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Paper

A Review of Ferroresonance in Capacitive Voltage Transformer

Ab Halim Abu Bakar*[a], Non-member
Shakil Ahamed Khan*, Non-member
Tan Chia Kwang*, Non-member
Nasrudin Abd. Rahim*,**, Non-member

Ferroresonance incidences in electrical power system have been commonly regarded as unexplained phenomenon, which is not critical for utility engineers. As a result, research conducted in this area is limited and the awareness on ferroresonance is relatively low among utility engineers. However, as the electrical system evolves, its complexity increases in line with the increasing risk of ferroresonance. As a result, this paper provides a consolidated review on the research conducted on ferroresonance to highlight its importance. This paper covers the fundamental inductor–capacitor pair for ferroresonance initiation and the modes of ferroresonance, followed by ferroresonance in capacitive voltage transformer (CVT), constituting its impact, initiation, and suppression techniques. The core focus in this paper is ferroresonance in CVT due to switching events, on which the documented literature is very scarce. © 2014 Institute of Electrical Engineers of Japan. Published by John Wiley & Sons, Inc.

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1. Introduction

The power community recognizes that any disturbance in the fundamental power frequency waveforms of voltage and current will pose a danger to the electricity utility's operation. As such, these disturbances have been commonly described as power quality problems with the following definition: 'Any power problem manifested in voltage, current or frequency deviations that result in failure or misoperation of customer equipment' [1]. The main power quality problems include voltage sag, voltage swell, transients, and harmonic distortions. Voltage sag has been given the most attention because of its higher frequency of occurrence as well as the huge financial implications compared to other power quality problems [1,2]. Harmonic distortions are also given special attention because of their implications, which include losses, heating damages, and maloperation of power electronic devices capable of halting the entire processing plant [1,2]. The interest in the rest of the power quality problems is relatively low. However, it must be noted that ferroresonance incidences, which distorts the sinusoidal voltage, are commonly not given sufficient attention in most power quality literature. This explains the relatively low level of awareness among utility engineers on the topic of ferroresonance. Because of the very rare frequency of occurrence, coupled with difficulties in detection, ferroresonance is commonly regarded by utility engineers grossly as transient events due to switching operations, which do not pose any risk to the power equipment. However, several papers have proven otherwise, by establishing a link between equipment failures to ferroresonance [3–7]. As a result, this paper will provide a consolidated review on the research conducted on ferroresonance to highlight its initiation, impact, and suppression techniques. Special attention is paid to ferroresonance in capacitive voltage transformers (CVTs).

Ferroresonance phenomenon in electric power systems were recognized and investigated in numerous technical papers as early as the ?rst decades of the twentieth century [7,8]. The term was first documented by Boucherotin in 1920, describing the unusual coexisting operating points and oscillations in a series circuit with nonlinear inductance [6,9]. It has been extensively analyzed with different approaches, spanning nearly a century of accumulated research, but it still remains a challenge because of the complexity of the factors that can lead to this phenomenon [7]. The occurrence of ferroresonance in electrical power systems can cause energy quality and security problems. Nowadays, the occurrence of ferroresonance is more frequent with the growth, expansion, and complexity of power systems, which can cause subsequent catastrophic damage to electrical equipment affecting the reliability of power networks [10].

According to the ANSI/IEEEC37.100 standard, ferroresonance is de?ned as 'an electrical resonance condition associated with the saturation of a ferromagnetic device, such as a transformer through capacitance' [7]. This phenomenon generally appears on a series circuit consisting of a nonlinear inductor with abnormal, temporary transient behavior. The authors in Refs [9–11] have explained ferroresonance as a jump phenomenon. This phenomenon is characterized by an abrupt jump from one normal steady-state response to another ferroresonance steady-state response due to a small perturbation introduced to a system parameter. Ferroresonance is defined in Ref. [6] as a complex oscillatory interaction of energy exchange between system capacitances and nonlinear magnetizing inductances of ferromagnetic cores. Ferroresonance systems are considered as a nonlinear dynamic system because of the nonlinear nature of this phenomenon, so linear methods cannot be applied to analyze ferroresonance systems [5].

2. Ferroresonance Phenomenon

Ferroresonance can be defined generally as a nonlinear series resonance involving a nonlinear inductor in series with a capacitor

[a] Correspondence to: A. H. A. Bakar. E-mail: a.halim@um.edu.my

* UM Power Energy Dedicated Advanced Centre (UMPEDAC), University of Malaya, Level 4, Wisma R&D, Jalan Pantai Baharu, 59990 Kuala Lumpur, Malaysia

** King Abdulaziz University, Jeddah 21589, Saudi Arabia