Electrical Power and Energy Systems 33 (2011) 861–867

Contents lists available at ScienceDirect

Electrical Power and Energy Systems

journal homepage: www.elsevier.com/locate/ijepes

Adaptive load blinder for distance protection

Hassan Khorashadi Zadeh [a,*], Zuyi Li [b]

[a] Siemens Energy Inc. Transmission Division, 7000 Siemens Road, Wendell, NC 27591, United States
[b] Illinois Institute of Technology, Department of Electrical and Computer Engineering, 3301S. Dearborn Street, Chicago, IL 60616, United States

ARTICLE INFO

Article history:
Received 2 August 2009
Received in revised form 26 September 2010
Accepted 22 November 2010

Keywords:
Distance relay
Load blinder
Load encroachment
Loadability
Blackout
Artificial neural network

ABSTRACT

This paper proposes a novel adaptive load blinder for distance protection. A distance relay can provide remote backup protection by zones 2 and 3, but it may mal-operate under heavy loading conditions and cause cascading trips in the network, which could further lead to a widespread blackout. To prevent cascading outages, load blinders or load encroachment elements are generally used to block the distance relay when there is heavy load in the system. However, these elements are not always able to discriminate heavy loading conditions from fault conditions, especially for heavy loads with low power factors or faults with fault resistance. This paper presents a novel load blinder scheme for distance protection by using artificial neural network (ANN). Test results show that the proposed ANN-based load blinder scheme is able to discriminate between different heavy loads with a wide range of power factors and different faults with fault resistance.

1. Introduction

Transmission line protection is the most elaborate and challenging function in power system protection. About two thirds of faults in power systems occur on the transmission line network. Consequently, it has received extensive attention from the researchers and designers in the area of power system protection.

Distance protection is the most common transmission line protection. Zone 1 of a distance relay is used to provide primary high-speed protection of a significant portion of a transmission line. Zone 2 is used to cover the rest of the protected line and provide some backup for the remote end bus. Zone 3 is the backup protection for all the lines connected to the remote end. The impedance of loads can be actually less than the impedance of some faults in very long and heavily loaded transmission line applications. This phenomenon may cause distance relays to mal-operate.

Studies of several large blackouts during the past decades indicate that backup zones of distance relays are involved in most of the major blackout incidences, such as the Northeast Blackout on November 9, 1965 [2], the New York City Blackout on July 13, 1977 [3], the West Coast Blackout on July 2, 1996 [4], the West Coast Blackout on August 10, 1996 [4], and the Northeast Blackout on August 14, 2003 [5].

Many of the operations of zone 3 of distance relays, during major disturbances, were caused by line overloading conditions [1]. The undesired operation of zone 3 distance relays caused by line overloads is the most obvious distance relay characteristics that have been widely discussed after the August 14, 2003 blackout [6–8]. Because zone 3 distance relay operations (or other overreaching zone operations) have contributed to the severity of blackouts, a lot of efforts have been placed into reviewing their settings and developing loadability requirements and standards. The protection relays must be made selective enough to discriminate between load and fault conditions. Difference between loads and unsymmetrical faults can be detected by unbalance conditions. However, it is more difficult to discriminate between heavy loads and three-phase faults. One solution is to use lenticular or elliptical shape characteristics for load rejection. Unfortunately, these characteristics reduce the fault-resistance coverage [9]. Another solution is to use additional comparators to make blinders parallel to the transmission line characteristics. However, it will limit the impedance plane coverage thus exclude load from the tripping characteristics [10]. All traditional solutions are based on the same idea: to shape the operating characteristics of the relay to avoid or minimize load encroachment. The traditional solutions have some disadvantages:

- Reducing the size of the relay characteristics desensitizes the relay to faults with resistance [11]. Notice that some symmetrical faults as shown in Fig. 1 with fault resistance can affect the impedance measured by distance relay.
- Avoiding a small area of load encroachment often requires the sacrifice of much larger areas of fault coverage [11].

* Corresponding author. Tel.: +1 3125196976.
E-mail address: hassan.zadeh@siemens.com (H. Khorashadi Zadeh).

0142-0615/$ - see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.ijepes.2010.11.012

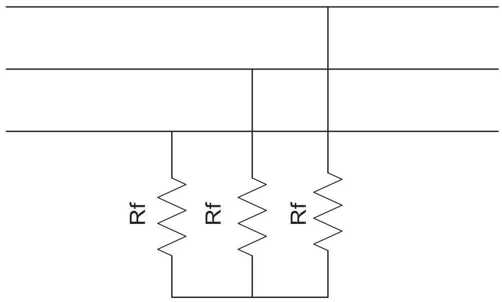

Fig. 1. Symmetrical fault with fault resistance.

- Power factor may not always be a sure indicator that a load rather than a fault exists on the line [1] if significant amounts of VARs are being transmitted under unusual system conditions.

Protection relaying is just as much a candidate for the application of pattern recognition techniques. The majority of power system protection techniques involve the definition of system states through identifying the pattern of the associated voltage and current waveforms measured at the relay location. This means that the development of adaptive protection can be essentially treated as a problem of pattern recognition or classification, for which artificial intelligence (AI) based techniques are powerful. AI possesses excellent features such as generalization capability, noise immunity, robustness, and fault tolerance. Consequently, the decision made by an AI-based relay will not be seriously affected by variations in system parameters. AI-based techniques have been used in power system protection and encouraging results have been obtained [12–15].

In this paper, a new scheme is proposed for designing an accurate and reliable load blinder. The proposed scheme is based on artificial neural network (ANN). Various power system scenarios are modeled and an ANN based algorithm is used for the recognition of these patterns. Performance of the proposed scheme is evaluated under various conditions and encouraging results are obtained. It is shown that the algorithm is able to perform correctly for different combinations of conditions, e.g., fault resistances, fault locations, pre-fault power flow directions, source impedance ratios, and load power factors.

The rest of the paper is organized as follows. Section 2 presents the structure of the proposed ANN-based load blinder. Test results of the proposed scheme are demonstrated in Section 3. Section 4 concludes the paper.

2. The proposed neural network based load blinder

The structure of a distance relay with the proposed load blinder is shown in Fig. 2. In this scheme, a conventional three-zone distance relay is used to detect faults. To prevent the second and the third zones from undesired trip due to heavy load, an ANN-based load blinder is used. Load blinder will be activated only when the condition is balanced. By using suitable functions of voltage and current as inputs, the load blinder is able to discriminate between faults and heavy loads and accordingly block distance relay operation during heavy loads [16].

2.1. Balancing condition check

A heavy load can be considered as a balancing condition. Therefore there is no loadability concern if a condition is unbalanced, such as an unbalance fault (single phase, phase to phase). To detect balancing conditions, the negative-sequence current is compared

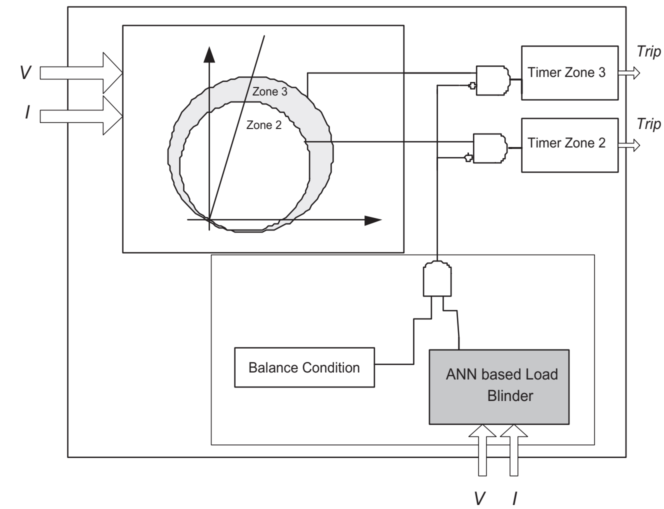

Fig. 2. The structure of the proposed scheme.

with a threshold (0.1 p.u. on a base of 1500 A in this paper). A condition is detected as a balancing condition if the negative-sequence current is less than the threshold.

2.2. ANN-based load blinder

The block diagram of the proposed ANN-based load blinder scheme is shown in Fig. 3. The details are discussed as follows.

2.2.1. Preprocessing

The input current and voltage signals to the preprocessing module are sampled at 1 kHz. A 2-sample FIR digital filter removes the dc component, which enhances the training capabilities of the ANN. Next the full cycle discrete Fourier transform (DFT) algorithm is applied to obtain the phasors (including magnitudes and angles) of voltage and current signals. The preprocessing stage can significantly reduce the size of the neural networks based classifiers, which in turn improves the performance and speed of the training process [17].

2.2.2. ANN inputs

One of the keys to the success of any ANN application is the choice of input signals. After analyzing different factors such as current and voltage magnitudes, impedance, change rate of voltage, current, and power, we have chosen active power, reactive power, voltage, the change rate of phase A voltage, and the change rate of phase A current as input signals to ANN. The change rate of voltage and current are defined as follows:

$$\Delta I_A = I_A(n) - I_A^*(p) \tag{1}$$

$$\Delta V_A = V_A(n) - V_A^*(p) \tag{2}$$

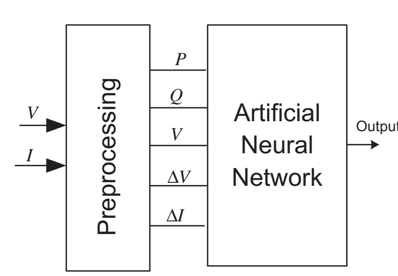

Fig. 3. The structure of ANN-based load blinder.