 9V AC which is use to run the electronic circuit by converting it to DC by means of full wave rectifier. Zero crossing detector circuit and bridge rectifier circuit is connected in such a way the output of bridge rectifier connected to the zero crossing detector by maintaining 5V DC through voltage regulator. The ZCD pulse is sent to the microcontroller. We are used 82C59, 40 pin IC which has four ports, one port has 8 pins. This controller is 8051 family and there is a switching panel which is used for the purpose of selection of angle and to ON/OFF the SCR present in the solid state relay with triggering and protective circuit the seven segment display is used for the purpose of displaying the selection of angle and the value of inrush current.

3. FLOWCHART



4. METHODOLOGY

First of all we have to start, as we start the program it will initialize all the ports of microcontroller then we have to select an angle, by angle increment/decrement switches available on switch panel. Depending on the selection of angle the controller will develop the delay the angle and delay selection is given in single interrupt from the output of the zero crossing detector the total cycle time is 20 milliseconds in 50Hz system. Zero crossing detector is the important circuit to detect the zero crossing on the voltage wave. To detect the phase shift from point to point it required a pulse which tense that whenever the sine wave is zero from that point we have to make calculations the switching of SSR is depend on ZCD [8]. The SSR turns on when the load voltage crosses zero after the input signal is activated. It turns off when the load current subsequently crosses zero after the input signal is deactivated. A phase difference between the voltage and current may supply a transient spike to the SSR when it is turned off. While the snubber circuit absorbs this spike, an excessively large spike may result in a dv/dt error in the SSR's internal triac. The connection from the switching panel when the circuit measures the inrush it measures two times that is first time it records the highest peak value of current and second time it records the difference of both the values.

First we have selected angle on 18^0 degree, this time delay is generated according to the time required to reach 18^0 angle on the voltage cycle and this time is 4 milliseconds in 50Hz system. at the zero position we cannot measure the inrush current because to detect the phase shift from one point to another point it required a pulse which tends that whenever the sine wave is zero from that point we have to calculate the phase so that after the selection of angle the ZCD will generate the interrupt. When the port get initialize that is port0, port1, port2, port3. The zero-crossing detector circuit sends the pulses for the positive and negative zero-crossings to the microcontroller [1]. The microcontroller then reads these pulses, and it will wait for the last negative zero crossing pulse calculate the time delay on voltage wave and trigger the SCR at the angle which is corresponding to time delay on the next zero crossing. In this research work for the triggering of SCR to single phase supply voltage, a stage triggering method is employed. We repeat the above procedure up to the angle 90^0 and at this angle we get minimum value of inrush current in transformer, the simplified equation often used to calculate the peak value of the first cycle of inrush current in Amps is as follows[1].

$$I_{Inrush} = \frac{\sqrt{2}V}{\sqrt{(wL)^2+R^2}}\left[\frac{2.B_N+B_R-B_S}{B_N}\right]$$

V = Applied voltage in volts, L = Air core inductance of the transformer windings in ohms, BR = Remnant flux density of the transformer core in Tesla, BS = Saturation flux density of the core material in Tesla, and BN = Normal rated flux density of the transformer core in Tesla.

The above formula is used for the calculation of inrush current is placed in the program such that the value of inrush current can be calculated as we increase the angle that is we increase the delay the magnitude of voltage will be change which results reduce in starting current of transformer.

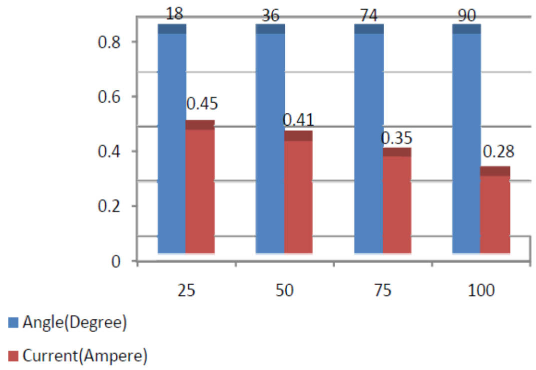
As a zero crossing detector was used to control the phase shift at the angle between 0^0 to 90^0 the phase control and a microcontroller are used for controlling thyristors, triacs and transistors. A power electronic element called triac is used to energize the transformer primary winding to the main supply in a very short period of time. To isolate power circuit from microcontroller, the triggered pulses will reach triac through an optocoupler for the circuit the firing angle of triacs and voltage injection can be set manually before energization. The factors that will influence inrush current include residual flux, the moment of transformer switched on to supply, core configuration, magnetic coupling and winding connection of transformers. Due to many factors which will affect the inrush current in three phase transformer, controlling of conduction period of triacs to suppress the inrush current was almost efficient, and the trend of average inrush current decreased when the firing angle delay increased gradually to 90^0.

5. RESULT

Table 1. Values of inrush current

Angle(Degree)	Current(Ampere)
18^0	0.45
36^0	0.41
74^0	0.35
90^0	0.28

It is observed when the transformer is operated at an angle of 90 degree the value of the inrush current was found to be minimum.



6. CONCLUSION

The method of point on wave switching is achievable by use of a microcontroller, solid state relay, and zero crossing detectors. Inrush current produced in single phase and three-phase transformers can be controlled by long pulse duration due to lagging of current with respect to voltage. When the firing angle delay increases, the inrush current in the transformer is reduced. The transformer is operated at an angle of 90 degree the value of the inrush current was found to be minimum.

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