Technological Use of Artificial Neural Network (ANN) for Fault Location and Fault Detection in DC Microgrid System

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Abstract

Power electrical devices in DC microgrids may experience over current during short circuit breakdowns. An appropriate protection approach on DC lines is essential as high fault currents cannot be supported by DC bus systems. This study describes a novel application of artificial neural networks (ANN) for low-voltage DC bus fault identification and detection with the help of Microgrid technology. The suggested technique allows for quick failure detection and isolation on DC buses without completely shutting down the system, leading to a more reliable DC microgrid. To confirm its validity, the neural network is trained using various DC bus short circuit faults. In this proposed design, a microgrid with a ring DC bus that is divided into overlapping nodes and connected by circuit breakers is constructed. Finally, the entire design has been simulated using authentic software (PSCAD) which gives a satisfactory result.

Keywords: *ANN, PSCAD/EMTDC, Microgrid, Short Circuit fault, Fault detection, Fault Location*

1. Introduction

The conventional power system is currently being expanded to include numerous renewable energy sources and energy storage technologies [1]. However, the widespread adoption of distributed generations may provide difficulties. Voltage increase, frequency swings, and protection issues, to conventional power generation and distribution systems [2]. As a result, the microgrid, which is a low voltage system with generating and energy storage devices that meets local demand for electricity, is gaining popularity [3]. Numerous earlier studies looked into the use of AC microgrids. However, it has been demonstrated that DC microgrids have a number of advantages over AC microgrids. First of all, DC power sources like batteries and solar panels are largely incorporated into AC microgrids, where a lot of converters are required, which necessitates a significant investment in power conversion systems. Additionally, power conversion is required for micro AC power supplies that differ in voltage or frequency from those of utility grids [4]. In a DC microgrid, compared to an AC system, fewer power converters are needed, which leads to improved efficiency and less investment [5]. Secondly, there is no need for synchronized, and DC microgrid does not lose reactive power or harmonics. The DC microgrid system is also more suited to a straightforward and effective power electrical interface [6-7]. Building a DC transmission network in a microgrid to link distributed power sources and loads has thus emerged as a new area of study. Although DC microgrids have several benefits, protecting them still presents certain difficulties [8-9]. In general, it is challenging to identify the defect prior to isolation and to obtain pertinent data for fault identification [10]. The detection and location of DC bus faults are the main topics of this research. Rapid fault identification and detection using fault current or transient voltage signals is crucial in a protective mechanism. Because of its accuracy, resilience, and speed, the ANN-based method is one of the most effective methods for fault detection and fault placement on AC grid and HVDC systems, as shown in [11–13]. To the best of the authors' knowledge, no published study has addressed the use of ANN for DC microgrid protection. Therefore, this research introduces a defect detection and fault localization approach based on artificial intelligence (AI) for a DC microgrid system. In PSCAD/EMTDC, a DC microgrid is constructed to simulate the DC system in both steady-state and transient circumstances in order to study the fault profile and create a training set for ANN. The test network is used to study various fault kinds, fault resistances, and fault sites. For fault location and detection, respectively, two neural networks are set up. The faulty portion will be isolated, while the remainder of the system will continue to function. The simulation results demonstrate how accurately the suggested strategy performs.

2. Description and Modeling of the System

Figure 1 depicts the general layout of a typical DC microgrid, which primarily consists of four components: a wind power generation system, an energy storage system, loads, and an AC main grid connection. The wind turbine is utilized as a standard form of grid-connected distributed generating. A simple model is used to create wind turbines that function as a typical distributed generation system in [14]. To maximize wind energy capture, the converter station is run in maximum power point tracking (MPPT) mode [15]. Based on the process given in the reference [16], a simulation of the DC battery energy storage with the bidirectional DC/DC converter was performed and used as an energy storage unit in this study. The power supply for the charging statues or as a backup. However, to maintain stable and consistent operation of the DC voltage during island operation, battery energy storage is used as a slack bus. DC loads are connected directly to DC microgrid is connected to the grid via a DC/DC converter, while AC loads are connected via a VSC converter. The load shedding control approach will be used when the power supply is insufficient to maintain power balance. By using a VSC converter with bi-directional power flow, the DC microgrid is integrated into the primary AC grid [17]. The active power balancing is maintained when the DC microgrid network is running normally by controlling the DC voltage through the VSC converter. However, VSC will lose the stability of managing DC voltage and instead limit the current during the AC voltage drop brought on by a short circuit failure. DC systems can use a variety of topologies, including general topologies, central-ring topologies, radial topologies, and ring topologies. In this paper, a DC microgrid with a ring topology is chosen. This type of topology is more adaptable and durable, even though the investment will increase owing to the growth of the DC transmission line length and capacity, which leads to the expansion of the number of circuit breakers. To maintain steady operation with no power losses during a DC line fault, the circuit breakers function and cut the fault at both ends of the line.

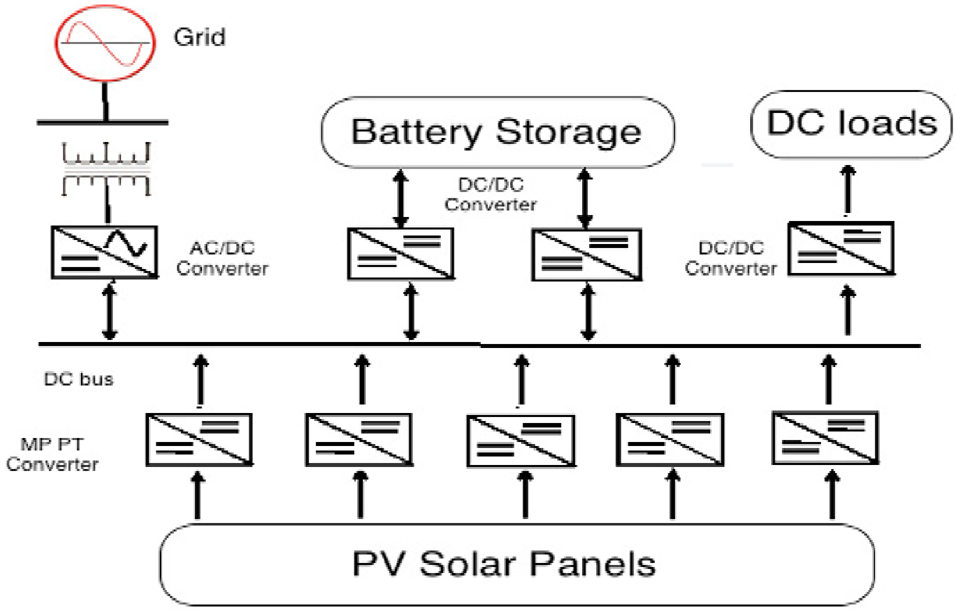

Figure 1. DC Microgrid

The DC lines of other segment will boost its transmission capacity. Consequently, the ring topology can utilize DC microgrid's benefits for optimum networking.

3. ANN based methodology for fault detection and fault location

The pole-to-pole fault and the pole-to-ground fault are the two fault types considered by the fault detection method in DC systems. In general, pole-to-pole fault is a type of permanent fault that is brought on by external mechanical force. Pole-to-ground fault, a type of transient fault brought on by a branch fall or lightning, occurs frequently. The right line protection technique helps to minimize system loss and prevent damage to the entire DC system. It is important to consider the system's post-fault recovery capability and protective techniques. Low voltage direct current (LVDC) systems for power systems are a more recent idea than high voltage direct current (HVDC) systems [10]. In the event of a fault, a complete path will develop through the VSC's antiparallel diode, allowing the converter station to discharge active power to the fault location. This could result in an overcurrent on a DC bus, a very high value transmission line, and a shift in the current's direction. Figure 2 depicts the basic architecture of the simulated system. At both ends of the line, DC circuit breakers are installed in order to quickly break the fault, which is important for DC fault isolation. It is easy to see the current direction before and after the fault. The current is flowing in various directions on different faulty segments.

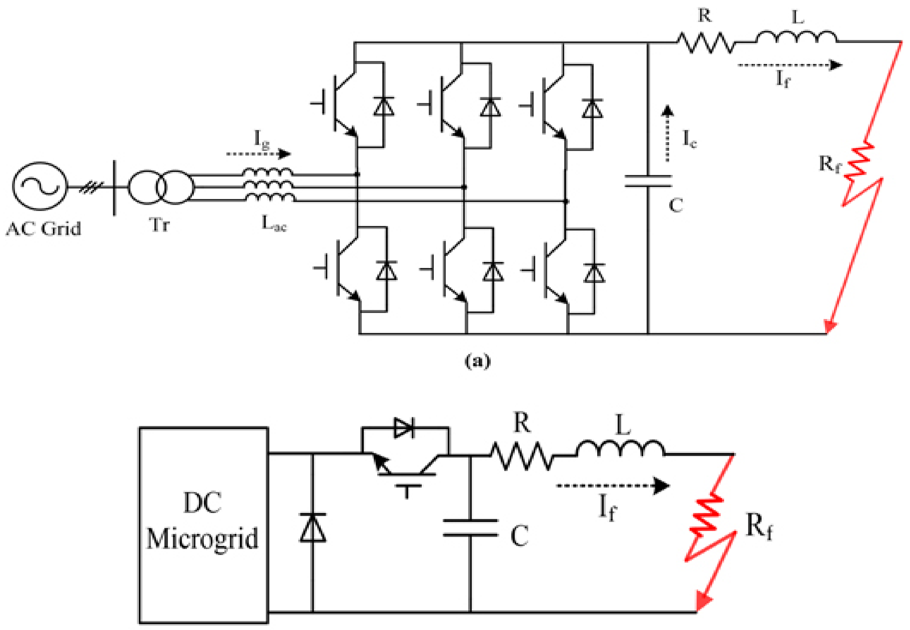

Figure 2. Current Direction of Short circuit fault condition

The required information regarding the various power system conditions is provided by the current signal (figure 3). A defect causes the currents on each terminal to rapidly climb to very large values, which could seriously harm the electrical devices. Additionally, it can be seen that, depending on the fault location and fault resistance, the fault current's magnitude varies. Figure 3 illustrates how the peak magnitude and the current increase's slopes differ. The same fault location appears to have the same rate of current rise, it can be deduced. As a result, the planned ANNs employ the current signals at both ends of the wire as inputs.

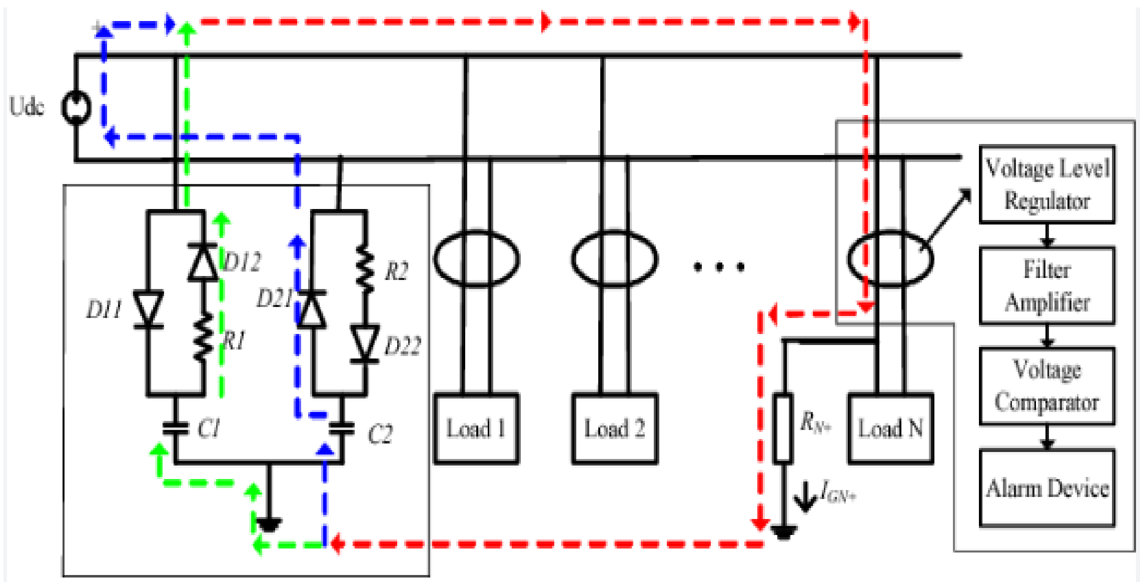

Figure 3. DC Current Fault Detection Circuit

The built ANN modules for fault identification and detection on the bus segments of the simulated system are shown in Figure 4. The machine learning algorithm will aid the system in making a wise decision. Determining whether a defect exists or not and where it is located.

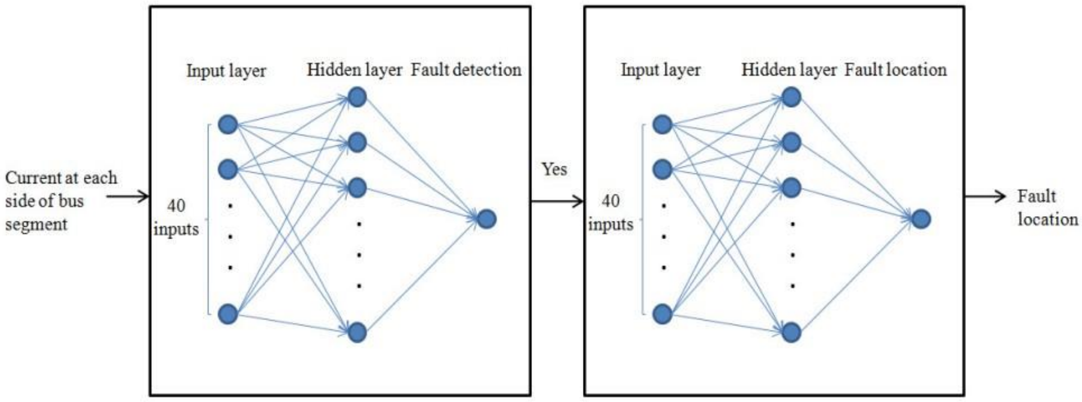

Figure 4. Model of Artificial Neural Network (ANN)

As seen in the DC fault analysis, samples of the collected current waveforms signals. Hence in the protection scheme, there are two ANNs are designed. Using the identical input data, one ANN will detect the fault, and the other will locate the defect on the dc bus segments. Circuit breakers are used to isolate the bus segment after faults are detected.

4. Result of Simulation Test

Using PSCAD / EMTDC as a simulator platform, simulation is done based on the DC microgrid model mentioned above. Wind turbines, battery energy storage, loads, and the AC grid all have respective power in network values of 22 kW, 10 kW, 30 kW, and 18 kW. On the DC bus segment between the wind turbine and the AC grid, the fault is set at 1.5 seconds and 0.01 seconds. Figure 5 displays the current information gathered from each terminal of the bus segments. The sudden increase in current and the shift in positive/negative value were clearly seen through the simulation.

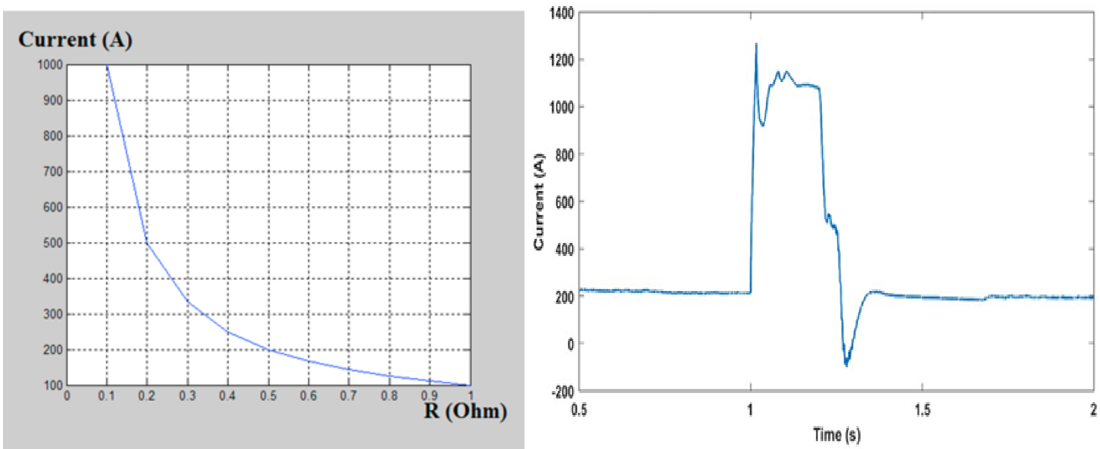

Figure 5. DC Current on Transmission Line

Signals are acquired at a sampling rate of 5 kHz, and 20-sample current data windows are collected on either side of the source and used as ANN input. Thus, the neural network in figure 4's constructed ANN receives 40 input vectors. For neural network training, several cases are considered, including the circumstance in various fault locations and fault resistances. 20 samples of instances are selected for data training that have fault locations of 10%, 30%, 50%, 70%, and 90% in each bus segment and fault resistances of 0.1 ohm, 0.5 ohm, 1 ohm , 2 ohm, and 10 ohm.2250 cases are used to train the fault detection and location.

Table 1. Results of ANN method

Fault Type	Fault resistance	Fault location	Measured location	Error
Pole-to-pole	0.7	56%	55.32%	0.68%
Pole-to-ground	0.65	78%	78.09%	0.09%
Pole-to-pole	2.5	25%	25.25%	0.25%
Pole-to-ground	6	47%	46.84%	0.16%
Pole-to-pole	1.2	89%	88.82%	0.18%
Pole-to-ground	0.25	11%	11.03%	0.03%

The outcomes are shown in table 1. As a result, problems can be accurately and completely recognized on every bus segment using the proposed ANN. Circuit breakers at the terminals will quickly isolate the fault on each segment with reliable detection. Additionally, a 1% inaccuracy in fault location can be found.

5. Conclusion

This research work represents a defect detection and fault localization approach based on artificial neural networks. In PSCAD/EMTDC, a detailed simulation of the DC microgrid, including the wind turbine, battery energy storage system, loads, and AC grid, is performed. The proposed method uses DC current signals as inputs to identify problems in the modelled system. The outcomes showed that every form of DC issue may be quickly and accurately recognized. The defect site can also be found with a 1% error. After having a look in the simulation result, this ANN-based approach regarding DC microgrid can be considered well and it is expected that it will be very effective in real life application.

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