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Simulation of Renewable Energy Integrated Smart Grid Using ANN and Fuzzy Logic in Matlab

Aditya Kumar[1] and Naushine Abid[2]

*M.Tech Scholar, Department of Electrical Engineering (Power System)[1]

Assistant Professor, Department of Electrical Engineering (Power System)[2]

Shri Phanishwar Nath Renu Engineering College, Araria, Bihar

Abstract: *The increasing demand for clean and sustainable energy has encouraged the development of efficient solar photovoltaic (PV) power conversion systems. This study presents the modelling and simulation of a solar PV system integrating a fuzzy logic controller (FLC)-based maximum power point tracking (MPPT) technique, a Cuk converter, and a multilevel inverter. The proposed FLC-based MPPT controller is employed to effectively extract maximum available power from the PV array under the given operating conditions and enhance the DC voltage to approximately 200 V through the Cuk converter. The boosted DC voltage is subsequently converted into AC using a multilevel inverter controlled by sinusoidal pulse-width modulation (SPWM). Simulation results demonstrate effective voltage enhancement, stable switching operation, and the generation of a constant five-level AC output voltage waveform. The proposed system exhibits significant potential for efficient, reliable, and high-quality renewable energy conversion, making it suitable for various solar PV power applications.*

Keywords: Fuzzy Logic Controller (FLC); Maximum Power Point Tracking (MPPT); Cuk Converter; Multilevel Inverter.

I. INTRODUCTION

A Bidirectional DC-to-DC Cuk Converter is a modified cuk converter topology in which the current flows in a bidirectional way where the diodes in the conventional cuk converter topology are replaced with another switch mostly by a MOSFET switch. This topology has been designed in order to minimize the current ripple at the input end and at the output end of the converter. This converter is a combination of Boost and Buck converter topology that consisted of a series capacitor with the function as an energy storage where the output voltage (Vo) can be adjusted higher or lower than the input voltage (Vin) according to the duty cycle with reverse polarity on output side.

While implementing this kind of bidirectional DC-to-DC cuk converter topologies in the real time applications like Hybrid Electric Vehicles, Energy Storage Applications and other Renewable Energy Applications, it experiences losses due to switching transitions and by means of dv/dt and di/dt losses, as a result it provides a low power conversion efficiency to the load applications with the inclusion of these losses.

In order to overcome these difficulties various soft switching techniques has been implemented with the bidirectional DC-to-DC cuk converter topologies like Zero Voltage Switching (ZVS) and Zero Current Switching (ZCS). This soft switching technique can be achieved by means of clamping action as the resonant circuits absorb almost all the parasitic reactance of switches, including transistor output capacitances which makes this converter, suitable for high-frequency operation. In this paper, the literature review of various bidirectional DC-to-DC cuk converter topologies has been made with respect to their Mode of Operation, Steady State Analysis, and a performance comparison of these converter A capacitor to couple energy. As this converter topology has low power conversion efficiency and has a higher electromagnetic interference and uncontrolled power flow due to wide input voltage variation with respect to the switching losses and dv/dt and di/dt losses, there is a need for a bidirectional dc-to-dc cuk converter to overcome these difficulties.

A bidirectional dc-to-dc cuk converter topology is implemented by replacing the diodes of the conventional cuk converter topology by a MOSFET switch, which allows the current to flow in a bidirectional way as a result it minimizes the current ripple at the input end and at the output end of the converter. Different topologies has been proposed to operate bidirectional dc-to-dc cuk converters in high frequency.

This paper describes about the literature review of various topologies of bidirectional dc-to-dc cuk converters starting from the conventional cuk converter topology, bidirectional dc-to-dc cuk converter topology using Lead Acid Batteries, the bidirectional quasi cuk dc-to- dc converter with reduced voltage stress on capacitor and capability of changing the output polarity, and the Zero Voltage Switching (ZVS) Active-clamping of dc-to-dc cuk converter.

II. LITERATURE REVIEW

Gustavo A. Finamor, (et.al 2025) proposed a constancy examination of a solar electrical phenomenon array (PV) system purposeful in a very practical active Grid. The structure totals twenty kW at rated setting cluster of ten unit with a pair of kW, every unit is fed with an electrical phenomenon sequence and a three level change cell-fed boost DC to DC convertor, consequently connected to the DC-bus of an active Grid. Additionally, to it he bestowed a stability analysis of the solar PV array system, supported MPP and Droop operation modes. He fails to compare the results with various converters.

Smita Sinha, (et.al 2024) proposed about the increased utilization of renewable energy (RE) inside the facility sector, Grid technology is developing speedily. In her reviews associate isolated DC Grid is simulated with PV phenomenon as a result of the renewable energy provide supply power to resistive DC beside a (HESS) energy storage system of Battery and Super device bank. It's ascertained that Energy Storage System helps to scale back DC bus voltage transients terribly effectively all told the things. She fails to discuss about her proposed system for wind energy conversion system.

Md. Khurshedul Islam, (et.al 2024) presents the usual Voltage based Inverter (VSI) or Current based Inverter (CSI) is deals with the key part in the field of individual application. This type of converters are fails to perform at our needed level due to some critical disadvantages like they can execute as either buck mode or boost mode of operation and they have significant amount of both harmonics and EMI noise. So this exiting inverter is replaced by PWM based Z-Source electrical converter (ZSI) that provides each buck and boost modes of operation which capable of utilizing shoot through state and manufacture less EMI noise. It's been proved by victimisation MATLAB Simulink simulation. He fails to gift a MPPT algorithmic rule for optimum electrical outlet trailing.

Faranda. R, (et.al 2023) presents solar power will be vital energy supply within the world. A most electric receptacle technique is required to draw a lot of power from the solar battery to maximise the energy and maintain the operating point of PV array's at MPP. The proposed work presented a comparison of ten various MPP methods in relation to their characteristics and operation costs. The results indicate that the P&O and IC algorithms are the most efficient MPPT techniques. In that the algorithm Perturb and Observe is extensively used to find the maximum power point algorithm and the incremental conductance is not efficient for boost converter. He fails to discuss about his proposed system for wind energy system.

Jung-Sik Choi, (et.al 2022) presents a novel methodology to approximate the utmost power or an electrical phenomenon electrical converter system and trailing method. The Fuzzy and Neural Network (FNN) is projected for optimum outlet trailing (MPPT) and provides a replacement easy thanks to approximate the optimum or rated voltage, current and most power rating created by a solar array and electrical phenomenon electrical converter. The projected FNN management formula obtains quick trailing speed and short steady time higher than standard fuzzy.

Haixin Wang, (et.al 2021) presents a An Energy generation and consumption model has been designed and, based on the models the surplus and shortage of energy demand will be estimated and accordingly the energy transmission algorithm will identify the shortest path for dispatch with minimum loss. Tree topology has been deployed for sharing energy among clusters. The results are proven to be yielding higher system efficiency and more return on investment. Also the algorithms take care of varying energy consumption pattern, fluctuating cost of energy and intermittent renewable energy availability. The algorithm uses the energy forecast data from renewable and consumption pattern from historical data.

A.H.M.A. Rahim, (2022) proposed the optimum MPPT algorithm for maximum power point tracking and has been deployed on a permanent magnet wind generator for feeding an energy to the utility grid. The algorithm P&O depends on stable relationship between the converter powers with the dc electrical energy for different wind speeds. The algorithm P&O does not need the values of wind speed or the wind turbine parameters. Also, the algorithms take care of varying energy consumption pattern, fluctuating cost of energy and intermittent renewable energy availability. Simulations results explain that the wind stream turbine can distribute energy to the electrical grid to maintaining the optimum power coefficient for by chance of varying the wind conditions.

Amit Mendapara, (et.al 2021) presents simulation and analysis of AC-DC fly back convertor that is operated in Discontinuous physical phenomenon Mode (DCM) to feed provide to Vector Controlled PMSM Drive. During this operation conjointly Improved Power Quality at provide current and voltage of PMSM Drive. The review concludes with the low Doctor of Theology worth at provide aspect with power issue improvement.

III. PROPOSED SYSTEM

Recently, a few isolated and non-disengaged topologies for multi-input converters have been presented in light of varied applications. The volume, cost, and complexity of separated converters are increased by the inclusion of transformers along with additional ancillary hardware. Therefore, non-confined converters are better appropriate in a few cases where disengagement is not necessary.

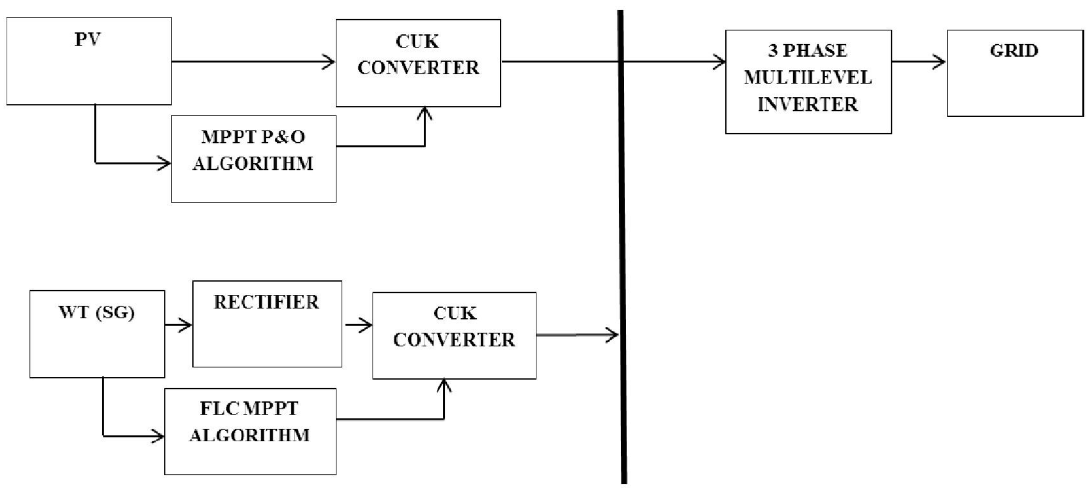

Figure 1 Block Diagram of Proposed system fed CUK Converter

In order to provide each information source with the necessary voltage gain, a three-port converter is proposed in which two lift converters with connected inductors are used. Additionally, two dynamic clasp circuits are used to provide a sensitive exchanging environment and recycle the spilled inductance energy. By using a bidirectional power stream way, this converter shares the charging/releasing way to reduce the number of converter parts. To increase the voltage gain, two lift converters with connected inductors are arranged in this converter. However, this tactic forces the power administration to heavily rely on the power status of each piece of information.

Components of Proposed System

Reducing the number of converter segments is one of the factors that should be taken into account when designing multi-input converters, and sharing converter components is one way to explain this test. In this paper, a new three-port DC-DC converter with one independent stage for each information is proposed so that the part assignments can be altered

according to the operating modes. As a result, a few components are used in different operating modes, resulting in a decreased segment tally.

3.1 CUK Converter

A driver is a circuit that controls another circuit or component, such as a strong transistor, a liquid crystal display (LCD), or one of many other electronic components. They are frequently used to regulate various elements, such as various circuit segments and a few devices, or to manage the current flowing through a circuit. For example, the word is frequently used to describe a specific integrated circuit that operates high-control switches in exchanged mode control converters. An intensifier can also be thought of as a driver for amplifiers or a voltage regulator that keeps a connected component operating within a range of information voltages.

3.2 Three-Phase Multi-Level Inverter

There are more switches and voltage sources in the present S-Type Multi level inverter. One of the most profitable power converters for high power applications and modern applications with few switches is the multilevel level inverter. The 13-level multilevel inverter's fundamentally sound configuration involves getting ventured voltage from a few levels of DC voltages. The controller uses PWM approach to provide true day and age to switches through the driver circuit. MATLAB/Simulink is used to examine the multilevel inverter's execution. This strategy stands out among others since it is different from every other one that is currently in use.

3.3 Fuzzy Logic Converter

In wind energy systems, fuzzy logic controllers have been used to track the MPP. Since they don't need to know the precise model, they have the advantage of being reliable and relatively easy to create.

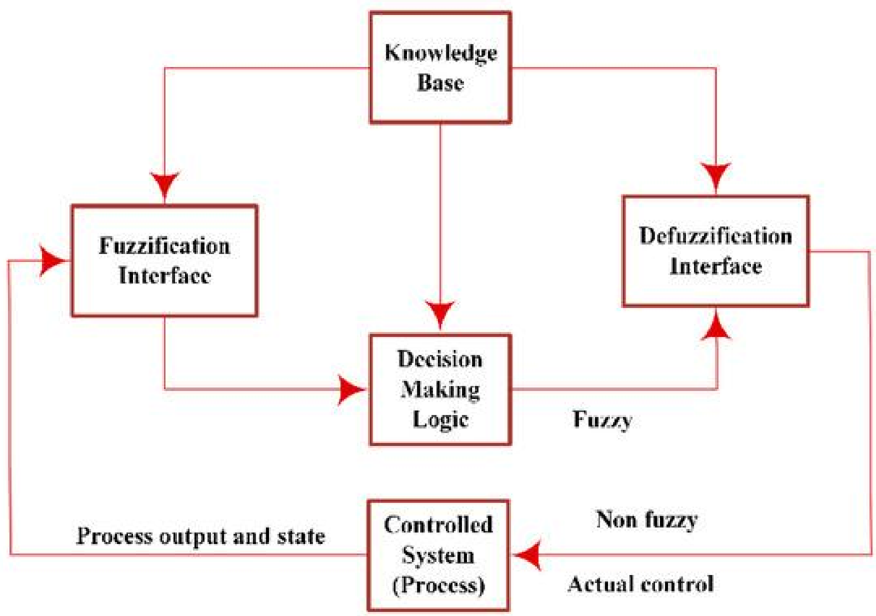

Figure 2. FLC Algorithm Block representation

On the other hand, they do necessitate that the designer has thorough knowledge of how the wind system functions.

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IV. PROPOSED SYSTEM SIMULATION

The MATLAB/Simulink Simulation Software is used to simulate the suggested system. As seen in figure 3, the primary simulation schematic is displayed.

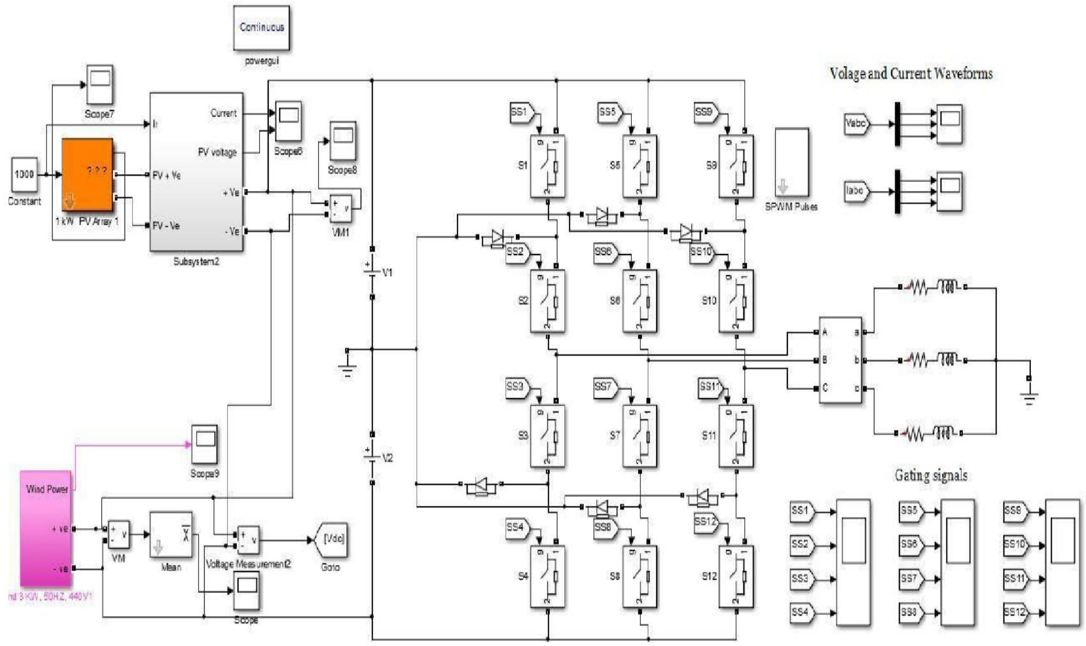

Figure 3. simulation diagram of proposed system

The figure illustrates a MATLAB/Simulink-based photovoltaic (PV) power conversion and three-phase inverter system designed to convert the DC power generated by a PV array into controlled three-phase AC power. The model consists of several interconnected subsystems, including the PV source, DC-link voltage, inverter switching network, SPWM pulse generation, load, and measurement units.

At the left side, a Constant block provides the solar irradiance input, shown as 1000 W/m², which corresponds to Standard Test Conditions. This signal is supplied to the 1 kW PV Array block. The PV array generates electrical output in the form of PV voltage and current, which are measured using scopes and voltage/current measurement blocks. The generated DC power is then connected to the DC-link section, represented by voltage sources V1 and V2, which establish the required DC voltage for the inverter.

The central portion of the model represents a three-phase, three-level inverter topology consisting of twelve semiconductor switches, labelled S1 to S12. These switches are arranged in three legs corresponding to phases A, B, and C. The inverter converts the DC input into a three-phase AC output by appropriately controlling the switching states of the semiconductor devices. The switching signals are generated using Sinusoidal Pulse Width Modulation (SPWM). The gating signals are labelled SS1 to SS12, with each signal controlling its corresponding switch. The inverter output is connected to a three-phase inductive load, represented by three series resistor–inductor branches. This load arrangement enables the analysis of the AC output current and voltage under practical operating conditions.

On the right side, the model includes Voltage and Current Waveforms measurement blocks. The three-phase voltage and current signals are collected and displayed through scopes for analysing the quality and behaviour of the inverter output. Additionally, the Gating Signals section displays the switching pulses applied to the twelve semiconductor switches.

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V. RESULT ANALYSIS & DISCUSION

The modelled proposed system is successfully compiled in the simulation software and the simulation output is observed. The output voltage of PV system is as shown in the figure 4.

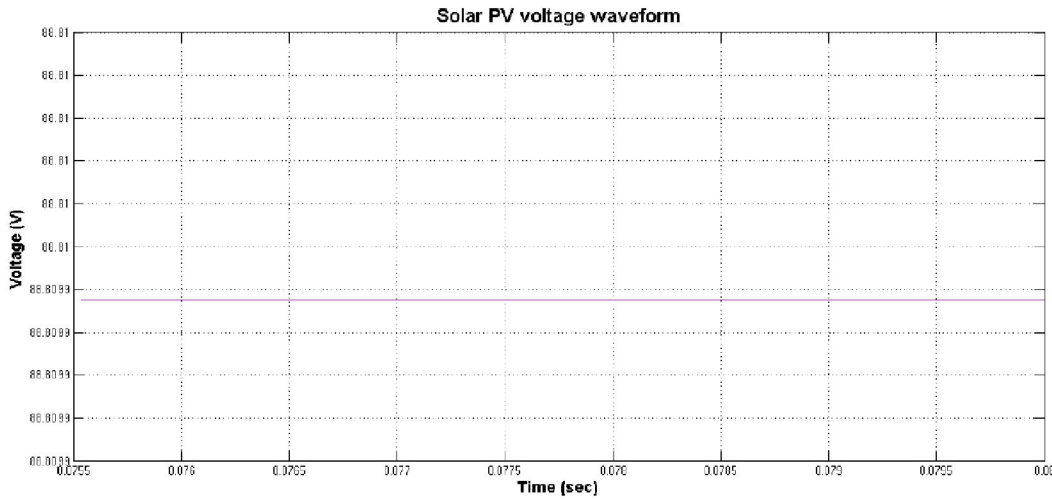

Figure 4 Solar PV Voltage output

The output voltage waveform of proposed wind power system is as shown in the figure 5.

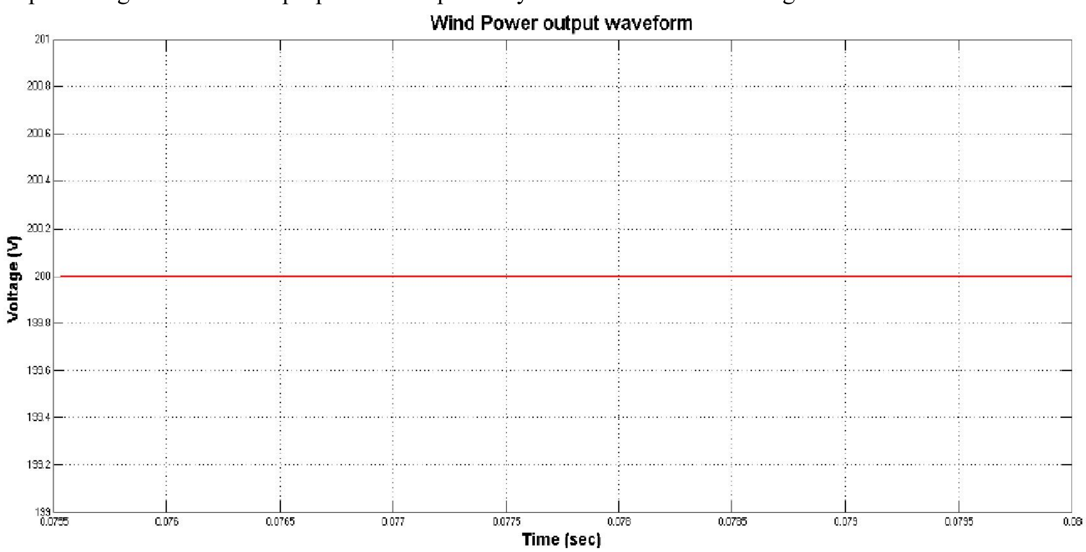

Figure 5 Wind power output voltage waveform

The solar power is enhanced to the main 200 voltage by using FLC MPPT controller the output of MPPT controller is as shown in the figure 6.

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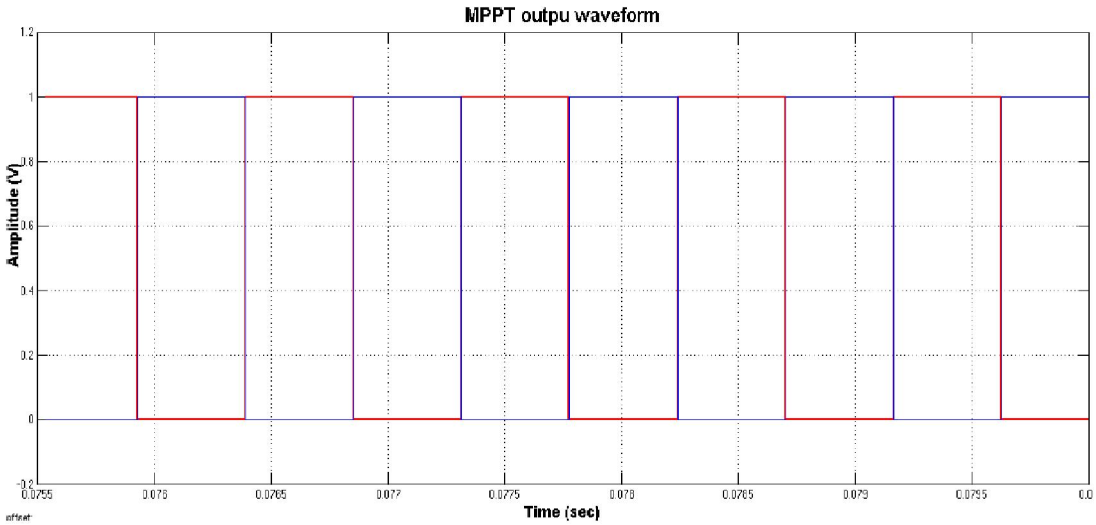

Figure 6 MPPT output pulse for cuk converter

Then the DC output voltage is converted into AC by using proposed multilevel converter. The output is generated with the help of SPWM pulse given to semiconductor devices in the multilevel inverter. The SPWM wave is as shown in the figure 7.

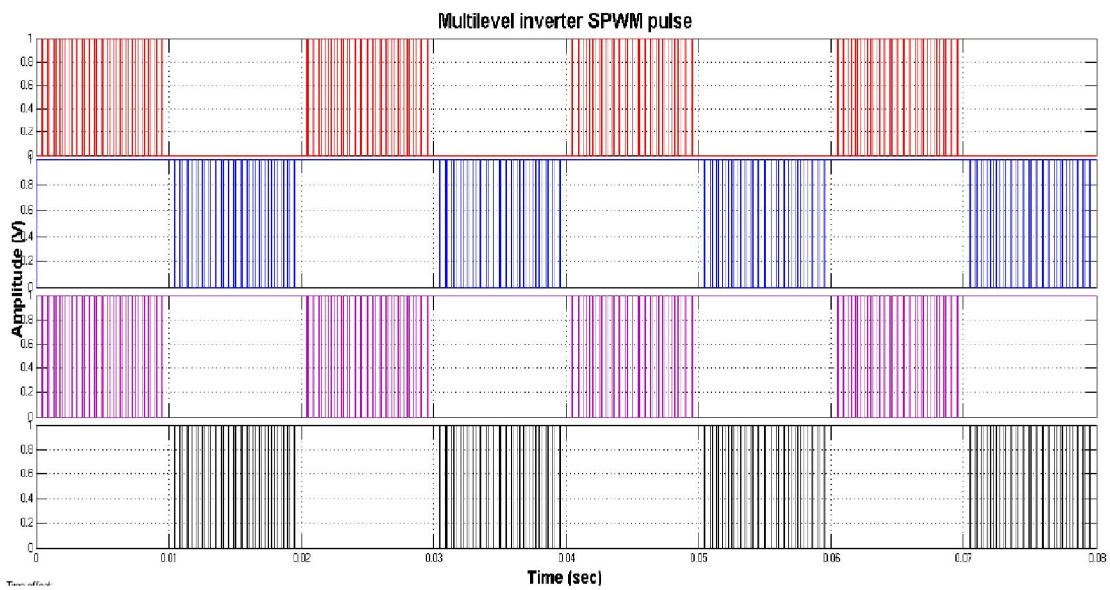

Figure 7 Multilevel inverter SPWM waveform

By SPWM wave to the multilevel inverter the output generated is constant 5 level voltage as shown in the figure 6.11.

VI. CONCLUSION

This study presents the modelling and simulation of an efficient solar photovoltaic power conversion system incorporating an FLC-based MPPT-controlled Cuk converter and a multilevel inverter. The proposed control strategy effectively extracts and enhances the available PV power, achieving a DC output voltage of approximately 200 V.

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Subsequently, the generated DC power is converted into AC through the proposed multilevel inverter using SPWM-based switching control. The simulation results confirm the generation of a stable five-level output voltage with effective switching performance. Overall, the proposed system demonstrates considerable potential for efficient, reliable, and high-quality renewable energy conversion applications

REFERENCES

[1] R.G. del Valle, M. Cotorogea, B. Rabelo and W. Hofmann, "On the emulation of an isolated wind energy conversion system: experimental results". Proc. IEEE Electronics, Robotics and Automotive Mechanics Conf. CERMA '09, 22–25 September 2024, pp. 462–467

[2] N.A. Orlando, M. Liserre, R.A. Mastromauro and A. Dell'Aquila, " A survey of control issues in PMSG-based small wind turbine system" IEEE transactions on Industrial Informatics, vol.9, no.3, pp 1211-1221,July 2024.

[3] S. Sharma and B. Singh, "Asynchronous generator with battery storage for standalone wind energy conversion system," in Proc. 2023 IEEE Ninth International Conference on Power Electronics and Drive Systems(PEDS), pp.345-350.

[4] I. Penava, S. Galijasevic, A. Muharemovic and M. Penava, "Optimal design and demonstrative application of standalone hybrid renewable energy system" IEEE International Energy Conference(ENERGYCON), pp.960-967, 13-16 May 2023.

[5] N. Adhikari, B. Singh, A.L. Vyas and A. Chandra, "Analysis, design andcontrol of a standalone hybrid renewable energy conversion system" 4th IEEE International Power Electronics for Distributed Generation Systems (PEDG), pp. 1-8, 8-11 July 2022.

[6] Emmanouil A. Bakirtzis and Charis Demoulias "Control of a micro gridsupplied by renewable energy sources and storage batteries" 20th International Conference on Electrical Machines (ICEM), pp. 2053- 2059, 2-5 Sept. 2022.

[7] Chen Jian, Che Yanbo and Zao Lihua "Design and Research of Off-grid Wind- Solar Hybrid Power Generation Systems" 4th International Conference on Power Electronics Systems and Applications (PESA), pp. 1-5, 8-10 June 2021.

[8] Fernando Ornelas-Tellez "Optimal Control for a Renewable-energy based Micro-grid", Special session on renewable energy ROPEC, 2021.

[9] K.A. Corzine, J.R. Baker, Reduced parts-count multilevel rectifiers. IEEE Trans. Ind. Electron. 49, 766–774 (2020).

[10] K.A. Corzine, M.W. Wielebski, F.Z. Peng, J. Wang, Control of cascaded multilevel inverters. IEEE Trans. Power Electron. 19(3), 732–738 (2020).

[11] J. Rodriguez, L.G. Franquelo, S. Kouro, J.I. Leon, R.C. Portillo, M.A.M. Prats, M.A. Perez, Multilevel converters: an enabling technology for high-power applications. Proc. IEEE 97(11), 1786–1817 (2019).

[12] F.Z. Peng, A generalized multilevel inverter topology with self-voltage balancing. IEEE Trans. Ind. Appl. 37, 611–618 (2019).

[13] M.D. Manjrekar, P.K. Steimer, T.A. Lipo, Hybrid multilevel power conversion system: a competitive solution for high-power applications. IEEE Trans. Ind. Appl. 36, 834–841 (2018).

[14] Bala BK, Siddique SA. Optimal design of a PV–diesel hybrid system for electrification of an isolated island – Sandwip in Bangladesh using genetic algorithm. Energy for Sustainable Development 2018; 13(3):137–42.

[15] Koutroulis E, Kolokotsa D, Potirakis A, Kalaitzakis K. Methodology for optimal sizing of stand-alone photovoltaic/wind generator systems using genetic algorithms. Solar Energy 2016; 80(9):1072–88.

[16] Yang H, Zhou W, Lou C. Optimal design and techno-economic analysis of a hybrid solar wind power generation system. Applied Energy 2019; 86(2):163–9.

[17] Lopez RD, Agustin JLB. Design and control strategies of PV– diesel systems using genetic algorithms. Solar Energy 2015; 79(1):33–46.

[18] Daud Abdel-Karim, Ismail M., Kukhun Walid and Mahmoud Marwan M., Simulation of a Hybrid Power System Consisting of Wind Turbine, PV, Storage Battery and Diesel Generator: Design, Optimization and Economical Evaluation, International Journal of Energy Engineering.

[19] Khan M. J., Iqbal M. T., Analysis of a small wind-hydrogen standalone hybrid energy system, Applied Energy 2019; 86(11):2429- 2442.

[20] Lagorse Jeremy, Simoes Marcelo G., Miraoui Abdellatif, Costerg Philippe, Energy cost analysis of a solar-hydrogen hybrid energy system for stand-alone applications, International Journal of Hydrogen Energy 2018;33(12):2871-2879.

[21] G. C. Seeling-Hochmuth, A combined optimization concept for the design and operation strategy of hybrid-PV energy systems, Solar Energy, Volume 61, Issue 2, August 2017, Pages 77-87.