# Theoretical Considerations about Magnetic Hysteresis and Transformer Inrush Current

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## I. INTRODUCTION

This paper presents an application of a vector Hysteresis model to the prediction of the inrush current due the arbitrary initial excitation of a transformer after a fault. The approach proposed seems promising in order to predict the optimal time to close the circuit after the fault.

Inrush currents are high value transient currents generated when a magnetic core is driven into saturation during initial excitation. They have many undesirable effects, such as opening of the power circuit by means of protective relays, and this fact can strongly reduce the quality and the continuity of the power systems, especially in the case of uninterruptible power supplies. The effects of inrush currents are generally mitigated by using suitable late-closing relays, over-size fuses, or other passive components. Although reduction in inrush currents magnitudes has been achieved with hardware, active controls, such as controlled closing ones, they seem to be promising in order to reduce the complexity and the cost of the power system. The control strategies are based on the prediction of the residual magnetic flux acting in the transformer in order to avoid a transient overshoot in the current, by selecting the closing time correspondent to the given residual flux [1].

The problem is to evaluate the residual flux with accuracy, since it is a very difficult and complex problem to solve, for the two following reasons: the effects of the eddy currents in the laminated cores is in general considerable, and the hysteresis in the magnetic materials must be taken into account.

## II. MODELING AND PRELIMINARY RESULTS

In this paper we approach the general problem of the prediction of the optimal closing time in a single-phase transformer, introducing a model of hysteresis in the transient during the transformer initial excitation. In this first approach to the problem, we postulate that magnetic hysteresis as a rate-independent phenomena and that the magnetic induction is uniform in the cross section of the magnetic core of the transformer.

The vector model of static magnetic hysteresis we use in this paper is based on the rule of a phenomenological vector hysteresis operator defined in the ***H***-space [2]. The vector model of hysteresis above has been implemented as circuital block in the equivalent network of the transformer at industrial frequency. The magnetic and electric equilibrium equations have been solved in time domain via a suitable finite difference scheme.

Preliminary results are reported in the following using a numerical simulation for the initial excitation of the transformer after a short circuit fault, respectively in both cases of good and bad closing operations.

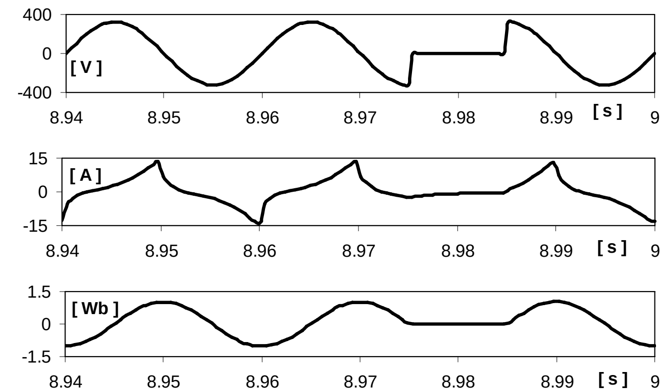


Fig. 1 - Voltage, current and magnetic flux on the primary winding calculated after a single-phase fault and an optimal closing time.

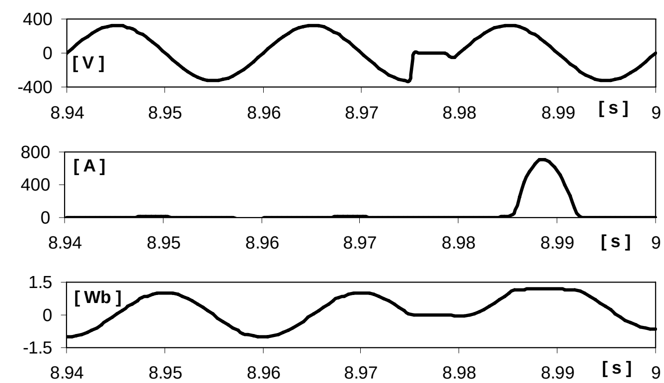


Fig. 2 - Voltage, current and magnetic flux on the primary winding calculated after a single-phase fault and an arbitrary closing time.

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## REFERENCES

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[2] E. Cardelli, E. Della Torre, and A. Faba, "Numerical Implementation of the DPC Model", IEEE Transaction on Magnetics, VOL. 45, NO. 3, March 2009.