Role of Soft Computing Techniques in Fault Detection of Switches in Multilevel Inverter

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Abstract

A Multilevel Inverter (MLI) with an advantage of low Total Harmonic Distortion (THD) is appropriate for the grid integration of solar photovoltaic power plants but the high number of switches makes them prone to failures affecting their reliability. In this paper a comprehensive outlook of fault diagnosis methods to increase the reliability are discussed. Based on the literature survey, an outlay of fault diagnosis using various soft computing techniques are briefly studied and an attempt is made to identify appropriate technique based on high convergence speed, low training time and less requirement of memory.

Key Words: Quantitative approach, Qualitative approach, Fast Fourier Transform, Wavelet Transform, Discrete Wavelet Transform, Back-Propagation, Particle Swarm Optimization.
The number of solar photovoltaic power plants throughout the world has increased due to the concern of increasing carbon footprint in environment. These solar plants require the connection of grid and one of the most important specifications for grid synchronization is reduced amount of Total Harmonic Distortion (THD).

In literature it has been proved that compared to conventional full bridge inverter, MLI such as Diode Clamp MLI (DCMLI) [1], Flying Capacitor MLI (FCMLI) [2], and Cascaded H-Bridge MLI (CHBMLI) [3] have a low THD value. The main concern about the MLI are the number of switches utilized to have low THD which makes the controlling aspect more complicated and the fact that the warranty period of solar PV cell is 2.5 times the inverter in micro inverters [4] and the survey made in [5, 6] it is shown that in any system power electronic switches are more susceptible to failure due to many factors such as environment in which it operates thus reducing the reliability of MLI. In literature the control aspect of MLI is extensively studied and this paper emphasis on the reliability aspect. The block diagram of PV based Micro grid is shown in Fig.1

![Fig. 1. Asymmetric multilevel inverter for PV Power Injection into Micro grid](image)

An occurrence of fault in one switch it can shut down the whole conventional inverter units. The usage of MLI can solve this problem by reconfiguration so that an m-level MLI can operate as n-level MLI (m>n). The [7] has used a combination of half bridge two level inverter, a three level Diode Clamped Multilevel Inverter and a bidirectional switch. This topology was used to maintain the voltage level during fault condition operating as a 3-level inverter instead of 5-level inverter. The similar work for different configurations has been carried out in [8, 9, 10].
In [11] it has been proved that if the fault diagnosis and reconfiguration is incorporated in the MLI then reliability of three phase cascaded MLI has increased from 86% to 99%. The most important requirement of the technique is to detect the faulty switch so that it can eliminate from the switching circuit and either troubleshooting or replacement can be done. The following sections provide a brief explanations on methodology used for fault diagnosis.

2 Fault Detection Techniques

In [13] the methodology of fault detection is broadly classified as

2.1. Quantitative Approach

In this approach the parameters are measured and compared with parameters of a reference model and the corresponding conclusion is obtained. This approach requires immense knowledge and behavior of system and difficult for many nonlinear systems. In [14] the abnormal variation of DC bus bar is used to detect fault. In [15] the parameter used is normalized mean voltages method for model reference. This approach is difficult for complex nonlinear system since accurate mathematical models are not available resulting in large modeling errors.

2.2. Qualitative Approach

In this approach the large errors due to modeling has been removed due to the fact that partial knowledge of the system is enough to detect the fault. In this a disjoint set of input and output is created and the relationship between them is formed using the differential equations and calculations are carried out to detect the fault in a system. This method requires high computational power and a good skill of forming the differential equation from disjoint set. Qusim was the software tool used for this technique. Another methodology to detect the fault was a development of above method when instead of forming disjoint set a fuzzy set was formed and fuzzy relation was obtained to detect the fault. Fusim was the simulation tool used for this method. This methodology requires partial knowledge of the system. A similar approach for fault detection using fuzzy controller is explained in [4].

2.3. Soft Computing Techniques

This methodology requires little knowledge of the system such as the input and output of a sample to train the system, thus the engineering time for design gets reduced for complex systems. This method mainly revolves round the Artificial Neural Network (ANN) because of the requirement of classification of data. The following section explains the ANN technology used for fault detection based on literature survey.
3 ANN in Fault Detection

The process of obtaining the fault from the parameter can be described by following steps shown in flowchart shown in Fig. 2 [12]. In this paper only fault detection techniques are discussed.

3.1. Selection of Proper Detection Signal

Each type of fault has a unique result in the parameter of the circuit. For example an open circuit fault in the switch for a cascaded H-Bridge multilevel inverter shows change in output voltage, while the short circuit of the switch results in the change in the input current but does not have any specific effect on the output voltage until the fuse of corresponding cell is blow due to high current. Thus making a decision about type of fault is necessary as it dictates selection of proper signal.

Fig.2 Flowchart showing Methodology of fault detection and reconfiguration

3.2. Selection of Appropriate AI Technique

The AI technique consist of two components

3.1. Feature Extraction

Any abnormal behavior in the circuit can be easily detected visually by observing the waveform of the signals however computational unit cannot directly visualize, and the signals generated are difficult to
some of them are

3.2.1.1. Fast Fourier Transform

In [12] it is shown that the FFT technique has an advantage over the Discrete Fourier Transform in terms of the computational efforts. There are certain adverse effects such as Gibbs phenomenon which are due to the fact that DFT averages only over a limited time period.

3.2.1.2. Wavelet packet transform

In literature it is given that this method is inherited and developed from the localization of the FFT. In this the parent signal is decomposed into different frequency bands and energy of each frequency is calculated. The energy content of different frequencies of the signal should vary significantly if any switch fault occurs. It is desirable to have normalized energy values rather than high value so that convergence of neural network is faster. The Flow chart which explains 3 level wavelet decomposition is shown below in fig.3 in this S is parent signal, a represents the low frequency signal and D represents high frequency signal.

![Fig.3 Three layer wavelet packet decomposition](image)

3.2.1.3. Discrete Wavelet transform

In literature it is given that FFT has a limitation of detecting frequency and magnitude for a non-stationary signal. As the multilevel inverter is widely used in drives where the magnitude and frequency varies a lot it is not viable to use it. It proposed the use of Discrete Wavelet Transform to overcome this problem and this also reduces number of inputs to the neural network there by reducing the size and computational efforts as well as memory requirements.

3.2. Classification of Data Using Neural Network

The Artificial Neural Network is generally used for classification of data. This data is obtained from the extraction of feature by using any
In [11] principal component analysis (PCA) is utilized to reduce the redundant information from FFT extract and Genetic Algorithm is used for selecting best principal component. In [12] the data is extracted by FFT technique and multilayer feed forward perceptron neural network is used.

The back propagation neural network has a disadvantage of converging into local minima due to usage of gradient-descent on the error surface, low convergence speed. In Literature Particle swarm optimization (PSO) is utilized so that the Back Propagation neural network do not enter the local minima and the convergence speed increases.

3.3. Decision on the Structure of Neural Network

The structure of neural network is dependent on the conclusions obtained for the above steps. For example the input layer depends on the feature extraction. The output layer depends on number of switches and possible combination of failure.

3.4. Creation of an Input and Output Data to Train the Neural Network.

The data of input and output i.e., fault and corresponding output to determine which switch is under fault condition is created.

4 Conclusion

Through this paper an attempt is made to select appropriate techniques for fault detection. Based on the discussion in fault detection techniques it is understood that the most appropriate methodology for complex nonlinear system is soft computing techniques. The soft computing techniques especially extraction techniques like FFT, Wavelet transform, DWT are reviewed and the most appropriate extraction technique may be DWT since it reduces the redundant data and number of inputs to neural network there by reducing the required memory. There are many neural networks that are present but only back propagation technique is widely present in the research but other networks such as the ADALINE or MADALINE or many other techniques present in literature can be tested for fault diagnosis. The drawback of BP neural network is addressed by using a hybrid neural network such as PSO-BP. The main consideration for the selection of fault diagnosis by neural network is the uniqueness that is required in the output for fault in each switch due to fact that extraction unit should give unique energy level so that classification is possible by neural networks. So further research could be done to generalize and condition of uniqueness can be overdone.


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