ISSN: 2836-8495

Research Article

Journal of Current Trends in Computer Science Research

Current Inrush Mitigation Method in Transformers Without an External Power Source or Complex Circuitry

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Submitted: 2024, Aug 02; **Accepted**: 2024, Aug 20; **Published**: 2024, Sep 04

Citation: Meisel, D. (2024). Current Inrush Mitigation Method in Transformers Without an External Power Source or Complex Circuitry. *J Curr Trends Comp Sci Res,* 3(5), 01-03.

Abstract

Coil based devices such as transformers are rated for maximum continuous current operation. However, during the first few A.C. cycles at power up, input current (otherwise known as inrush current) can exceed ten times the rated continuous current of a transformer primary winding even with the secondary winding unconnected. These extra high inrush currents can cause nuisance circuit breaker tripping, winding insulation degradation and make black starting difficult. This is especially important when high efficiency transformers are used, as they tend to have higher inrush currents. The proposed circuit is a "fundamental" transformer design addition with respect to power up characteristics.

Index Terms: D.O.E. 2016, Inrush Current, Motor, Pre-Flux, Pre-Magnetize, Solenoid, Tertiary Winding, Transformer

1. Introduction

This paper will present a novel method and apparatus for mitigating transformer inrush currents at start up, using only a few passive components and a tertiary winding added to (or around) the primary winding of a transformer. Over the years, numerous devices known as pre-magnetizers and reduced voltage starters have been produced. To date it appears all of these design topographies require an additional power source for operation and are often complex and costly.

2. The Test Apparatus and Test Transformer

A single-phase transformer rated 2 K.V.A. at 120 V.A.C. 60 Hz., with a maximum current draw of 16.7 Amperes was selected for experimentation. The transformer is energized using an electromechanical motor starter/contactor that replicates real world switching equipment, as most distribution transformers are not switched with solid state devices. An oscilloscope set for one-shot captures is used for data collection.

A. The Test Apparatus and Proposed Circuit Topography

Shown in Figure 1A is the schematic of the test apparatus and proposed design. An isolated voltage probe is connected across the primary winding N, and is placed after the starter/contactor at points A. An inductive type current probe is placed in series with the primary winding at point B. Shown in Fig. 1b is a photograph of the transformer M under test with the tertiary winding P wrapped around the primary winding N.

The starter/contactor comprised of point C, along with the primary winding is triggered simultaneously at a non-repeatable random point in the A.C. cycle commonly referred to as "random phase-angle triggering."

B. The Proposed Pre-Fluxing Circuit

The proposed pre-flux device is comprised of tertiary winding P, resistor S, relay coil Q and normally closed relay contacts R. Also shown is the transformer M, primary winding N and secondary winding O.

The specifications of the two windings involved are as follows:
The primary winding N inductance is 62 mH. at 1 kHz..
The secondary winding O is left unconnected through all testing.
The tertiary winding P inductance is 0.40 mH. at 1 kHz..
The resistor S is 10 Ohms D. C.. Rated at 50 Watts.

C. Description of Circuit Operation

When power is applied to the transformer primary winding N, power is simultaneously applied to tertiary winding P through resistor S and normally closed relay contacts R, additionally relay coil Q is also ener-gized.

Tertiary winding P charges much faster than primary winding N because it has significantly lower in-ductance of 0.40 mH. versus 62.0 mH. for the primary winding N. This lower inductance enables the ter-tiary winding to "pre-flux" the primary winding N. The result is lower inrush current at startup of the pri-mary winding N.

The duration of the tertiary winding P staying energized is determined by the response time of the relay coil Q to charge, thus opening relay contacts R, de-energizing the tertiary winding P.

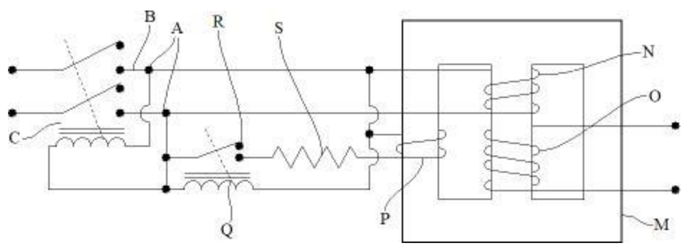

Figure 1A: the test apparatus and proposed design schematic!

Figure 1B: Photograph of the 2 k.V.A test transformer M with tertiary winding P wrapped around the pri-mary winding N!

D. Baseline Transformer Inrush Current Observations

Depicted in Figure 2 is data showing the startup characteristics of the transformer. Note; data within Figure 2 and 3 are taken from an average of thirty separate test events. This is necessary due to the random nature of the trigger event with respect to the A.C. phase-angle at the "trigger-on instant."

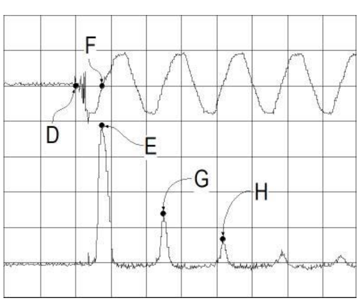

Figure 2: Test Data Without the Proposed Design!

E. Analysis of Data in Figure 2. Transformer Without the Proposed Pre-Flux Design

The data in Figure 3 begins with the rising voltage edge of the switched-on contactor at point D. This is when the oscilloscope begins its capture. Point E depicts the current peak of 79.2 Amperes. Note the current peak of point E is in near synchronization with the next zero voltage at point F. Point G shows the next current peak within the A.C. cycle has a peak current of 31.0 Amperes. Point H shows the next current peak of 18.0 Amperes, where, after this point the current drops to the no-load current draw of the transformer.

F. Analysis of the Data in Figure 3. Transformer with the Proposed Pre-Flux Design

The data in Figure 3 begins with the rising voltage edge of the switched-on contactor at point I. This is when the oscilloscope begins its capture. Point J depicts the current peak of 38.6 Amperes. Note the current peak of point J is in closer synchronization with the higher voltage at point K. Point L shows where the relay opens, turning off the tertiary winding. Point M shows the no-load current draw settles at 43 ms versus the data of Figure 2 at 68ms.

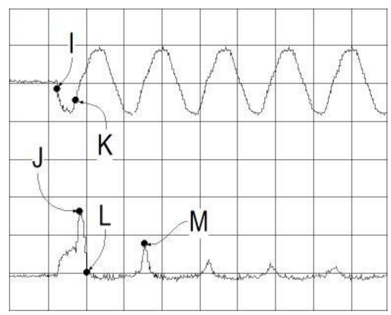

Figure 3: Test Data Using the Proposed Pre-Flux Design!

3. Conclusions

Comparing the data in Figure 2 of the test transformer without the proposed invention to Figure 3 of the test transformer with the proposed invention, it is clear there is a definite reduction of the highest inrush current peaks at start up. The invention does, with repeatability reduce inrush currents by >50%.

Dark starting transformer blocks that have many hundreds and often thousands of transformers to start in parallel is often difficult, especially on weaker or heavily loaded transmission lines and systems. This proposed pre-flux invention solves these common starting problems.

The installation of the tertiary winding is easily performed on new and used transformers that have a minimum gap of 1 mm between the outside of the primary and secondary winding bundle and the inside face of the iron core. Or, installation of the tertiary winding is simple to add to the winding bundle by a transformer manufacturer.

The entire design requires three passive and very common com-ponents. The ease of installation combined with elegant design presents owner/operators of electric power distribution systems an exciting solution toward improved system stability.

References

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