Applications of ANFIS in Loss of Excitation Faults Detection in Hydro-Generators

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ABSTRACT

This article presents a new methodology for Loss of Excitation (LOE) faults detection in Hydro-generators using Adaptive Neuro Fuzzy Inference System. The proposed structure was trained by data from simulation of a 345kV system under different faults conditions and tested for various loading conditions. Details of the design process and the results of performance using the proposed technique are discussed in the article. Two different techniques are discussed in this article according to the type of inputs to the proposed ANFIS unit, the generator terminal impedance measurements (R and X) and the generator RMS Line to Line voltage and Phase current (Vtrms and Ia). The two proposed techniques results are compared with each other and are compared with the traditional distance relay response in addition to other techniques. The results show that the proposed Artificial Intelligent based technique is efficient in the Loss of Excitation faults (LOE) detection process. The obtained results are very promising.

KEYWORDS

Adaptive Neuro Fuzzy Inference System, Discrete Fourier Transform, Dynamic Performance, Hydro-Generator, Loss of Excitation, Simulation

1. INTRODUCTION

Synchronous machines suffer from a very common fault which is a Loss of Excitation (LOE) fault. It is usually can be caused by short circuit of the field winding, unpredicted field breaker open or Loss of Excitation (LOE) which triggers relay mal-operation. According to the statistics in China, the generator failure due to Loss of Excitation (LOE) accounts for 69.5% of all generator failures as discussed in (Weijian 2002; Shi 2010). Loss of Excitation (LOE) may originate severe damages to both generator and system. For the generator; when Loss of Excitation (LOE) happens, a slip occurs which may cause rotor over heating due to the slip frequency in rotor circuits. Also, as the synchronous machine runs as an induction machine after Loss of Excitation (LOE) conditions, large amount of reactive power supplied by stator current is required and the stator may suffer over heating due to this large current. On the other hand, for the system; its voltage drops after the generator loses its excitation, because the synchronous generator operates as an induction machine and absorbs reactive power from the system. For some weak system, the system voltage may collapse due to the Loss of Excitation (LOE) of an important synchronous generators discussed in (Elkington et al. 2008). Also, when a generator loses its excitation, other synchronous generators in the system will increase their reactive power output. This may represent a source of the overloading in some transmission lines.
or transformers and the over-current relay may consider this overloading as a fault and isolate the non-fault equipment as presented in (Benmouyal 2007; Kundur 1994; Paithankar and Bhide 2010; IEEE Std 2006; Blackburn and Domin 2014; Elmore 2003; Reimert 2005; Mozina et al. 2008; Patel et al. 2004; Ebrahimi and Ghorbani 2015). These above reasons motivate this research work to solve for this dilemma.

1.1. Literature Review

In 1949, a single phase offset mho relay was introduced for the high speed detection of Loss of Excitation (LOE) in synchronous generators. This distance relay approach was developed to provide improved selectivity between Loss of Excitation (LOE) conditions and other normal or abnormal operating conditions and to provide the operating times necessary for optimum protection of both the generator and the system (Berdy 1975). Over the years, the offset mho relay has been widely accepted for loss of excitation protection and experience with the relay has been accepted. The relay has demonstrated its capability of detecting a variety of excitation system failures and to discriminate between such failures and other operating conditions. The relatively few cases of incorrect operation that have occurred can be attributed to incorrect relay connections (major cause), and blown potential transformer fuses. In spite of this accepted experience, there has been some user worry about the performance of distance type of relaying for loss of excitation protection. In particular, there has been concern over possible incorrect operation of the relay when operating the generator in the underexcited region, during stable transient swings and during major system disturbances that cause under frequency conditions. In view of this continuing concern over relay performance and in view of the fact that machine parameters have changed appreciably during the past twenty years, a general study was initiated to review the application and the performance of the offset mho Loss of Excitation (LOE) relay for a variety of system conditions. Therefore, many techniques and optimization algorithms have been addressed as a solution to the generators Loss of Excitation (LOE) problem such as:

- ANN based technique (Sharaf and Lie 1994);
- Adaptive or dynamic Loss of Excitation based relay (Tambay and Paithankar 2005);
- Fuzzy inference mechanism based technique (De Morais et al. 2010);
- Adaptive loss of excitation protection relay based on the steady-state stability limit (Liu et al. 2013);
- Technique based on the derivative of the terminal voltage and the output reactive power of the generator (Amini et al. 2015).

From this point, the need for this research article appeared when the shortage of Loss of Excitation (LOE) conventional relays became visible. As these conventional relays behavior to different Loss of Excitation (LOE) conditions is totally depending on the generator loading and the percentage loss of excitation and many loss of excitation (LOE) conditions are not detected by these conventional relays. So it becomes essential to overcome these problems by developing Artificial Intelligent (AI) based relay.

1.2. Description of the Article

This article suggests two recent optimization algorithms based on Artificial Intelligence (AI) techniques. The two different techniques discussed in this article classified based on the type of inputs to the proposed ANFIS unit, the generator terminal impedance measurements (R and X) and the generator RMS Line to Line voltage and Phase current (V_{rms} and I_{a}). The two proposed techniques results are compared with each other and are compared with the conventional distance relay response in addition to other techniques. The results show that the proposed Artificial Intelligent (AI) based techniques are efficient in the Loss of Excitation faults (LOE) detection process. The obtained results...
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