A Review Paper on Open-Switch Fault Diagnosis in Neutral-Point-Clamped (NPC) Inverter using Data-Mining Technique

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Abstract-During the last several years, multilevel inverters have become increasingly popular. Among their good properties, one can mention their output voltage quality, their improvement, and the reduction of the electrical constraints on the power switches as well as the reduction of the switching frequency. Issue location can expand the reliability quality and productivity of intensity electronic converters utilized in power frameworks. Among the converters in the force framework, a Neutral Point Clamped (NPC) three-level inverter is most normally used to drive electric engines. In this paper, different methodologies for open-circuit deficiency discovery and area of the NPC three-level inverter for a moving procedure utilizing a steady voltage-to-recurrence proportion is proposed. So as to analyze open-circuit shortcoming in as short a period as could be expected under the circumstances, information mining calculation is proposed to pick single electrical periods from continuous three-stage flow signals. The measurable qualities of the electrical period signals are extricated, and an arbitrary timberland model is built to understand the state arrangement. Contrasted and the customary fault determination strategy, the proposed calculation discovers issue areas rapidly and precisely. The adequacy and exactness of the proposed calculation are confirmed by tests.

Index Terms—three-level neutral-point clamped (NPC) active rectifier; open-switch fault; fault diagnosis and tolerant control method; space vector modulation (SVM)

I. INTRODUCTION

In recent decades, more and more applications in industrial, manufacturing, or the transportation domain have been increasingly electrified for efficiency and environmental issues [1–3]. However, due to the reliability, availability, and maintainability requirements [4], the system must remain operational despite fault occurrence and its performances must remain robust to environmental nuisances. Along these lines, exertion is put toward the plan and wellbeing observing of the electrical drives. Adjacent to electrical machines, voltage source inverters are one of the most delicate parts inclined to faults or disappointments [5]. Such inverters create less electromagnetic annoyances, and, in this manner, the size and the expense of their principle channel can be diminished. The NPC inverter has end up being the most productive. In any case, contrasted with the old style 2-level inverter, the principle disadvantages of the staggered inverters are the higher number of parts (power switches and capacitors) and an increasingly mind complex control.

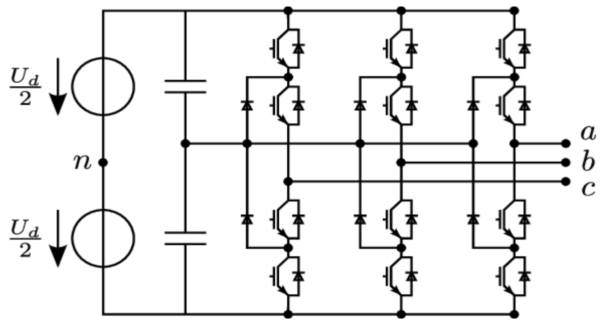

Figure 1: Neutral-Point-Clamped (NPC).

In this paper, we have chosen the three-level NPC inverter since it has lower inverter losses, and lower stress on the power switches at higher switching frequencies when compared to a two-level inverter for electric vehicle applications. In industrial applications using variable-speed AC drives, different studies have proved that about 38% of the faults are due to failures in the power device. These faults can be classified in three classes shown below.

• Abrupt faults that suddenly occur, inducing significant changes in the system behavior.

• Gradual faults. These fault types can be considered as a slight but abnormal increasing over time variation in parameters and/or variables of the process.

• Intermittent faults. The immediate effect can be negligible but its repetition may lead to failures.

II. LITERATURE SURVEY

In this section the comparison of the techniques which are proposed by several authors in order to perform fault detection as well as the classification is performed.

In this paper [1] author proposes a fault diagnosis and tolerant control methods for an open-switch fault caused in a three-phase three-level neutral-point-clamped (NPC) pulse-width modulation (PWM) active rectifier. The open-switch deficiency in the three-level NPC dynamic rectifier causes a mutilation in the information stage current and a wave in the DC-interface capacitor voltage. Subsequently, appropriate fault determination and lenient control strategies are required to forestall extra disappointments and execution corruption in the rectifier framework. This paper led a definite investigation of the impact of the single open-switch fault on the NPC PWM dynamic rectifier and proposed a deficiency conclusion strategy using the DC interface voltage and the stage point of the information lattice voltage. Moreover, this paper proposes a deficiency lenient control technique to decrease the impact of the open-switch issue by remunerating a misshaped reference voltage. The viability of the proposed deficiency analysis and lenient control techniques are confirmed through trial results.In this paper [2] author proposed an approach is based on the already available phase current time series measurements for different operating conditions (motor speed, load, and environment noise). Both fault detection and classification are studied and the efficiency performances of the proposed selected features are shown. For the fault detection, we focus on the first four statistical moments and the extracted features and then the Cumulative Sum (CUSUM) algorithm as the feature analysis technique to improve the performances. For the classification study, we propose to couple the knowledge on the faulty system brought by the statistical moments and the Kullback-Leibler divergence particularly suitable for the detection of incipient changes. The Principal Component Analysis (PCA) is then used to perform the classification. A 2D framework is obtained, which allows the faults to be classified efficiently within the considered operating conditions for all the selected fault durations.In this paper [6] creator proposed a multiscale adaptive issue conclusion strategy dependent on signal symmetric reproduction preprocessing was prescribed to analyze self-assertive exchanging deficiencies of microgrid inverters under factor load conditions. Creator likewise built up a methodology for distinguishing open-circuit blames by developing normalized factors for shortcoming modes. An issue model dependent on the envelope of the voltage between the yield lines of the inverter was utilized for shortcoming analysis and proposed a scientific model dependent on the distinction between the momentary voltage of the deficiency state and the deliberate sign. Be that as it may, voltage-based strategies need extra voltage sensors and complex investigation unit and are effortlessly influenced by the difference in load. Current-based open-circuit shortcoming analysis strategies dependent on the yield current alter pattern and course of the power switches are for the most part utilized in inverters. Park's change strategies are ordinarily embraced in current-based techniques. In [11], a shortcoming determination strategy dependent on the normal of the current and prompt edges of the current vector was progressed. In an open-circuit deficiency analysis strategy dependent on the standardized mean current Park's Vector Modulus (PVM) and point was proposed. In, the normal current stopping vector was utilized to build a three-level NPC signature table for conceivable deficiency conditions. A converter-based half and half rationale dynamic (MLD) model was utilized to assess the opencircuit issue of lattice current in [14]. In this paper [15] creator proposed an open circuit fault analysis procedure dependent on the difference in rotor current was offered additionally suggested that issue determination of the T-type staggered converter is accomplished by checking the unusual difference in the nonpartisan current of the DC transport. Set forth a three-stage voltage source inverter (VSI) current sensor and open circuit fault analysis calculation dependent on versatile edge. Park change strategies are required to contrast with the set limit with understand the analysis. Setting the limit an incentive to a consistent when the heap changes is troublesome on the grounds that the current abundancy can't be anticipated. In this manner, it is hard to ensure the precision of these shortcoming finding techniques and apply them in real frameworks. Vulnerability is an incredible test in the fault conclusion of inverters. The vulnerability can be brought about by a few elements, for example, predisposition and clamor of sensors. Inspired by taking care of these vulnerability issues, we propose an information driven fault analysis approach in three-stage inverters. As of late, numerous calculations dependent on sign and information strategies have demonstrated great execution in the fault conclusion of inverters [18]. In this paper [19] creator proposed an element was separated by Fast Fourier Transform (FFT) and characterized by help vector machine (SVM) to identify faults of the staggered inverter. However, in this paper, fault qualities are separated from the yield voltage waveform and just unadulterated R load is broke down while the heaps in the power framework by and large are RL type. Likewise, the FFT technique is utilized for signal investigation. This examination doesn't have great execution in transient conditions of the framework and can't show us the hour of the deficiency event. The fault determination calculations executed in the past exploration papers are predominantly founded on signals under steady speed condition or conditions in various rates of the engine, once in a while thinking about the moving procedure. A consistent voltage-to-recurrence proportion technique is utilized to alter the speed during the moving procedure while the sufficiency and recurrence change all through the entire procedure.

Table 1: Comparative analysis of various papers.

Authors	Methods	Purposes	Tasks
Jun-Hyung Jung 1 , Hyun-Keun Ku 2 [1]	Pulse-Width Modulation (PWM) active rectifier.	Fault Diagnosis	This paper proposes a fault-tolerant control method to reduce the effect of the open-switch fault by compensating a distorted reference voltage.
Mehdi Baghli 1,2, Claude Delpha 3 [2]	Cumulative Sum (CUSUM) algorithm	Diagnosis	It allows the faults to be classified efficiently within the considered operating conditions for all the selected fault durations.
Z. Wang, Z. Huang, C. Song, and H. Zhang [6]	Multiscale Adaptive Fault Diagnosis Method	Diagnosis & Identification	Current-based open-circuit fault diagnosis methods based on the output current change trend and direction of the power switches are mostly used in inverters.
C. Yong, L. Zhilong, and C. Zhangyong [11]	Park's Vector Modulus (PVM)	Diagnosis Strategy	Normal and fault conditions
A. Joseph, T. R. Chelliah, R. Selvaraj [15]	Voltage Source Inverter (VSI)	Detection & identification Detection algorithm	It is difficult to guarantee the accuracy of these fault diagnosis methods and apply them in actual systems.
T. Wang, J. Qi, H. Xu, Y. Wang, L. Liu, and D. Gao [19]	Support Vector Machine (SVM)	Diagnosis Strategy	A constant voltage-to-frequency ratio method is used to adjust the speed during the shifting process while the amplitude and frequency change throughout the whole process.

In the above table 1 the comparative analysis over previously used algorithms is given.

III. CLASSIFICATION OF FAULTS DETECTION METHODOLOGY

We propose a fault detection methodology that can be described in four main steps.

• The initial step is the Modeling. In this progression, a model depicting the conduct of the framework is inferred. This model can be logical (i.e., utilizing physical laws depicting the framework), etymological (i.e., utilizing a semantic portrayal of the framework), or information driven (i.e., utilizing information history from the framework). In the proposed work, an information driven-based methodology is thought of. The drive is recreated for various states of clamor, OSF lengths, and working focuses (burden and speed).

The subsequent advance is the pre-handling. The gathered information is pre-prepared in the fitting working space (e.g., time of recurrence). In this examination, the information (stage current signs) is orchestrated in time space arrangement.

• The third step is the Features extraction. The objective of this progression is to extricate from the gathered and handled information the most delicate data (deficiency highlights) to the issue event. The effectiveness of these highlights will have basic results on the shortcoming location exhibitions. For our proposition, we assess the initial four measurable snapshots of the sign and the Kulback-Leibler difference [18].

• The fourth step is for highlights examination. The removed highlights are dissected to play out the fault identification and arrangement. In this work, we have examined the extricated highlights utilizing factual components as the boundaries, edge rationale, Cumulative Sum (CUSUM), or the Principal Component Analysis (PCA) [19].

IV. PROBLEM DEFINITION

(1) There are various noise interference problems in the signal

(2) The period value and peak value in one period of the output current signal are constantly changing during the acceleration process

(3) It is difficult to locate the peak and valley of one signal period, especially in the low-frequency stage of the output current. The maximum and minimum positions cannot represent the peak and valley.

(4) Half-cycle malformations or missing output currents caused by open-circuit fault must be addressed

V. CONCLUSION

Open-circuit fault-detection and fault-tolerant control methods for the NPC inverter under the grid connection have been proposed. In the start of this paper, the activity of the network associated NPC inverter under the open circuit fault conditions has been considered. At that point, the open-circuit issue identification and issue lenient control techniques for the network associated NPC inverter framework have been introduced. Under the lattice associated condition, it is difficult to distinguish the fault switch by existing techniques, which have been created dependent on the outputs bends for the traditional two-level inverter framework. The issue among switches and cinching diodes can be recognized by checking whether the current streams or not during the half time of the output current of the faulted stage. The faulted switch between the upper two switches or between the lower two switches is characterized by infusing an underexcited receptive current during a brief period. On account of the open-circuit deficiency in the clipping diode, the faulttolerant control technique can be applied. Despite the fact that the THD of the output flows increment, the NPC inverter can be worked with worthy output execution and without de-rating of the output power. The achievability and adequacy of the proposed open-circuit fault recognition and shortcoming lenient control strategies have been checked by the test results.

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