

# Chapter 14

## Differential Protection Enhancement for Power Transformer

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### **ABSTRACT**

*A power transformer is protected against internal faults using a differential protection which is sensitive and a fast. However, during transformer magnetization (inrush current or over-excitation), the differential relay may operate unnecessarily. This phenomenon appears only when a transformer is first energized or after clearing external fault. During periodic magnetization condition due to over-excitation, the third and fifth harmonic components are largely noticed; however, during the normal aperiodic inrush conditions, the second harmonic is relatively high. In the conventional techniques, these harmonic components have been used to block differential protection to operate. However, in smart power transformer, these harmonic components are small even during the transformer magnetization; they cannot be used as block protection functions. The differential protection security has to be improved so that it can distinguish between differential current produced by magnetization and that produced by internal fault using the most advanced computer with most improved DSP algorithms.*

### **INTRODUCTION**

Power transformer is one of the most important elements in the power systems. Therefore, the protection of power transformers is crucial for the continuity of the power supply. A power transformer is mostly protected against internal faults using a differential protection which is sensitive and a fast clearing technique (Abdelmoumene, A. and Bentarzi, 2012). This technique of protection detects nonzero differential current, and then activates a circuit breaker that disconnects the power transformer. However,

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this nonzero differential current may be produced by transformer magnetization, due to so called inrush current or over-excitation, and may cause the relay to operate unnecessarily. This magnetization current is a transient current that appears only when a transformer is first energized or after clearing external fault. Even though, it can be as great as 8 times the full load current and it contains harmonic components, however, it is harmless due to rapidity. During periodic magnetization condition due to over-excitation the third and fifth harmonic components are largely noticed; however, during the normal aperiodic inrush conditions, the second harmonic is relatively high.

Differential relays are prone to mal-operation in the presence of transformer inrush currents. Inrush currents are produced from transformer magnetic flux (Sonnemann W.K., et al, 1958). The first solution to this problem has been investigated by introducing an intentional time delay in the differential relay. Another proposal has been performed by desensitizing the relay for a given time, to overcome the inrush condition (Kennedy L. F. and Hayward C. D. 1938; Hayward C. D., 1941). Others have suggested adding a voltage signal to restrain (Guzman, A. and Zocholl, S., 2001). Much work has been conducted in making the protective relays recognize the difference between overcurrents at a fault and a magnetizing inrush current (Meckic, F., et al, 2006; Kasztenny B. and Kezunovic M., 1998).

This book chapter motivation is the presentation of the recent developed blocking techniques of differential protection during inrush conditions. This is following a number of questions that has been arisen while applying differential relays for transformer protection. Protection of large power transformers is a very challenging problem in power system relaying. Large transformers are a class of very expensive and vital components of electric power systems. Since it is very important to minimize the frequency and duration of unwanted outages, there is a high demand imposed on power transformer protective relays; this includes the requirements of dependability associated with mal-operation, security associated with no false tripping, and operating speed associated with short fault clearing time (Bouderbala R., Bentarzi, H. and Ouadi A., 2010).

This research will analyze the problem and its effect on transformer differential protection. Since the magnetizing inrush current generally contains a large second harmonic component in comparison to an internal fault, conventional transformer protection systems are designed to restrain during inrush transient phenomena by sensing this large second harmonic. However, the second harmonic component may also be generated during internal faults in the power transformer (Manana, M., et al, 2005). This may be due to current transformer (CT) saturation, presence of shunt capacitance, or the capacitance in long extra high voltage transmission lines to which the transformer may be connected. The magnitude of the second harmonic in an internal fault current can be close to or greater than that present in the magnetizing inrush current (Bouderbala R., et al, 2011). The second harmonic components in the magnetizing inrush currents tend to be relatively small in modern large power transformers because of the improvements in the power transformer core material. The commonly employed conventional differential protection technique based on the second harmonic restraint will have difficulty in distinguishing between an internal fault and the inrush current thereby threatening transformer stability (Bouderbala R., Bentarzi H., 2013). This chapter presents an approach proposed by (Bouderbala, R., Bentarzi, H., 2016) that uses two harmonics (second and fourth) for restraining or blocking a differential relay and reducing the blocking time during an internal fault. Besides, it suggests a further work for protecting a smart transformer

Three characteristics generally provide means for detecting transformer internal faults. These characteristics include an increase in phase currents, an increase in the differential current, and gas formation. When transformer internal faults occur, immediate disconnection of the faulted transformer is necessary to avoid extensive damage and preserve power system stability. Three types of protection are normally

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