

Diagnosis winding short-circuit faults of power transformer

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Abstract

Diagnostic goal of transformers in service is to detect the winding or the core in fault. Transformers are valuable equipment which makes a major contribution to the supply security of a power system. Consequently, it is of great importance to disequilibria the three phases courant of power transformers. So, vector diagram analysis is a useful tool for reliable detection of incipient mechanical fault in a transformer, by finding winding or core defects. The authors propose this article, the coupled circuits method, because, it gives most possible exhaustive modelling of transformers. Measurement courant homopolaire in order to improve and simplify the response for a faulty transformer. This study can be used as a base data for the other transformers of the same categories intended for distribution grid.

Keywords: Diagnostic, short-circuit, transformer faults, unbalanced current.

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1. Introduction

Transformers are valuable equipment which makes a major contribution to the supply security of a power system. So the diagnostic methods are systematically being improved and extended due to growing requirements for reliability of power systems in terms of uninterrupted power supply and avoidance of blackouts. Hence, the detection of winding faults in transformers, during exploitation is an important aspect of power transformer failure prevention.

If a transformer is inflicted by a fault, it is necessary to take it out of service as soon as possible in order to minimise the expected damage. The cost associated with repairing a damaged transformer is very high. An unplanned outage of a power transformer can cause a very important socio-economical prejudice.



Figure 1. Winding short-circuit

Consequently, it is of great importance to minimise the frequency and duration of unwanted outages of power transformers. The defects which lead to put the transformers in out of service have various natures; in our work we are interested in those of the electric type, which affect the winding circuit.

Because investigation shows that transformer failures are caused by internal winding short-circuit faults. One important reason for these faults is erosion of the winding and conductor insulation due to vibrations initiated by the electromechanical forces at service current and over currents.

In the majority of the cases, the transformers are put out of service by their protection systems, which react only if the transformer undergoes a serious incident, such as transformer differential protection which contains a number of additional functions (matching to transformation ratio and vector group, restraint against inrush currents and over-excitation). Therefore it requires some fundamental consideration for configuration and selection of the setting values. Optimum design of the transformer protection ensures that any faults that may occur are cleared quickly and possible consequential damage is minimised [1].

2. Transformer faults detection

The partial internal winding short-circuit faults lead to over-current in windings that result in terrible damages such as severe hot-spots, oil heating, winding deformation, damage to the clamping structure, core damage and even explosion of transformer.

The idea is to detect faults at their embryonic states. And, is conditioned neither by the transformer Plug off (disconnection) nor by its operation mode.

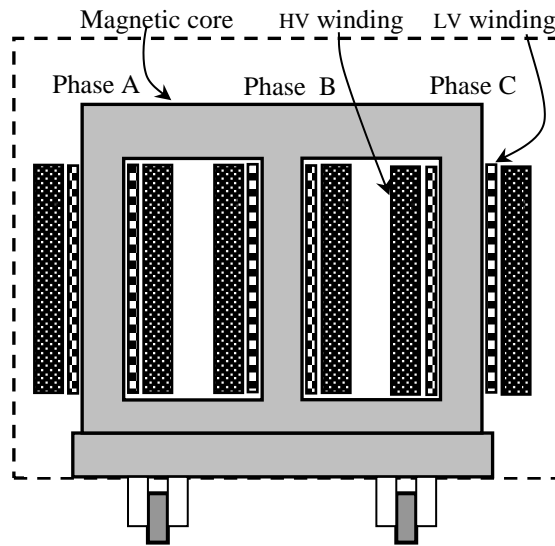


Figure 2. Transformer architecture

3. Model of power transformer

The windings belong to the active part of a transformer, and their function is to carry current. The windings are arranged as cylindrical shells around the core limb Figure 1. In several works, one considers that the electromagnetic coupling of a winding coil of a phase is perfect; consequently, they make an equality approximation between self and mutual inductance unit.

From the currents three-phase system:

$$\begin{cases} i_A(t) = I_{mA} * \sin(\omega t) \\ i_B(t) = I_{mB} * \sin\left(\omega t + \frac{2\pi}{3}\right) \\ i_C(t) = I_{mC} * \sin\left(\omega t + \frac{4\pi}{3}\right) \end{cases} \quad (1)$$

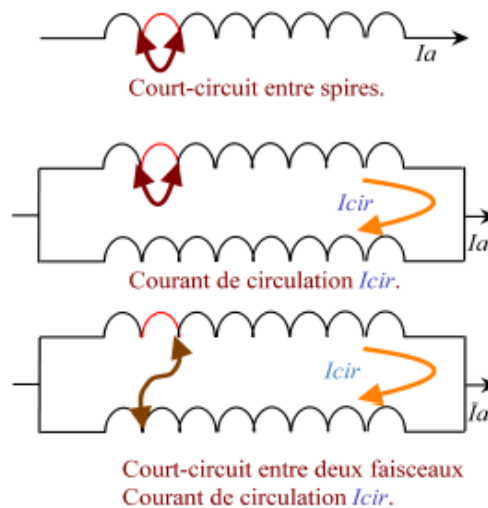


Figure 3. Short circuit between coils

If the following variables changed:

Know that

$$\begin{cases} I_{mA} = I_A + \Delta I_A \\ I_{mB} = I_B + \Delta I_B \\ I_{mC} = I_C + \Delta I_C \end{cases} \quad (2)$$

$\Delta I_A, \Delta I_B, \Delta I_C$: the current values add following the short circuit fault

Calculating the zero sequence current:

$$i_{H0} = i_A(t) + i_B(t) + i_C(t) \quad (3)$$

After simplification a general relation that shows the short-circuit fault of the winding of a power transformer is proposed:

$$i_{H0} = (\Delta i_A - 0.5 * \Delta i_B - 0.5 * \Delta i_C) * \sin(\omega t) - \frac{\sqrt{3}}{2} * (\Delta i_B - \Delta i_C) * \cos(\omega t) \quad (4)$$

$$A = \rho * \cos(\beta) = (\Delta i_A - 0.5 * \Delta i_B - 0.5 * \Delta i_C)$$

$$B = \rho * \sin(\beta) = -\frac{\sqrt{3}}{2} (\Delta i_B - \Delta i_C)$$

It implies that: $\rho = \sqrt{A^2 + B^2}$

$$\beta = \text{atn}\left(\frac{B}{A}\right)$$

ρ : The module of the zero sequence current informs on the defect gravity.

β : The phase shift of the zero sequence current tells on the phase in default.

4. Simulation results

For the study and short-circuit fault detection, a design of a simulation program by the MATLAB software is proceeded for different possible cases of this type of fault: see Table 1

By measuring and analysing the zero sequence current of a power transformer, the detection and diagnosis of fault short circuit in its various forms are possible, and the study of its amplitude predicts the fault severity.

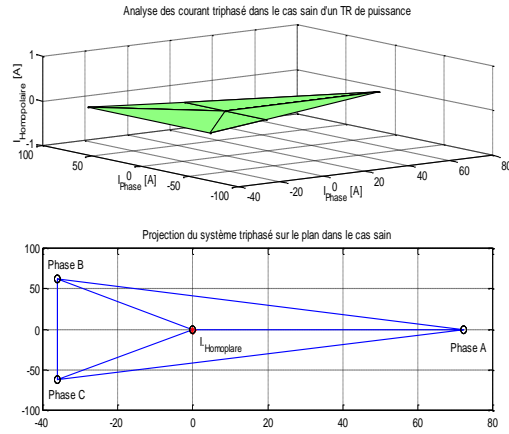


Figure 4. Case sain simulation of power transformer

Table 1. Different possible cases of this type of short-circuit fault

Differentes Cas de Simulation	Cas de court circuit une seule phase					Cas de court circuit deux phases			Trois phases en court circuit	
	Cas Sain	Legere défaut		Grand défaut						
Phase A	0%	5%	0%	0%	80%	0%	30%	0%	10%	20%
Phase B	0%	0%	5%	0%	0%	40%	70%	70%	60%	20%
Phase C	0%	0%	0%	5%	0%	40%	0%	30%	40%	20%

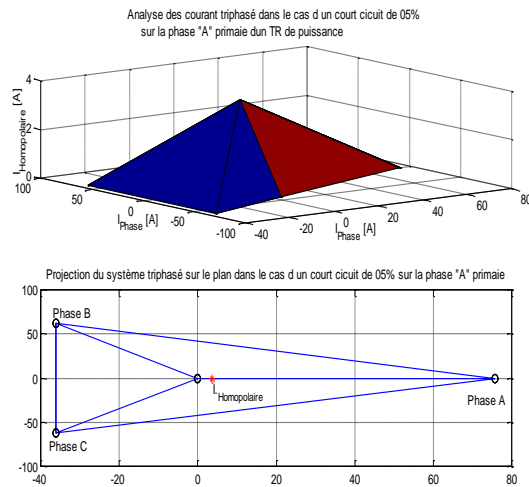


Figure 5. 05% Short circuit phase A simulation

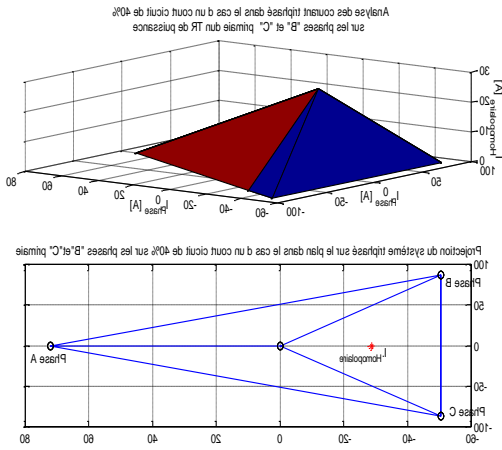


Figure 6. 40% Short circuit phase A and B simulation

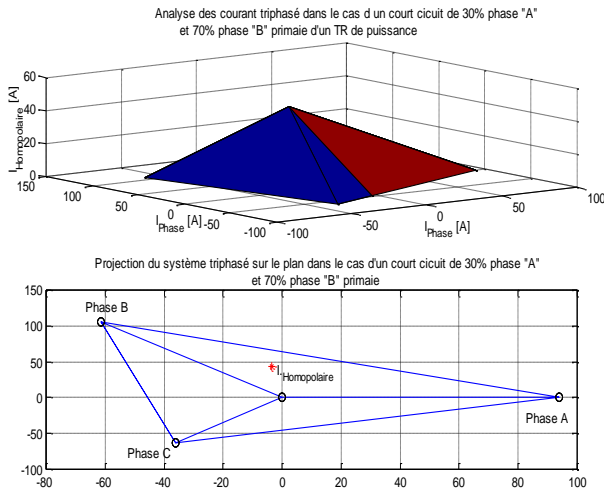


Figure 7. 30% Short circuit phase A and 70% Short circuit phase B simulation

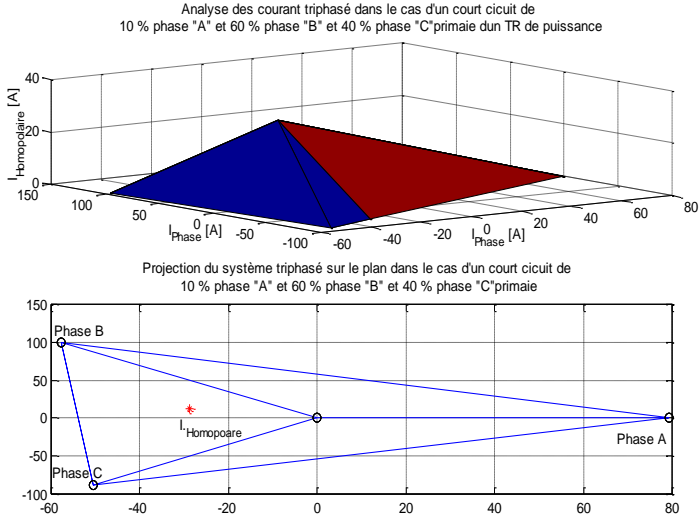


Figure 8. Short circuit 10% phase A, 60% phase B and 40% phase C simulation

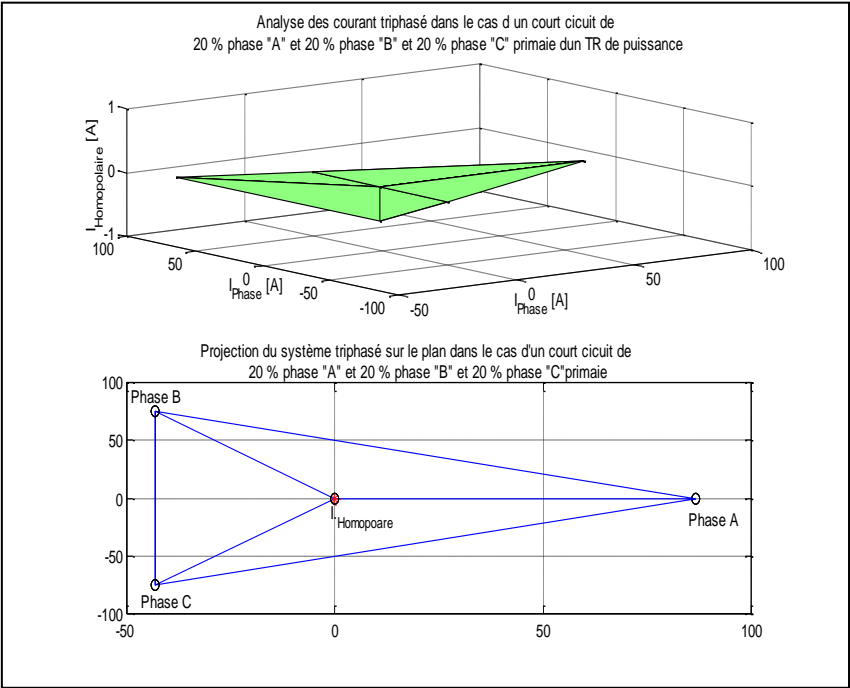


Figure 9. Short circuit 20% des phases A, B, C simulation

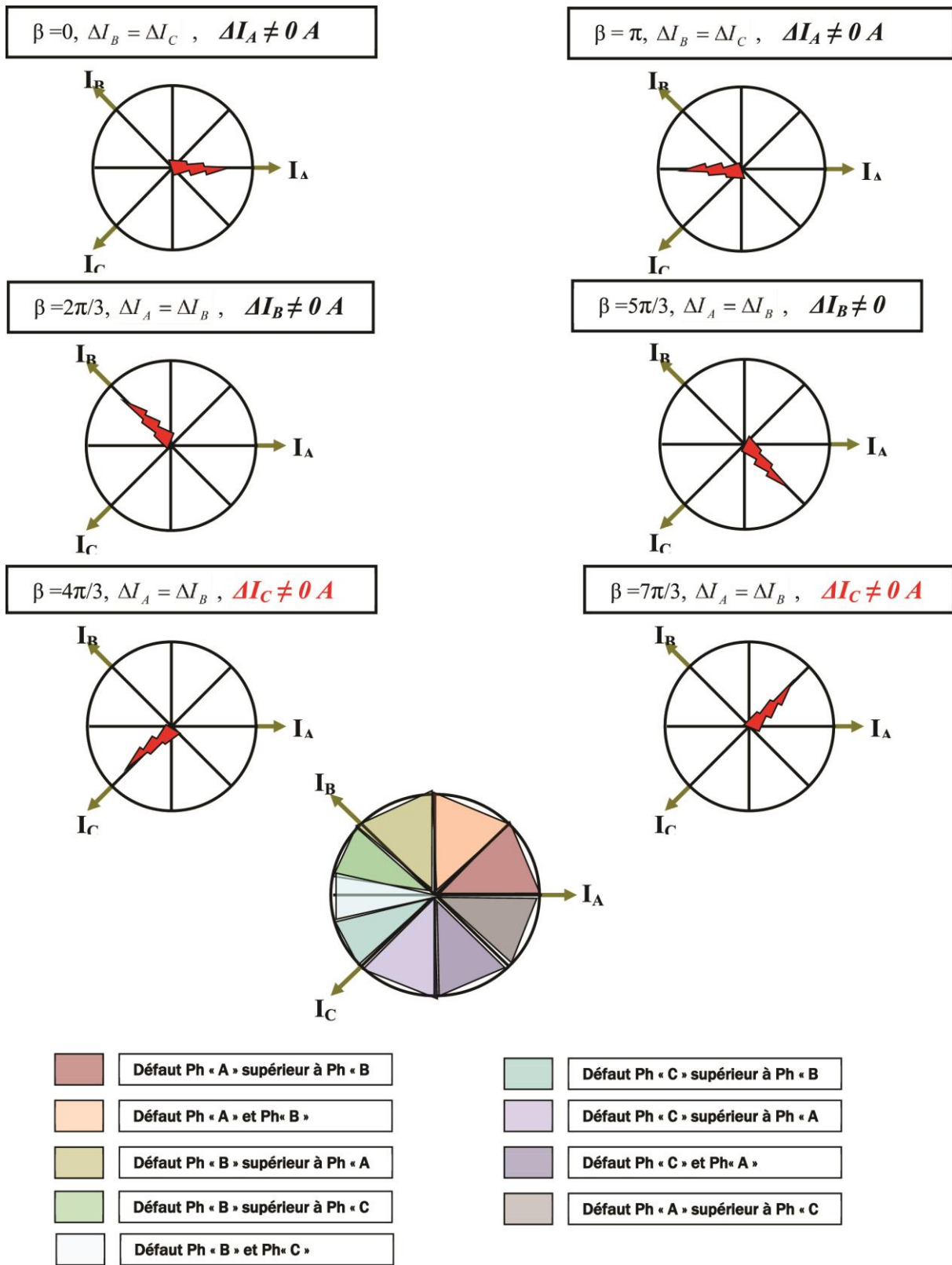


Figure 10. Parts of short circuit cases possible

5. Conclusion

We estimate that the diagnostic goal of transformers in service is to detect the winding or the core in fault, but it is not necessary to encumber the module of treatment, by other equations (then other circuits) for the exact localisation of the defect point, which can be dealt within the second phase of maintenance. Thus diagnostic is used in order to take a decision of assumption about the degree and urgency of the defect.

This study can be used as a bases data for the other transformers intended for distribution grid. Considering that they have the same category (rate power, voltages and frequency) and sizes (windings and core dimensions).

The coupled circuits' method proved as a powerful proceeding of modelling, and the results given by FRA in low frequency provide a simple and direct analysis of eventual internal defects.

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