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Fault Detection and Diagnosition System for a 19 Level Cascaded Multilevel Inverter using ANN

R. Ramkumar[*1], R. Harine[2], G. Akthar Shehanaz[3], S. Gowthami[4]
[*1]Assistant Professor, Department of EEE,K.Ramakrishnan college of Technology, Tiruchirapalli, Tamilnadu, India
[2,3,4]Department of EEE,K.Ramakrishnan college of Technology, Tiruchirapalli, Tamilnadu, India

ABSTRACT

An inverter is a circuit used for converting direct current to alternating current. They are used in a wide range of applications, from small power supply for a computer to large industrial applications for transporting bulk power. Multilevel inverters as compared to single level inverters have advantages like minimum harmonic distortion and it can operate on several voltage levels. The paper aims at the detection and diagnosition of the various faults occurring in a single phase nineteen level inverter based on Artificial Neural Networks. The role of Artificial Neural Network in fault diagnosition is studied and simulated using MATLAB/SIMULINK. The single phase nineteen level inverter system is designed and their characteristics are observed. The datas like voltage, current and the error values of an inverter is collected by varying the load conditions. The neural network is trained to detect the faults with the help of the data sets and tested in order to eliminate the faults occurring in an inverter. Thus, by utilizing the proposed neural network fault diagnosis system, a better understanding about fault behaviors, diagnostics, and detections of a multilevel inverter system can be accomplished.
Keywords : Back propagation algorithm, Fault diagnosis, Multilevel inverter, Neural network, Power electronics.

I. INTRODUCTION

When AC loads are fed through inverters it required that the output voltage of desired magnitude and frequency should be achieved. A variable output voltage can be obtained by varying the input DC voltage and maintaining the gain of the inverter constant. On the other hand, if the DC input voltage is fixed and it is not controllable, a variable output voltage can be obtained by varying the gain of the inverter, which is normally accomplished by Pulse Width Modulation (PWM) control within the inverter. The inverters which produce an output voltage or a current with levels either zero, positive or negative voltages are known as two level inverters. In high power and high voltage applications these two level inverters however have some limitations in operating at high frequency mainly due to switching losses and constraints of device rating. This is where multilevel inverters are advantageous [1]. Increasing the number of voltage levels in the inverter without requiring higher rating on individual devices can increase power rating. The unique structure of multilevel voltage source inverters allows them to reach high voltages with low harmonics without the use of transformers or series connected synchronized switching devices. The harmonic content of the output voltage waveform decreases significantly. Figure 1 shows the power circuit of a cascaded multilevel inverter of two stage five level.

Artificial Intelligence (AI) techniques, particularly the neural networks, are recently having significant impact on power electronics and motor drives. Neural networks have created a new and advancing frontier in power electronics, which is already a complex and multidisciplinary technology that is going through dynamic evolution in the recent years [2].

The conventional method deals with the implementation of five multilayer perceptron networks to identify the type and the location of occurring faults from inverter output voltage measurement. The faults they have taken are only short circuit and open circuit faults. The function used is sigmoid activation function, tansig for hidden nodes and logsig for the output node. The classification performance of the network between normal and abnormal condition is about 90%, and the classification performance among fault feature is about 85% [3].

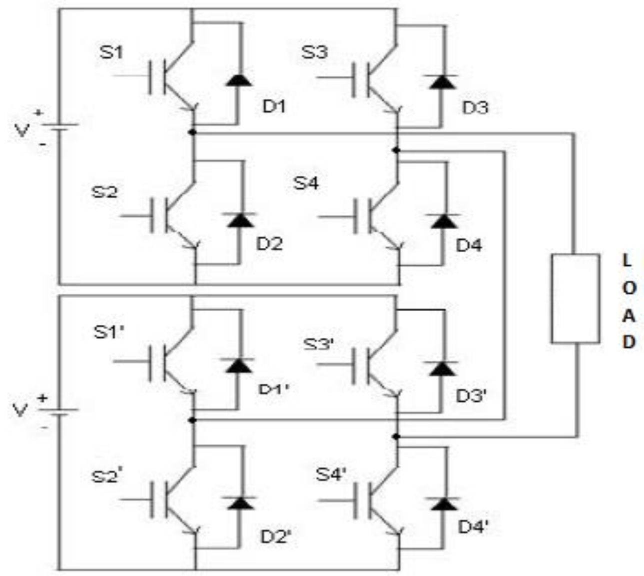

Figure 1: Five level Cascaded Multilevel Inverter

In another method, a topology with fault tolerant ability that improves the reliability of multilevel converters is proposed. This topology is developed through analysis of different power device's failure modes such as open circuit, short circuit and various switching device failure. With this scheme, the function of the power stage can be maintained even part of it fails. Its fault tolerant ability results from the redundant nature of the multi switching state topology and from control signal modification. Furthermore, it balances the voltage levels automatically without any assistance from other circuits. The validity of this scheme is confirmed by experiments in a five level single phase inverter prototype [4].

Surin Khomfoi et al.,proposed a genetic algorithm based selective principal component neural network method for fault diagnosis system in a multilevel inverter.Multi Layer Perceptron (MLP) networks are used to identify the type and location of occurring faults from inverter output voltage measurement. Principal Component Analysis (PCA) is utilized to reduce the neural network input size. A lower dimensional input space will also usually reduce the time necessary to train a neural network, and the reduced noise may improve the mapping performance. The genetic algorithm is also applied to select the valuable principal components. The neural network design process including principal component analysis and the use of genetic algorithm is clearly described [5].

The ability of cascaded H-bridge Multilevel Inverter Drives (MLID) to operate under faulty condition including AI based fault diagnosis and reconfiguration system was described. Output phase voltages of a MLID can be used as valuable information to diagnose faults and their locations. It is difficult to diagnose a MLID system using a mathematical model because MLID systems consist of many switching devices and their system complexity has a nonlinear factor. Therefore, a neural network (NN) classification is applied to the fault diagnosis of a MLID system. Multilayer Perceptron (MLP) networks are used to identify the type and location of occurring faults. The principal component analysis is utilized in the feature extraction process to reduce the NN input size [6]. A lower dimensional input space will also usually reduce the time necessary to train a NN, and the reduced noise may improve the mapping performance. The system is validated with simulation and experimental results [7].

A multilevel power converter structure has been introduced as an alternative in high power and medium voltage situations. A multilevel converter not only achieves high power ratings, but also enables the use of renewable energy sources. Renewable energy sources such as photovoltaic and fuel cells can be easily interfaced to a multilevel converter system for a high power application. The term multilevel comes from the three level converter. Subsequently, several multilevel converter topologies have been developed. However, the elementary concept of a multilevel converter to achieve higher power is to use a series of power semiconductor switches with several lower voltage DC sources to perform the power conversion by synthesizing a staircase voltage waveform. Capacitors, batteries, and renewable energy voltage sources can be used as the multiple DC voltage sources. The commutation of the power switches aggregates these multiple DC sources in order to achieve high voltage at the output. However, the rated voltage of the power semiconductor switches depends only upon the rating of the DC voltage sources to which they are connected. A multilevel converter has several advantages over a conventional two level converter that uses high switching frequency pulse width modulation (PWM) [8].

II. PROPOSED WORK

A fault diagnostic system in a single phase nineteen level inverter using an adaptive back-propagation neural network is proposed. An adaptive back propagation neural network classification is applied to the fault diagnosis of a MLI system to avoid the difficulties in using mathematical models. Generally, the conventional protection systems are passive devices such as fuses, overload relays, and circuit breakers to protect the inverter systems. The protection devices will disconnect the power sources from the multilevel inverter system whenever a fault occurs, stopping the operated process. For instance, AI based techniques do not require any mathematical models.

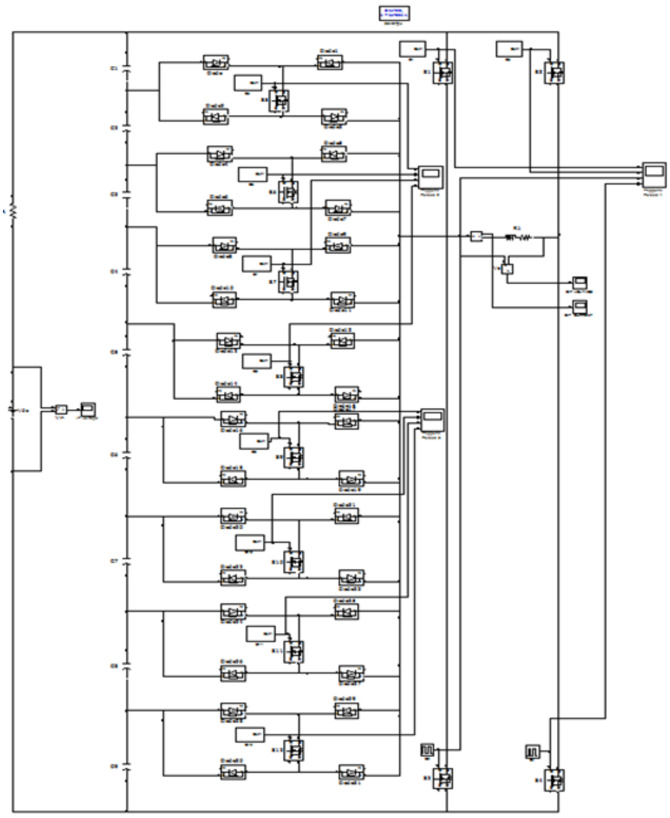

Figure 2: Proposed Nineteen level Cascaded Multilevel Inverter

A. FAULTS USED

- Open circuit fault(V=10V;I=0.09693A)
- Short circuit fault(V=0V;I=10.32A)
- Over voltage fault(V=99.96V;I=9.63A)
- Losing drive pulse fault(V=19.99;I=1.907A)

A short circuit in an electrical circuit allows a current to travel along a path where essentially no (or a very low) electrical impedance is encountered. It is an abnormal low resistance connection between two nodes of an electrical circuit that are meant to be at different voltages. This results in an excessive electric current (over current) limited only by the thevenin's equivalent resistance of the rest of the network and potentially causes circuit damage, overheating, fire or explosion. Such short circuits can be dangerous, particularly as they may not immediately result in a large current and are therefore less likely to be detected [9].

Open circuit faults occurs if any interruption in the circuit, such as an open switch, a break in the wiring, or a component such as a resistor that has changed its resistance to an extremely high value will cause current to cease. The open switch or the fault has caused what is commonly called an open circuit. Wherever an open circuit exists although voltage may be present there will be no current flow through the open circuit section of the circuit [10].

An over voltage is a condition in which the magnitude of the voltage increases. A transient over voltage has duration of less than one half cycle of the normal mains waveform. An over voltage condition is reached when the voltage exceeds the nominal voltage by 10% for more than 1 minute. This condition results in voltage that falls outside the acceptable power envelope. A voltage greater than that at which a device or circuit is designed to operate is known as over potential [10].

The losing drive pulse fault occurs when the pulse given to the circuit is lost or if the pulse is not given properly. This type of fault is clearly shown in the figure 4.6.where the pulse given to the circuit is removed so that there occurs no path. If the given pulse is wrong the normal output will not be displayed. The output may vary based on the pulse we have given [11].

III. BLOCK DIAGRAM

The structure of a fault diagnostic system is illustrated in the fig.1.

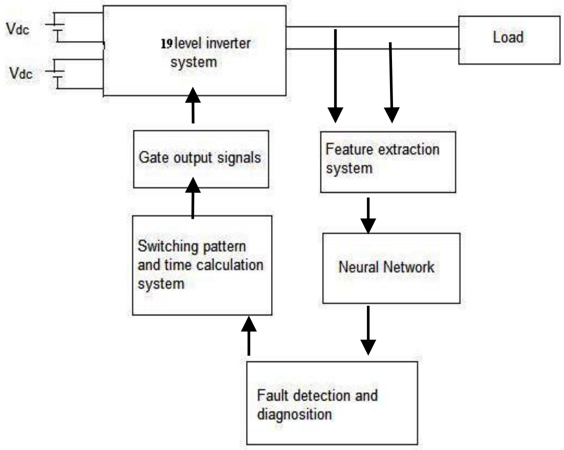

Figure 3: Structure of fault diagnostic system

The system is composed of four major states: feature extraction, neural network classification, fault diagnosis, and switching pattern calculation with gate signal output. The feature extraction performs the voltage input signal transformation, with rated signal values as important features, and the output of the transformed signal is transferred to the neural network classification. The networks are trained with both normal and abnormal data for the MLI systems. Thus, the output of this network is nearly 0 and 1 as binary code.

The binary code is sent to the fault diagnosis to decode the fault type and its location. Then, the switching pattern is calculated to reconfigure the MLID to bypass the failed level. A single phase cascaded multilevel inverter using 10V MOSFETs as the switching devices was used to produce the output voltage signals. The level of an inverter is given by m=2Ns+1.Here m denotes the level of an inverter and Ns denotes the number of stages included. Hence two stage five level inverter is used.

The Simpower MATLAB toolbox in Simulink is used to simulate the data of fault features with modulation index. An appropriate selection of the feature extractor is to provide the neural network with significant details in the pattern set so that the highest degree of accuracy in the neural network performance can be obtained. The features extracted are the voltage, current and the error values. The networks are examined with the test data sets when the proposed networks have trained to the desired error goal. Testing the network involves presenting the test set to the network and calculating the error. If the error goal is met, the training is complete. The training data set should cover the entire operating region. Thus, the test data sets and the testing sets are generated according to that requirement.

IV. NEURAL NETWORKS

Neural networks are typically organized in layers. Layers are made up of a number of interconnected 'nodes' which contain an 'activation function'. Patterns are presented to the network via the 'input layer', which communicates to one or more 'hidden layers' where the actual processing is done by a system of weighted 'connections'. The hidden layers then link to an 'output layer' [12].

The activation function of a node defines the output of that node given an input or set of inputs. It is a function used by a node in a neural net to transform input data from any domain of values into a finite range of values. Activation functions for the hidden units are needed to introduce nonlinearity into the network. Without nonlinearity, hidden units would not make nets more powerful than just plain perceptrons [13]. However, it is the nonlinearity that makes multilayer networks so powerful. For back propagation learning, the activation function must be differentiable, and it helps if the function is bounded.

A. BACK PROPAGATION NEURAL NETWORK ALGORITHM

The BPN algorithm first, takes a number of neurons and arrays them to form a layer. A layer has all its inputs connected to either a preceding layer or the inputs from the external world, but not both within the same layer. A layer has all its outputs connected to either a succeeding layer or the outputs to the external world, but not both within the same layer [14].Next, multiple layers are then arrayed one succeeding the other so that there is an input layer, multiple intermediate layers and finally an output layer. Intermediate layers, have no inputs or outputs to the external world, are called hidden layers. Back propagation neural networks are usually fully connected. This means that each neuron is connected to every output from the preceding layer or one input from the external world if the neuron is in the first layer and, correspondingly, each neuron has its output connected to every neuron in the succeeding layer as shown in the fig.2.

Generally, the input layer is considered as a distributor of the signals. Hidden layers are considered to be feature detectors of signals. The output layer is considered as a collector of the features detected and producer of the response [15].

The work done includes:

(i)Two stage nineteen level inverter is simulated using MATLAB

(ii)Voltage and current values were collected by varying the load conditions

(iii)With the help of datasets the neural network was trained with 29 epochs to get a best training performance curve

(iv)With the help of MATLAB program the network is trained to detect and diagnose the various faults

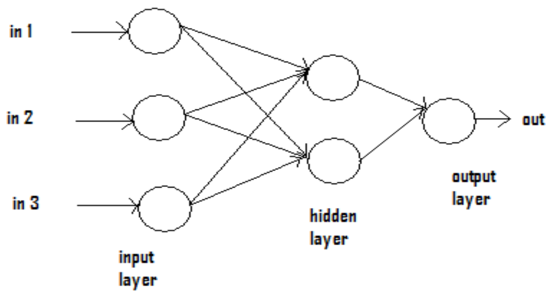

Figure 4: Backpropagation Network

V. SIMULATION RESULTS

The simulation results for various faults are shown in following figures. Without introducing any fault the normal waveform is obtained as shown in the fig.3. By introducing various faults like open circuit, short circuit, losing drive pulse and overvoltage faults, the waveforms are obtained as in the fig.4,5,6,7 respectively.Fig.9 shows the training performance curve trained in 29 epochs.

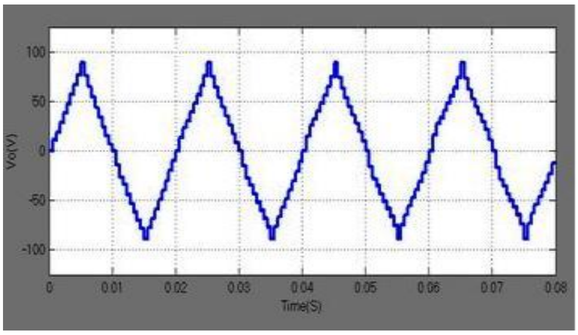

Figure 5: Normal 19 Level waveform

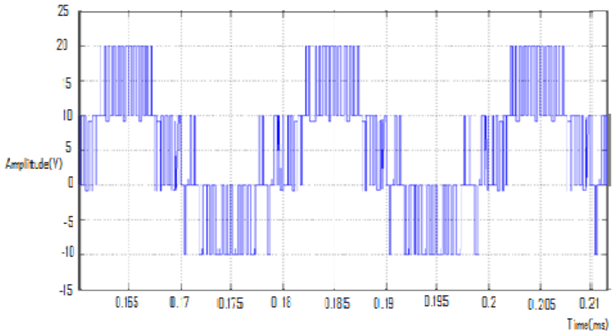

Figure 6 : open circuit fault

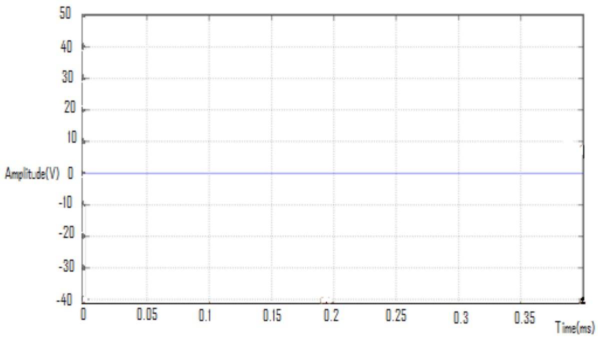

Figure 7 : short circuit fault

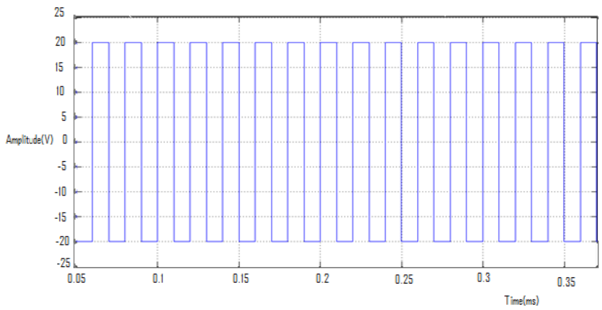

Figure 8 : Losing drive pulse fault

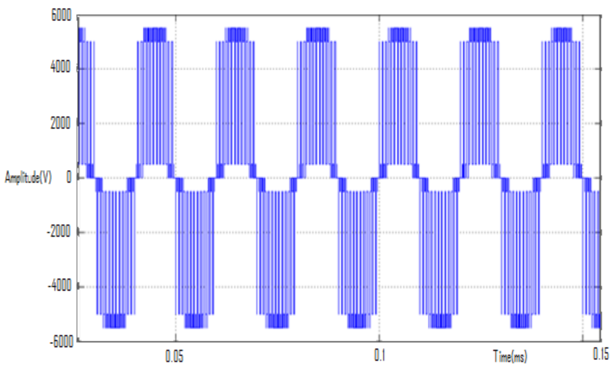

Figure 9 : Overvoltage fault

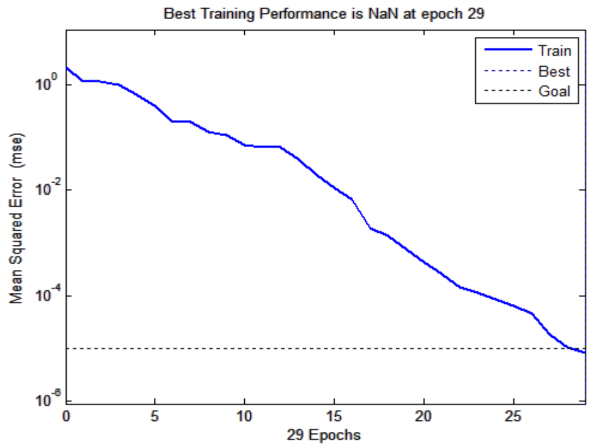

Figure10 : Training curve

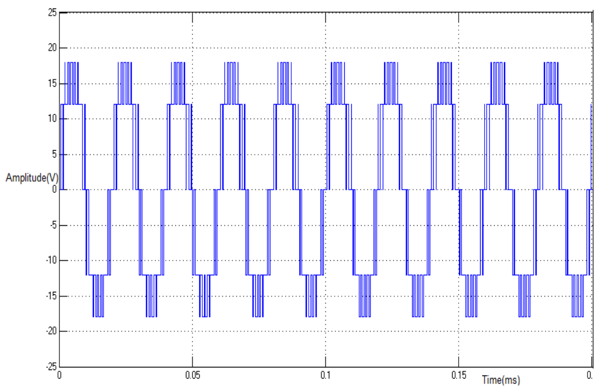

Figure 11: waveform after training

Table-I. Various Faults and Its Detection

Open circuit fault	00
Short circuit fault	01
Losing drive pulse fault	10
Overvoltage fault	11

The various faults have been detected by comparing the output waveform with the reference waveform in the relational operator conditions as shown in the table.1.According to the result the values are assigned to each faults as 00,01,10,11 respectively.

VI. CONCLUSION

A study of faults in a single phase 19 multilevel inverter and its diagnosition using Adaptive Back Propagation Neural Networks has been proposed. Adaptive means dynamic modification of learning rate so that we can reach the minimum error quickly. The proposed network performs well with the selected testing data set. It has the ability to classify normal and abnormal conditions, including the fault location. Therefore, by utilizing the proposed neural network fault diagnostic system, a better understanding of fault behaviors, diagnostics, and detections for multilevel inverter drive systems can be achieved.

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