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Fault Detection Techniques for Multilevel Inverter used in Smartgrid

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ABSTRACT: Modern renewable energy systems rely heavily on multilevel converters. These converters improve power quality and ensure smooth synchronization with the grid. Multilevel converters are electrical converters that can produce various voltage levels, resulting in a better sine wave output. However, their reliability is closely tied to the reliability of their switches, as switch failures are a common source of problems. This paper introduces a new 7-level Fault-Tolerant Cascaded H-Bridge Multilevel Inverter (FT-CHB-MLI). This design prioritizes high reliability and excellent power quality. To ensure smooth operation, a Fault Detection and Isolation (FDI) unit is included to diagnose faults and replace faulty switches with backup components. The system's diagnostic process relies on calculations of Total Harmonic Distortion (THD) and normalized output voltage factor. The Phase Disposition Pulse Width Modulation (PD-PWM) switching technique is used because it offers better performance than older methods. The fault detection system is designed to catch problems early, allowing for preventive maintenance that maintains stability and overall system health. The proposed system was simulated using MATLAB/Simulink, and the simulation results confirmed its effectiveness. The simulation showed that the advanced FDI unit significantly improves reliability by reducing THD by nearly 5%. Reliability analysis using Markov chains further demonstrated the system's high level of dependability. Comparisons with existing research show that the proposed system offers superior performance and reliability.

KEYWORDS: Fault-tolerant control, cascaded H-Bridge, 7-level multilevel inverter.

I. INTRODUCTION

The desired characteristics of Multilevel Inverters make them popular for PV systems by delivering high-quality waveform and high nominal power. Converter systems for different applications include cascade H-bridge converters together with neutral point clamped converters while hybrid multilevel converters also exist. The converters serve high and medium power use cases. Multilevel converters entered the market to power industrial high-voltage drives and advanced power train systems. The renewable energy sector implemented these converters for utility-scale energy at first and they continue to serve utility-scale power generation today. A single-phase multilevel converter exists in three separate categories which include the Neutral Point Clamped (NPC) and Continuous Feedback (CFB) and Cascaded H-Bridge (CHB) converters. To use a three-level converter in a specific application requires implementing the diode-clamped converter as an NPC due to its operation at neutral point voltage level. The implementation of NPC converter with full bridge topology needs two distinct dc-link voltages as its main limitation [5]. Multiple levels of input DC supply voltage stem from capacitors in the H-bridge which have connected switches. Multiple Level Inverters serve extended applications by enabling control of medium voltage systems through higher voltage source inputs. Magnetic levitation systems and electric traction along with industrial drives, conveyors, vacuum cleaners, multiple gear systems and cooling systems and power plants, and smart houses utilize this technology. A lower step voltage allows multi-level inverters to generate stable voltages combined with enhanced power performance through lower harmonic content and reduced noise and improved power factor quality .

TABLE I. Units for magnetic properties.

| Component | Neutral Clamped | Point Flying Capacitor | Cascaded Bridge | H- |
|----------------------|--------------------|------------------------------|--------------------|----|
| Power Switches | 12 | 10 | 12 | |
| DC Capacitors | 6 | 0 | 2 | |
| Flying Capacitors | 0 | 14 | 0 | |
| Clamping Diodes | 16 | 0 | 0 | |
| Feed Back Diodes | 12 | 10 | 12 | |

II. LITERATURE

Multilevel inverters (MLIs) are power electronic devices of general concern because of their ability to generate high-quality output voltage waveforms with harmonic distortion. They are widely applied in renewable energy systems, industrial drives, and electric vehicles. However, like all power electronic devices, multilevel inverters are prone to faults like short circuits, open circuits, and semiconductor failures. Fault detection and diagnosis of such systems are of paramount significance to maintain reliability and prevent failure of a catastrophic kind. This literature review aims to examine the various fault detection techniques adopted for multilevel inverters, highlighting the advantage and disadvantage of each technique.

1. Fault Detection Approaches: General Classification Multilevel inverter fault detection techniques can be generally classified into two main classes: These rely on mathematical models or simulations of the inverter's operation to detect discrepancies between the actual system behavior and the expected behavior under normal conditions. Data-driven techniques: These rely on measured data (such as voltage, current, or temperature) and statistical or machine learning methods to identify faults.

2. Observer-based Techniques: Observer-based methods employ a dynamic model of the inverter and use observers (e.g., Luenberger observers or Kalman filters) to estimate the system's state. Any deviation between the estimated state and actual measurements can indicate a fault. In particular, Extended

Kalman Filters (EKF) have been employed for the detection of faults in MLIs, offering a powerful technique for the handling of nonlinearities and real-time fault detection. Strengths: High accuracy, small fault detectability, and capacity to work with noisy measurements. Weaknesses: Challenging model building, high computational cost, and need for good system parameters.

2.1. Model Predictive Control (MPC) Model Predictive Control techniques use a model of the inverter to predict future states and correctively control the system to minimize deviations. Faults can be detected by comparing the predicted output with the actual output. When a discrepancy occurs, it can indicate a fault. Advantages: Can handle multi-variable systems and nonlinearities well. Limitations: High computational burden, especially for real-time applications.

2.2. Parameter Estimation and System Identification This method involves estimating the parameters of the inverter model (such as switching states, power losses, etc.) in real-time. Faults in the system are detected by observing changes in these parameters. Techniques like Least Squares Estimation (LSE) and Recursive Least Squares () are common approaches for parameter estimation in fault detection.

III. METHODOLOGY

The fault detection techniques for multi-level inverters of smart grids are of greatest significance in maintaining system reliability, efficiency, and ensuring smooth power delivery. The methodology for fault detection involves a detailed analysis of the inverter's operational performance, fault characteristics, and monitoring of the grid to detect any malfunctions that may occur. In this context, the multi-level inverter is responsible for converting DC power to AC, providing the necessary energy distribution to various grid components. The approach begins with the identification of common fault types that typically occur in multi-level inverters, such as open-circuit, short-circuit, and partial failures in power switches. These faults may occur due to issues like component degradation, poor maintenance, or external environmental factors. The methodology then focuses on developing algorithms for monitoring the system parameters, including voltage, current, and temperature variations, which could indicate abnormal behavior.

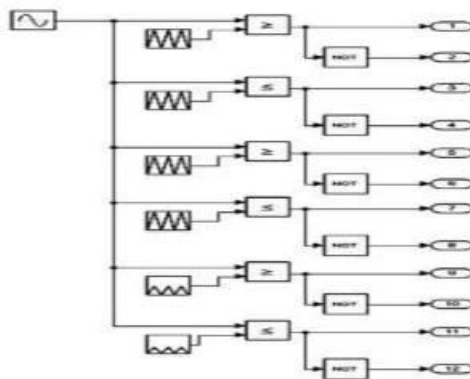


Fig-1: MATLAB- Simulink model for Phase disposition pulse width modulation

The system employs sensors and real-time data collection methods to monitor the performance of the inverter. Data from the inverter are analyzed to detect patterns of anomalies or deviations from the expected behavior. These anomalies could signify an impending fault, which could affect the overall functioning of the smart grid. The detection technique often combines signal processing methods, machine learning models, and diagnostic algorithms, which can be applied in both real-time and predictive fault detection. By using artificial intelligence techniques like neural networks and decision trees, the system learns the normal operational patterns and identifies any deviations in the inverter's behavior. Upon detection, the system can send alerts or take corrective actions such as disconnecting the faulty component or adjusting grid operations to minimize the impact on the overall energy distribution.

IV. PROPOSED SYSTEM

The proposed fault detection system for multi-level inverter used in smart grids builds on advanced techniques to improve the accuracy and speed of fault identification. This system aims to enhance the detection capabilities by integrating real-time monitoring with predictive analytics. The system consists of multiple layers of fault detection where initial faults are detected using basic signal processing methods, followed by more advanced fault classification with machine learning techniques. Sensors are placed throughout the inverter components to gather data related to operational parameters such as current, voltage, temperature, and switching conditions.

The key innovation in the proposed system is the utilization of deep learning techniques that not only detect faults but also predict probable future failures. The system adapts to changes in operating conditions by training models on large datasets collected from inverters that are running under various conditions of faults. This enables the system to learn patterns and detect subtle faults that are difficult to detect using traditional techniques. The proposed system also integrates cloud-based analytics, which enables real-time monitoring and analysis of inverters in large geographic areas and provides real-time feedback to grid operators. The approach enables any detected faults to be corrected in time, reducing downtime and improving the reliability of the smart grid.

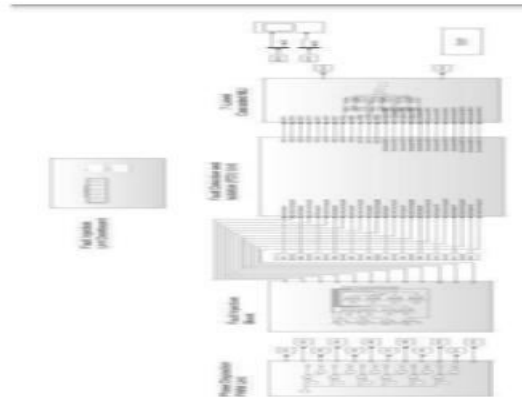


Fig-2:FT-CHB-MLI model

V. CONCLUSION&RESULT

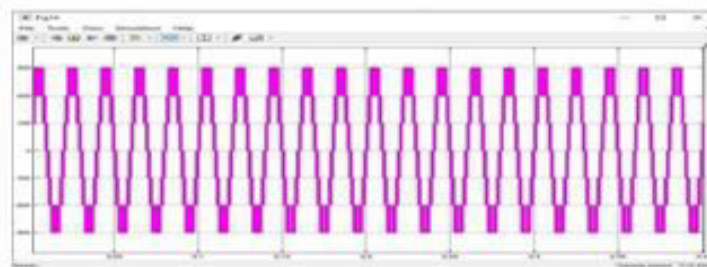


Fig 5.1:output waveforms of the CHB MLI in normal condition

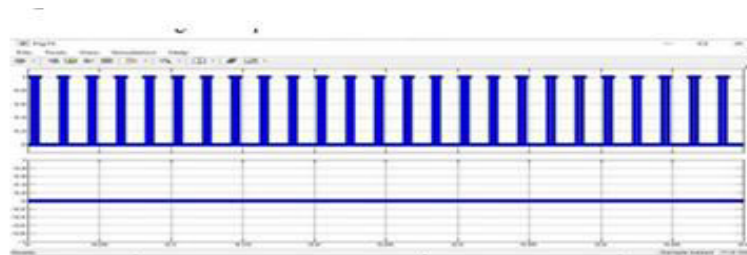


Fig 5.2:switch during normal condition

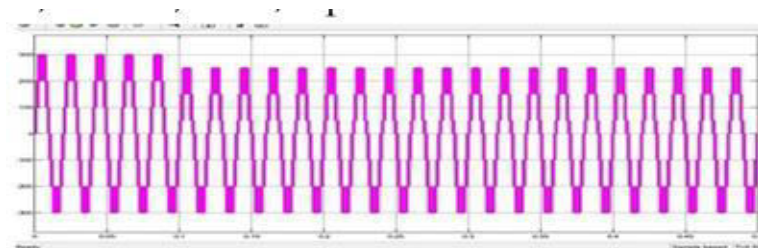


Fig 5.3: ouptut wave forms of CHB MLI during fault condition

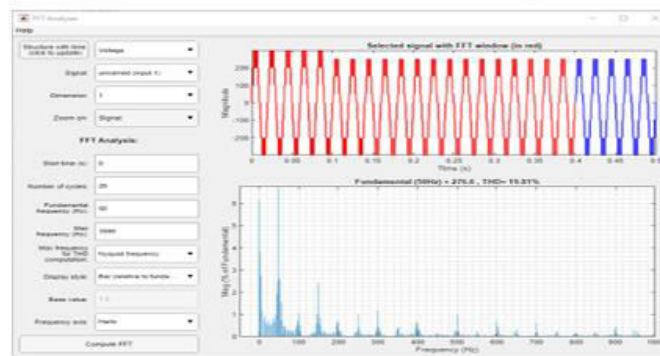


Fig-5.4: Total Harmonic Distortion in case of fault condition

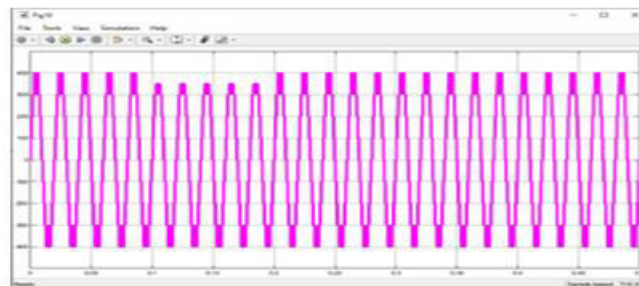


Fig-5.5: Output waveforms of the CHB MLI with AFTC

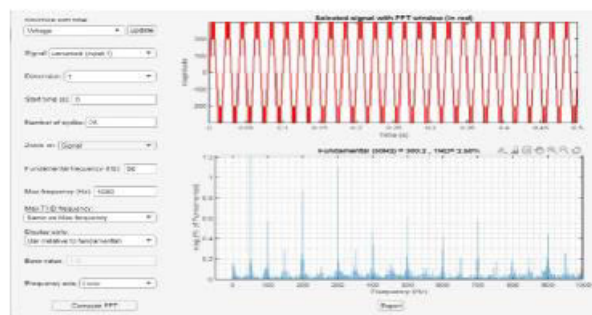


Fig-5.6: Total Harmonic Distortion of the CHB MLI with AFTC

VI. CONCLUSION

A new 7-level Fault-Tolerant Cascaded H-Bridge Multilevel Inverter (FTCHB-MLI) has been proposed to achieve high reliability and high power quality in the current paper. Programmed within the Fault Detection and Isolation (FDI) block the system detects faulty switches by using redundant standby switches for automatic switch replacement. Fault detection happens through the analysis of normalized output voltage factors together with Total Harmonic Distortion measurements. The PD PWM switching offers superior operating performance among the conventional techniques therefore researchers selected it for their application. Markov chains enhance the reliability of system operations. The reviewed literature demonstrates that the system leads to improved operating reliability and power quality. Future research should investigate AI-based fault location techniques with experimental hardware to further develop fault detection technology.

REFERENCES

- [1] C.S. Daher, J. Schmid, and F. L. M. Antunes, “Multilevel inverter topologies for stand-alone PV systems,” IEEE Trans. Ind. Electron., vol. 55, no. 7, pp. 2703–2712, Jul. 2008, doi: 10.1109/TIE.2008.922601
- [2] A. 32.Dekka, O. Beik, and M. Narimani, “Modulation and voltage balancing of a five-level series-connected multilevel inverter with reduced isolated direct current source,” IEEE trans. Ind.Electron., vil. 67, no. 10, pp. 8219- 8230, oct. 2020, dot:10.1109/TIE.2019.2949537
- [3] S. A. Gonzalez, M. I. Valla, and C.F. Cheistiansen, “Five-level cascade asymmetric multilevel converter,” IET Power Electron., vol. #, no. 1, p. 120, 2010, dot: 10.1049/iet pel.2008.0318.
- [4] S. S. Lee, “Single-stage switched-capacitor module (S3CM) topology for cascaded multilevel inverter,” IEEE trans. Power Electron., vol. 33, no. 10, pp. 8203 8207, oct.2018, doi : 10.1109/TPEL. 2018.2805685.
- [5] G.Konstantinou, S. R. Pulikanti, M. Ciobotaru, V. G. Agelidis, and K. Muttaqi, “The seven level flying capacitor based ANPC converter for grid integration of utility-scale PV system,” in proc. 3rd IEEE Int. Symp. Power Electron. Disturb. Gener. Syst.(PEDG), Jun. 2021, pp. 592-597.
- [6] P.N.V.S. Ayyappa, C.Srinivas, and T. R. S. Singh, “A novel way to deal with harmonic elimination in multi level CHB inverter using without filtering technique.” In Proc. Int. Conf. Electron., Common. Aerosp. Technol. (ICECA), Apr.2017. pp. 62-67.
- [7] A. R. Abbaspour, “ Active fault-tolerant control design for nonlinear system,” M>A> thesis, FIU Electron., 2018, vol. 3917.[Online], Available.



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