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PAPER

FULL PRE-COMMUTATION CURRENT

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Abstract

In this paper, the author will take a closer look at the peculiarities of the establishment of the entire pre-commutation current that takes place during switching processes in electrical circuits and transient processes that follow. A mathematical model of the current is given, comprising the sinusoid and the aperiodic current, along with the values which define its magnitude: the switching moment, the property of loads and the ratio of R/L. It is demonstrated that current that occurs pre-commutation can easily be greatly higher than nominal currents, posing more thermal and mechanical strain on power-engineering equipment. Graphical dependencies are given that shows the effect of the damping factor as well as the initial switching phase on the waveform and maximum current values. The research points out that full pre-commutation current consideration is a critical factor in the choice of switching equipment and establishing the breaking capacity of circuit breakers.

Key words: pre-commutation current, transient processes, aperiodic component, damping factor, initial switching phase, switching equipment, breaking capacity, mechanical stresses, electrical circuit.

INTRODUCTION

Electrical circuits can be switched, but the process that will always occur is the transient changes, one of which is the pre-commutation current. Its formation is connected with the immediate alteration of the current-carrying conditions resulting in the occurrence of both variable and aperiodic components. The amplitude of the pre-commutation current depends on the switching instant, electrical parameters of the circuit, the R/L ratio, network frequency and the phase state of the load at the time of making or breaking the circuit.[1]

The main peculiarity of the process is that the aperiodic component could significantly rise the high point of the current within the first milliseconds of switching. At some points the pre-commutation current can be significantly greater than nominal, posing significant thermal, dynamic and electromagnetic stresses on power-engineering equipment. This is especially important to high-voltage circuit breakers, transformers, reactors and current-carrying systems, where such currents

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do dictate much of the design parameters and play a central role in evaluating the mechanical robustness.[2]

The practical value of the study and correct determination of the entire pre-commutation current is considerable. Adequate attention to its highest values minimizes the possibility of equipment damages, improves the reliability of switching equipment, provides sufficient performance of relay protection, and improves the stability of the entire power system. The paper gives theoretical backgrounds of current formation in the pre-commutation, gives an analytical form of its representation, and graphical relationships and its practical effect on the operation of electric equipment.

LITERATURE REVIEW AND METHODOLOGY

When you switch power circuits, you inevitably create transients. The system changes too quickly—connecting, disconnecting, clearing a fault, transferring load—and the currents respond. One of the most important of these is the pre-commutation current: the current that appears right after the switching event, during those first few milliseconds. It's almost never a clean sine wave at the start. Instead, you get a mix of a sinusoidal component plus an aperiodic, exponentially decaying offset.[2,3] The result is an asymmetric waveform whose first peaks can be much higher than in steady state.

1) What creates the pre-commutation current

Classic R–L transient theory says any abrupt change imposes initial conditions the steady-state sinusoid can't satisfy immediately. The circuit "makes up the difference" with a DC-offset component. That offset isn't a separate source; it falls out of the differential equation and physically reflects stored magnetic energy in inductors and the fact that current can't jump instantaneously.

In inductive power circuits, current continuity is king. The mismatch between the steady-state current that would exist and the actual current at the instant of switching creates the offset, which then decays with the circuit time constant. In the first milliseconds, the waveform can be strongly asymmetric, and the instantaneous peak can far exceed the nominal current.

2) What sets the magnitude and shape Several coupled factors determine how big and how lopsided that current looks:

- Switching instant and phase (φ): Where on the voltage waveform you close or open changes the initial conditions. Certain angles maximize the DC offset and the first peak.

- Circuit parameters (R and L): The R/L ratio controls how fast the aperiodic part dies out.

- Damping and time constant: Lower R relative to L means slower decay, longer asymmetry, higher peaks.

- Network frequency (f): Sets the steady-state response and the voltage–current phase relationship.

Engineers often use the X/R ratio as a quick severity gauge. High X/R means the DC component decays slowly—so the asymmetric peak can be the limiting factor.

3) Why this matters for equipment

Those transient peaks aren't academic; they drive real stresses:

- **Thermal stress:** Heating scales with i^2, so even short spikes add noticeable thermal load. A common metric is the I^2t integral, $\int i^2\,dt$.

- **Mechanical (electrodynamic) stress:** Forces in conductors and windings also scale roughly with i^2. A brief surge can create large forces on busbars, transformer windings, reactors, and supports.

- **Switching equipment capability:** Breakers must make and break under asymmetric fault currents. Underestimating the first peak risks inadequate interrupting capacity, shortened lifespan, or outright failure.

- **Relay protection and measurements:** Current transformers and protection algorithms may be influenced by DC offset (saturation risk in CT cores), which can lead to delayed tripping or incorrect protection operation if not properly accounted for.[3]

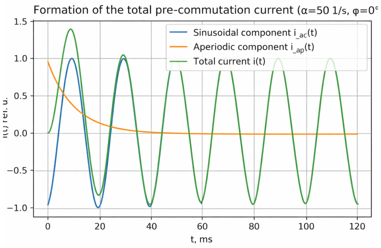

Figure 1. Formation of the total pre-commutation current

This graph illustrates the decomposition of the current into:

$I_{\mathrm{ac}}(t)$ — the sinusoidal (periodic) component,

$I_{\mathrm{ap}}(t)$ — the aperiodic (DC) component decaying exponentially,

The main physical point is that immediately after switching the aperiodic component can shift the waveform and create strong asymmetry, which results in a higher peak current during the first milliseconds.[5] This explains why pre-commutation current may exceed the nominal current significantly, producing increased thermal and electrodynamic stress.

The overall pre-commutation current expression is:

$$I(t) = I_{\mathrm{ac}}(t)\, e^{-\alpha t} \sin(\omega t + \varphi) + I_{\mathrm{dc}}(t)\, e^{-\alpha t}$$

where:

$I_{\mathrm{ac}}(t)$ – amplitude of the sinusoidal component,

$\alpha = \frac{R}{2L}$ – damping factor,

$\omega = 2\pi f$ – angular frequency,

φ – initial phase,

$I_{\mathrm{dc}}(t)$ – aperiodic component.

PRACTICAL SIGNIFICANCE

It is significant to account in the power industry the entire current before the commutation (prior to commutation):

- Switching equipment: correct choice of nominal currents and breaking capacity of circuit breakers.

- Transformers: electrodynamic forces and thermal forces on windings are evaluated.

- Relay protection: proper manipulation of parameters taking into account the aperiodic component.

- Power systems in general: minimization of probability of accidents and enhanced reliability of the network.

RESULTS AND CONCLUSIONS

Experimental experiments and mathematical analysis demonstrates that the character of the pre-commutation current is dictated by the parameters of the circuit (resistance, inductances) and the switching point as well as the phase of the voltage. Thus, to design and operate the modern power systems, there is a need to implement correct calculation procedures, computer modelling, and consider aperiodic component in the process of selecting equipment ratings.

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