Soft Start of Three-Phase Transformers

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ABSTRACT

Soft-starters of three-phase transformer. This article deal with nowadays used methods for three-phase transformer inrush current suppression. Second part of the article discussed possibility of application non-informed methods (no the remnant flux measuring) of one-phase transformers inrush current suppression to three phase transformers. Measurement results of the considered controlled switching method are published at the end of article. There was tested three-phase transformer Legrand 10 kVA.

Keywords*—Three pahse, transformer, control switching.*

I. Introduction

The inrush current of three-phase transformers arises as a result of their oversaturation magnetic circuit similarly to single-phase transformers. Oversaturation occurs when at the moment the transformer is connected to the power supply; the remnant magnetic flux in the flux core does not correspond in steady state. A more detailed explanation is provided in a number of sources, e.g. in [1].In the case of three-phase transformers, the analysis of the origin and solution of the inrush current is complicated by the great variability of the structural arrangements of the magnetic circuit common to all phases and by the number of group winding connections. At the same time, the various variants differ considerably. In this article they are methods presented for the connection of the primary windings into a star with a drawn center. Some methods however, they are also applicable to other group connections.

II. THREE-PHASE SWITCHING CURRENT LIMITATION METHODS TRANSFORMERS

Three-phase transformers are mostly used for larger outputs, many of the principles of limiting the inrush current for single-phase transformers, which are suitable for smaller performances,

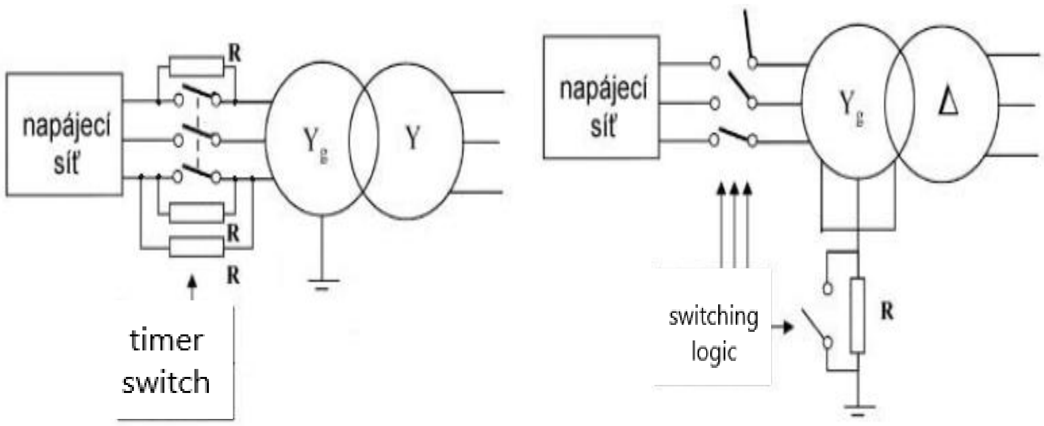

Fig .1: On the left, a resistive starter, on the right, a resistive starter in the middle conductor in combination with sequential switching according to [4, 5]

Several of the following methods appear in practical implementations and professional Publications. The standard method is to start with a resistance or induction starter. The transformer is connected via impedance limiting the inrush current, which is short-circuited after start-up. It is for greater performances this solution is expensive, so some authors are looking for ways to limit the number of starting impedances. Use one resistor connected to the middle conductor in combination with primitive sequential switching of individual phases. The most popular method is the sequential switching of individual phases. The sequences used are several (B–AC) with (1/4T) delay; (B–AC) with delay (2+1/4) T [2, 3]; (A–C–B) with (1/6T) delays [6] and more. For implementation, it is necessary to use separate switches in the individual phases and to know the remnant current in the transformer core. At the same time, the methods are optimized only for some group connections.

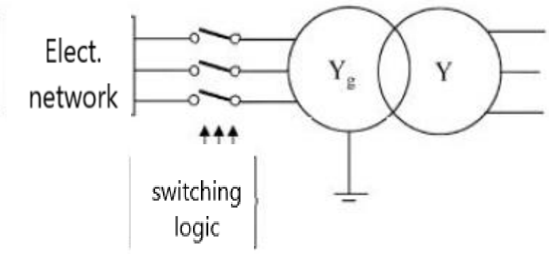

Fig.2. Simplicity of sequential switching

The same time, mechanical switches are commonly used for switching, which cannot avoid arc jumps and debouncing. In doing so, a defined pinning time must be ensured. It is therefore advisable to prefer sequences less sensitive to the accuracy of the switching times and to verify the properties of the switches. The biggest pitfall of sequential switching is detecting the initial remnant magnetization. Very often, the problematic measurement of magnetization is bypassed, for example, by a controlled sequential one by switching off the transformer [6] or by demagnetization using capacitors connected in parallel to the transformer. The magnetization measurement is then not necessary because the core is before the next pinning in a defined state.

III. USE OF UNINFORMED SOFT SWITCHING METHODS IN THREE-PHASE TRANSFORMERS

For single-phase transformers, controlled clamping is advantageously used to limit the inrush current without having to measure the initial remnant magnetization of the core. It is gradual Magnetization of the core with short pulses in individual periods, which ensure a defined magnetization of the core at the end of the sequence. We call such methods uninformed. Both methods [1,7] end at the same time sequence with a core magnetized at the saturation limit. By a suitable combination with sequential switching from [2,3], it would thus be possible to create a configuration for limiting the inrush current of a three-phase transformer without the need to measure the initial remnant magnetization of the core. In the first phase of the solution, the quality of the sequential switching algorithm from [2,3] was verified. Two variants (B–AC) with a delay of (1/4T) shown in Fig. 3, and a similar (B–AC) with a delay were tested.

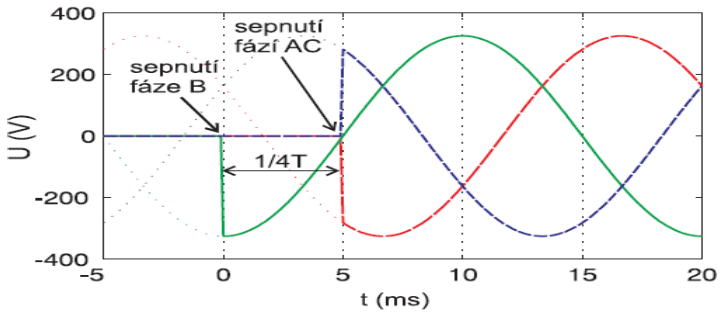

Fig.3. Tested B–AC switching sequence with 1/4T delay

For testing, an EI transformer Legrand 776862 (230//230V,10kVA) was used in the connection($Y_n y_n 0$). Connected to a star with the center drawn out. The couplings and posts are made of magnetically oriented steels, pulled bolts without interleaving, so they fit butt. So the core has considerable air gaps. The result is minimal residual magnetization. The highest measured value the initial remanent magnetization was 0.12 T. The measurement was made with the attached Hall probe at the point of contact of the coupling and the column with respect to the reference value of the amplitude of the magnetic flux in steady state operating status of the transformer. When measuring the inrush current diagrams, no initial was needed define or measure remanent magnetization. Due to this, the curves in the diagrams are only slight wavy. Fig.4,and 5 show measured diagrams for both switching sequences. Maximums are plotteof the starting current in the individual phases of the transformer L1, L2 and L3, then the starting current in middle conductor N. For clarity, the curve of the highest starting current of all phases is added in absolute value. The independent variable of the graph is the supply voltage pin-on angle measured on phase L1. For both sequences, two areas with suppressed inrush current suitable for use are evident soft start circuit. The reduced inrush current is a range of approximately (25°) of the clamping angle with the center at the maximum voltage of phase L2, which switches first. For correct operation of inrush current limitation therefore, switching must take place with an accuracy of 0.7 ms. it can be seen from the diagrams that both methods have a similar effect. The second variant with a delay (3 + 1/4) T shows a smaller inrush current when switched at an inappropriate angle, which is not for the application substantially. It is therefore more advantageous to use the faster first variant.

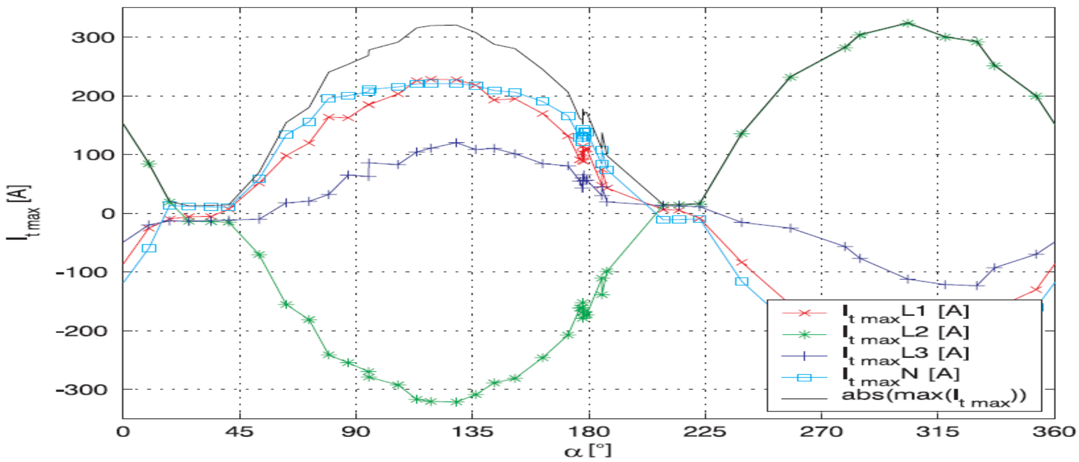

Fig.4.Diagram of maximum inrush current during sequential B–AC switching with 1/4T delay Files: In3fMode2_R50load_ProhozenoT1aT2_xx.

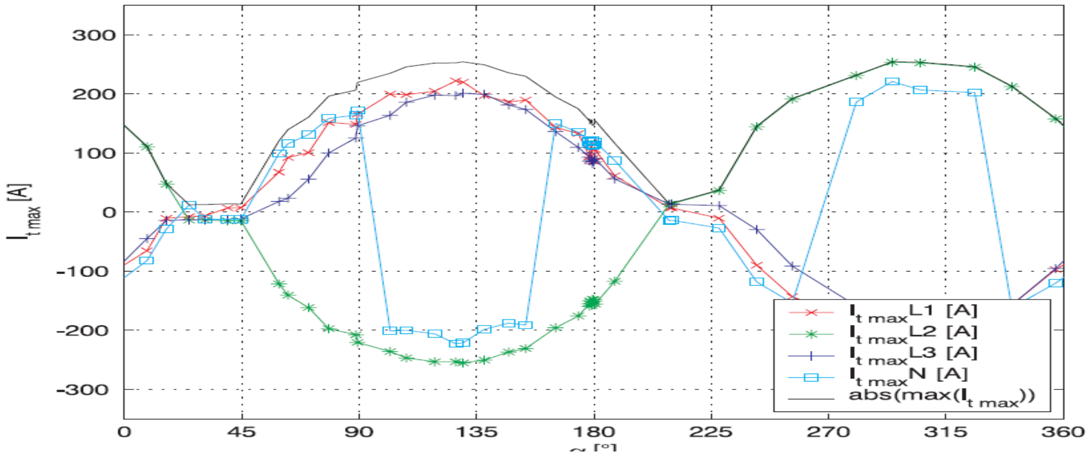

Fig.5. Diagram of maximum inrush current during sequential B–AC switching with delay (3+1/4) T
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IV. CONCLUSION

The combination of uninformed methods of limiting the inrush current and sequential switching is a suitable, technically simple, solution for three-phase transformers of smaller powers. For large machines, it is more advantageous to measure the initial remanent magnetization compared to the cost of the semiconductor switching element.

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