Chapter 9

Loss of Excitation Protection of Medium Voltage Hydro Generators Using Adaptive Neuro Fuzzy Inference System

Mohamed Salah El-Din Ahmed Abdel Aziz
Dar Al-Handasah (Shair and Partners) – Cairo, Egypt

Mohamed Ahmed Moustafa Hassan
Cairo University, Egypt

Fahmy Bendary
Benha University, Egypt

ABSTRACT

This chapter presents a new method for loss of excitation (LOE) faults detection in hydro-generators using adaptive neuro fuzzy inference system (ANFIS). The investigations were done under a complete loss of excitation conditions, and a partial loss of excitation conditions in different generator loading conditions. In this chapter, four different techniques are discussed according to the type of inputs to the proposed ANFIS unit, the generator terminal impedance measurements (R and X) and the generator terminal voltage and phase current (Vtrms and Ia), the positive sequence components of the generator terminal voltage magnitude, phase current magnitude and angle (V+ve, I+ve and I+ve) in addition to the stator current 3rd harmonics components (magnitudes and angles). The proposed techniques’ results are compared with each other and are compared with the conventional distance relay response in addition to other techniques. The promising obtained results show that the proposed technique is efficient.
INTRODUCTION

Loss of Excitation is a very common fault in synchronous generators. It happens due to short circuit of the field winding, unexpected field breaker open or Loss of Excitation relay incorrect-operation. According to the statistics, the generator failure due to Loss of Excitation represents about 69.5% of all generator failures as described in (Wang, 2002; Shi, 2010). Loss of Excitation causes severe damages to the generator and the system. When a generator loses its excitation, it overspeeds and operates as an induction generator. It continues to supply power to the system and receives its excitation from the system in the form of reactive power, as such; the stator may suffer over heating because of this large current. On the other hand, for the system; its voltage will be reduced after the generator loses its excitation, since the generator operates as an induction generator and absorbs reactive power from the system. For a weak system, the system voltage possibly will collapse due to the Loss of Excitation condition as described in (Ghandhari, 2008). Moreover, when a generator loses its excitation, the rest of generators in the system will boost their reactive power output. This might cause overloading to the transmission lines or transformers and the over-current protection may consider this overloading as a fault and trip the power system (Benmouyal, 2007; Paithankar and Bhide 2003; Blackburn and Domin 2015; Mozina et al. 2008; Ebrahimi and Ghorbani 2016; Mozina, 2010). The above reasons motivated this research work to propose an advanced solution for this problem.

The most widely applied method for detecting a generator loss of excitation condition is the use of impedance relays to sense the variation of impedance as viewed from the generator terminals. A two-zone impedance relay approach is generally used within the industry to provide high speed detection. Figure 1 shows this impedance approach as adopted from (NERC, 2008). It consists of two impedance circles. The first impedance circle (zone 2) diameter equals to the generator synchronous reactance (Xd) and offset downward by half of the generator transient reactance (Xd'/2). The operation of this element is delayed approximately 0.5 s and is used to detect loss of excitation conditions during light loading conditions. The second impedance circle (zone 1) is set at a diameter of 1.0 per unit (on the generator base), with the same offset of half of the generator transient reactance. This zone is delayed approximately 0.1 s and is used to detect loss of excitation conditions during heavy loading conditions (Vancouver and Mozina 1995).

This impedance relay was developed to provide improved selectivity between Loss of Excitation conditions and other normal or abnormal operating conditions. This relay confirmed its capability of detecting some of the excitation system failures. But some few cases of incorrect operation that have occurred due to incorrect relay setting, blown potential transformer fuses have initiated user’s worry about the performance of this type of relaying for loss of excitation protection. In addition, the performance of this impedance relay is found to be time delayed and is depending on the generator loading conditions and the percentage loss of excitation in the detection process (Benmouyal, 2007; Patel et al. 2004). Moreover; some loss of excitation cases are not detected by these impedance relays. As a result, widespread studies were recently proposed to overcome the problems associated with the performance of this relay. Therefore, several techniques and schemes have been recently proposed to enhance the generators Loss of Excitation relay performance. Some of these techniques are arranged historically and are based on:

- Artificial Neural Network (Sharaf and Lie 1994).
- Time-Derivatives of Impedance (Tambay and Paithankar 2005).
- Fuzzy Inference Mechanism (De Morais et al. 2010).