Transformer Energisation in Power Systems

This Technical Insight from CIGRE UK is based on the 2013 publication of CIGRE Technical Brochure (TB) 568.

Background

Transformers are one of the key components in any power systems which operates under AC principles. The impact of it is equally important to all the stakeholders involved (eg. DNOs, TSOs and Manufacturers).

Transformer energisation is a regular operation in transmission and/or distribution networks and the issues associated with it are not new. However, it is becoming increasingly relevant due to the changes that are shaping power networks. Frequent modifications in the network topology due to liberalisation (e.g. connection of distributed generation and private networks) and the expected increase in the penetration of offshore renewable energy are typical examples of such drivers for this change. This technical brochure presents a comprehensive study guide to transformer energisation phenomenon.

General issues which are applicable to UK ESI

Transformers may be switched on and off for various reasons. While network transformers are seldom switched, generator transformers may be switched more frequently depending on dispatch requirements. Hence, transformer energisation or re-energisation is a normal planned operation in an electric power system. Sometimes, energising a transformer results in the transformer drawing a relatively large initial inrush current which decays over time to a much smaller steady state magnetizing current. The transient magnetising current that occurs during transformer energisation (the inrush current) is produced by transformer core saturation following switch-on. Consequently, there is a voltage drop across the network impedance and a drop in the line voltages where the effect increases in the direction towards the transformer.

It is shown that the inrush currents depend on the residual flux in the transformer core and the closing instants of the circuit breaker poles. The mechanisms by which the RMS-voltage drop and the temporary overvoltages are generated, in addition to the system conditions under which these phenomena may appear are described. The temporary overvoltages (TOV) during transformer energisation are generated by the interaction of the harmonic components of the inrush currents with the resonances in the system.

A qualitative and simplified representation of the inrush current phenomenon is illustrated in Figure 1 for energisation at voltage zero crossing.

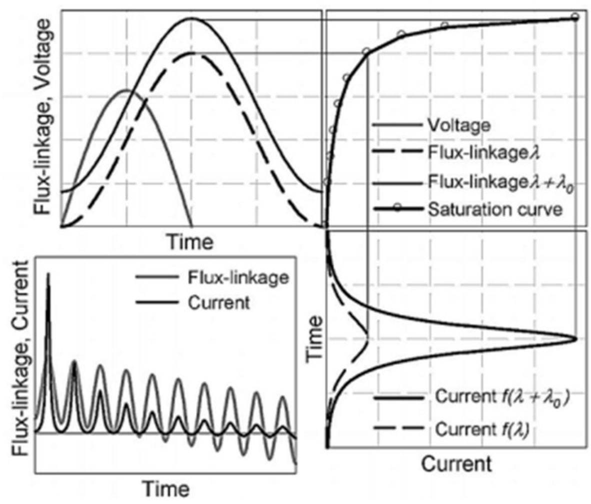

Figure 1 Qualitative representation of the inrush current and the effect of the residual flux.

Extensive information on some useful techniques that can be implemented to mitigate the RMS-voltage drop and/or the temporary overvoltages is also provided. Controlling the closing times of the energising circuit breaker (point-on-wave closing) is the most effective technique identified, since the whole transient can be virtually eliminated: the inrush current, the RMS-voltage drop and the TOV. Among other techniques, reducing the system voltage and/or adjusting the on-load tap before energising the transformer are good ways to reduce the inrush current and its consequences.

This TB provides exhaustive guidelines to simulate both RMS voltage drop and TOV and to assess their probability of exceeding pre-defined levels. Recommendations on modelling the various components while studying transformer energisation are also given. The assessment of the potential damaging effects of the temporary overvoltages are also addressed in the TB. It is shown that, for phase-to-ground TOV lasting a few seconds or less, the surge arresters connected between phase and ground to protect the transformers from switching and lightning surges are generally the most vulnerable equipment. For longer duration TOVs, the most vulnerable equipment to phase-to-ground TOV generally is power transformers.

Temporary overvoltage can have deleterious effects on electronic equipment. It is possible for the effects to be either immediate, as in the case of stress beyond a component's ability to withstand the voltage, or long-term, such as slow degradation brought on by long-term heating. There are different methods to mitigate inrush current and TOV and some of them are more effective than others depend on the application.

A large section of the TB is devoted to the treatment of uncertainty in energisation studies. Regarding the inrush currents, they are highly dependent on two random parameters: the residual flux in the core before the energisation and the circuit-breaker point-on-wave closing times. Due to their dependency on the uncertain parameters, the currents and voltages are not deterministic but rather stochastic variables. Often, however, the user is not interested in the whole distribution of the output but in the risk of exceeding a particular threshold limit, for instance a given RMS voltage drop limit or the equipment overvoltage withstand limit.

Specific issues which are applicable to UK ESI

The phenomenon of “pseudo inrush” can occur during the recovery process following a voltage sag event, such as after the clearance of a fault. This is a phenomenon by which transformers already in operation are driven into saturation after a fault has been cleared and the normal system voltage is restored at the transformer terminals. The process is also interchangeably referred to as “re-energization”. This problem, which is generally more severe in weak systems, may lead to tripping by under voltage and over-current relays.

Furthermore, the phenomenon of sympathetic interaction between transformers is also explained. Whenever a transformer is energised, the asymmetry of the generated inrush currents can drive the nearby already energised transformers into saturation.

Specific issues which are applicable to the wider ESI

The occurrence of TOV is of particular concern during network restoration following a system wide blackout (a highly unlikely event in UK) because, during such times, the network tends to have much lower resonant frequencies and higher impedances as well as less damping due to light loading conditions.

Practical techniques have been described in order for the practising engineers to be able to compute this risk, which in general is the final result of the engineering study.

Other Relevant CIGRE Publications

CIGRE has produced a number of Technical Brochures which will be relevant to those interested in the energisation of transformers, including:

- CIGRE Technical Brochure 568
- CIGRE Brochure 264

Find out more...

Founded in 1921, CIGRE, the Council on Large Electric Systems, is an international non-profit association for promoting collaboration with experts from all around the world by sharing knowledge and joining forces to improve the electric power systems of today and tomorrow.

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