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Artificial Intelligent Based Controller to Improve the Power Quality of Grid Connected Solar PV System

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Abstract- Grid-connected photovoltaic (PV) power systems are becoming increasingly common in many nations. Achieving optimal power and high power quality in a grid-connected photovoltaic system is regarded as one of the major problems. To this end, a novel cascade multilevel inverter (MLI) is suggested for PV system grid integration, and artificial intelligence (AI) controller-based maximum power point tracking (MPPT) algorithm has been studied for PV system. The suggested cascade MLI is best suitable for PV systems as it has fewer power electronic switches in its architecture and can run at asynchronous voltage sources. By raising the output voltage level, this suggested inverter can lower the total harmonic distortion (THD) at the output side, improving the system's power quality. An AI-based voltage source controller has been used to regulate the proposed inverter's micro-grid integration. The system has been constructed and simulated in a MATLAB environment under a variety of loads and weather scenarios.

Keywords— Grid-Connected Photovoltaic, Power Systems, Multilevel Inverter, Maximum Power Point Tracking.

INTRODUCTION

The use of fossil fuels for transportation and power generation, together with greenhouse gas emissions, is contributing to global warming, which is quickly becoming the most urgent issue facing humanity. Many countries have focused on renewable energy sources like solar and wind in recent years. In order to raise the solar-specific RPOs from 0.25 percent in 2012 to 3% in 2022, the Indian MNRE amended the regulation in January 2011. Additionally, the NAPCC projects that by 2020, the whole energy mix will include at least 15% renewable energy. Solid-state electronics has been crucial in facilitating the dispersion of power sources and renewable energy, which have conventionally been utilized in various network architectures. There were also other interface elements and checking strategies employed. They choose to modify their equipment and control protocols in order to optimise the benefits of the system. Microgrids now use a variety of alternative and renewable energy sources. These technologies are favoured in microgrids due to their capacity to optimise resource utilisation, improve power efficiency, and increase source stability. Multi-microgrids, interconnected AC-AC microgrids, and interconnected AC-DC microgrids are examples of modern grid infrastructure. Renewable energy sources and clean energy are optimised by this innovative network architecture. By linking two or more microgrids, it is possible to share resistance, voltage, and frequency as well as reserves, which increases overall durability and efficiency. Clean DC outputs are produced by fuel and PV systems. The configuration and control of output voltage depend heavily on the conversion of DC-DC and AC-DC converters. MPPT and DC-DC converters currently use Boost, Buck, Buck-Boost, and Cuk converters. The main drawbacks of conventional controllers are high output ripple current and voltage. Numerous academics focused on the aforementioned issue and discovered a solution in the Super-lift Luo converter. The Super-lift Luo converter has low ripple current and voltage. For increasing voltage and MPPT controller design, the super lift Luo converter is hence superior. In a same vein, they have been managed and regulated using a variety of control systems and tactics. The major goal of their control techniques and network topologies is to fulfil load needs while optimising advantages. These days, microgrids use a lot of alternative and renewable energy technology. Microgrid deployment of these new technologies is chosen because it offers several benefits, including better resource utilisation, higher power quality, and increased supply stability. Zone-based grid design, multi-microgrids, interrelated AC–AC microgrids, and interlinked AC–DC microgrids are some of the most sophisticated grid architectures that have recently come into existence.

PV SYSTEM MPPT ALGORITHM BASED ON ARTIFICIAL INTELLIGENCE

(i) PV system- Natural resources are the sole supply of energy from renewable sources, which results in nonlinear power generation. All renewable energy sources must use the MPPT algorithm in order to control and produce their maximum power under a range of operating situations (Anandha kumar et al. 2013). In the past, MPPT algorithms including P&O, incremental conductance, feedback voltage and current, feedback power, and various expert system-based algorithms have been implemented with conventional controllers. Due to the relatively low voltage production of PV cells, a single PV cell is unable to supply all consumer demands for electricity. PV cells are therefore set up in an array to provide high power. In order to get the required voltages, the PV cells in the array are first placed in series. Later, they are stacked in parallel to increase the system's current output. In this way, a 30 kW photovoltaic module has been constructed. Figure 1 depicts the MPPT with fuzzy controller scheme intended for a 30 kW photovoltaic system. the aforementioned model has been created in MATLAB Simulink. A 30 kW PV array has grown in this simulation model, which includes two input sources temperature and solar irradiation. The fuzzy based MPPT controller linked to the 30 kW PV array can generate the duty cycle for the boost converter. The output of the PV system is sent into an MPPT with a fuzzy controller (Chen et al. 2017) for analysis, producing a steady PV output power that can adjust to different irradiance circumstances.

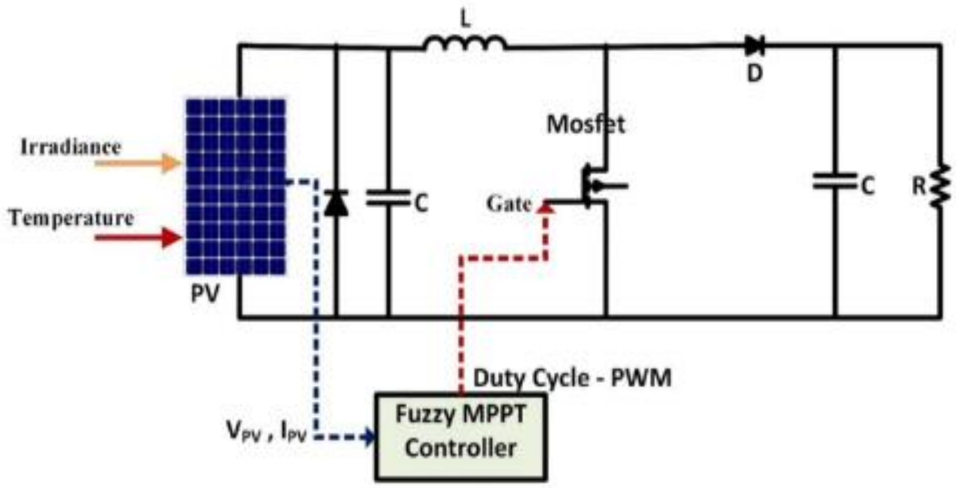

Figure 1-MPPT with fuzzy algorithm for PV system controller block diagram

(ii) Fuzzy rules formation for MPPT controller- Figure 2 shows the inputs, such as the PV cell's voltage and current, that the converter needs to create the necessary output, or duty cycle. Using the triangle function, a membership function that incorporates the fuzzy controller's input and output has been built. A fuzzy value can be transformed into a crisp value using the centroid approach. There are three categories in the fuzzy input membership function for solar voltage and current: small, medium, and high. The definition of a membership function for a fuzzy set-A on the discourse X universe is μA:X-> [0,1], where the value of each element of X ranges from 0 to 1. The grade of membership of the element in $\vec{X}$ is quantified by this value, which is known as the degree of membership.

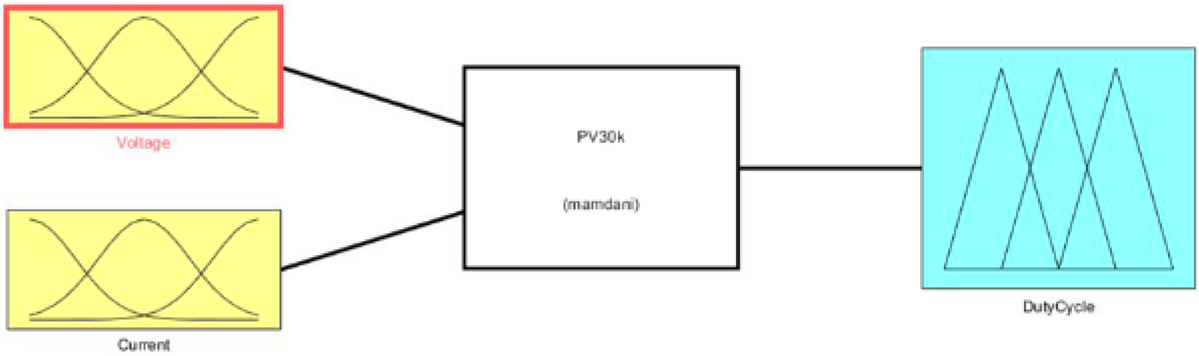

Figure 2- Fuzzy triangle membership function. b Fuzzy controller-based MPPT algorithm

FUZZY MPPT BASED PV SYSTEM

(i) The framework of Photo Voltaic System- Natural resources called renewables are employed to produce non-linear power. In any renewable energy system, the MPPT Algorithm plays a crucial role in controlling and generating maximum power. Important is the MPPT Algorithm. P&O, incremental conductance, voltage and current, input capacity, and other systems-based expert algorithms are examples of recent MPPT controllers. Because PV cells produce voltage at a low level, they are unable to provide the market's need for electricity. These PV cells are of the high energy series. The recommended system with the super-lift Luo converter is seen in Figure 3. In this circuit, a solar array is connected in place of a DC power source. PV cells in a solar array are first linked in series to produce the desired voltages, and then in parallel to provide higher current. This PV module is 5300W. In contrast, the 5300 W PV array may supply a gate signal for the converter switches using a fuzzy MPPT-based controller. The fuzzy - MPPT algorithm for the 5300 W PV system was developed in this paper and is based on a super lift Luo converter. By analysing the PV device output, the Fuzzy - MPPT controller generates a dependable PV output that can adapt to changing irradiance conditions.

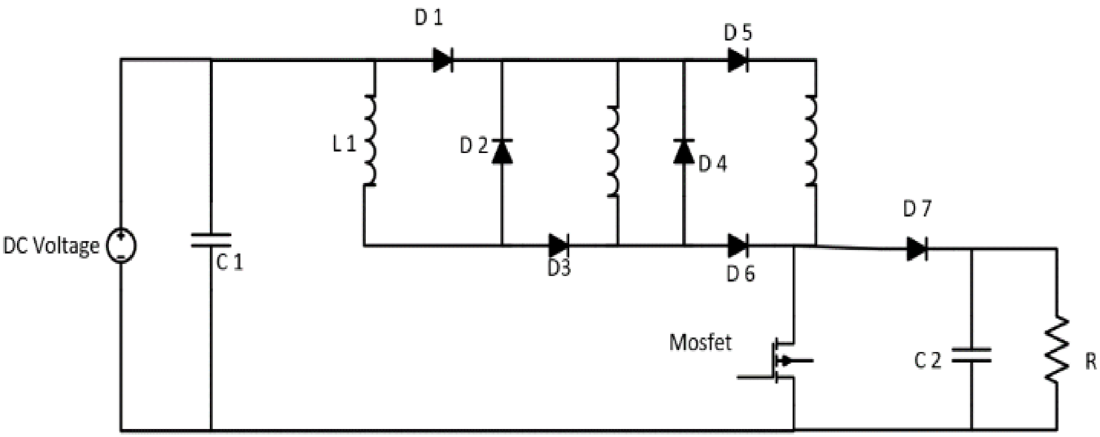

Figure 3- Super lift Luo converter topology

(ii) Fuzzy based MPPT controller- As shown in Figure 4, the fuzzy controller has two inputs photovoltaic voltage and current and one output, which is the duty cycle of the solid-state switches in the converter. The trapezoidal function was utilized to create the fuzzy input and output membership function, which is divided into three ranges: low, medium, and high. Fuzzy rules have been established for input and output membership functions based on these ranges.

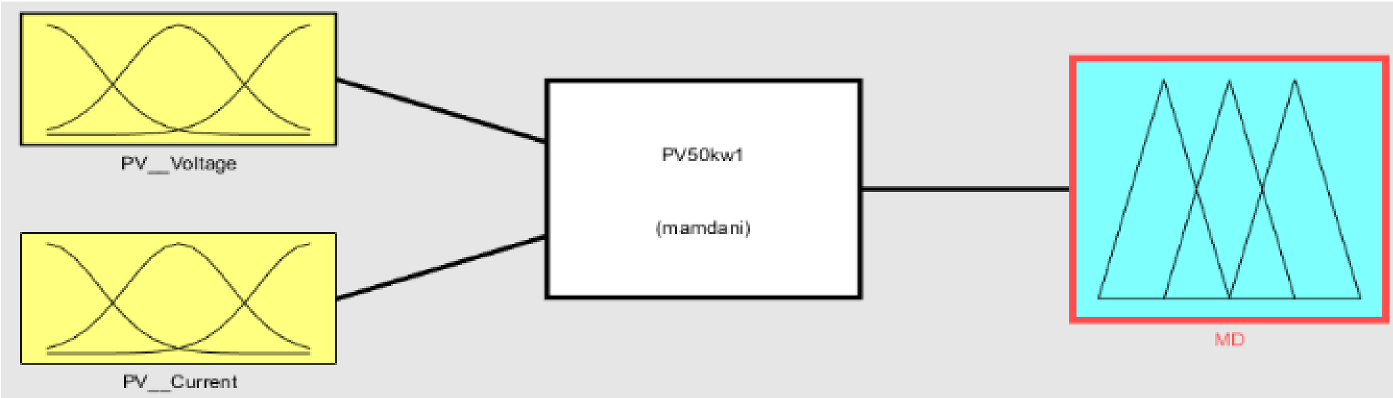

Figure 4- Fuzzy controller based MPPT algorithm

GRID INTEGRATION USING A MULTILAYER INVERTER FOR PV SYSTEM OUTPUT

(i) Grid integration of PV system- A MATLAB simulation of the PV system's grid integration using a suggested multilevel inverter and fuzzy controller is provided, along with a design overview for the PV system's grid integration using a novel cascaded MLI. This circuit uses a planned cascade multilevel inverter to integrate six PV systems into the grid. The voltage source converter (VSC) unit uses the grid characteristics as references to create PWM for the planned MLI, while the inverter provides the pure output that is supplied to the grid. In order to synchronise with PV and the grid, the VSC-based controller has been essential (Babaei et al. 2016a; Hemanand et al. 2018; Venkateshkumar and Raghavan 2015; Venkateshkumar 2019a). Because of the inverter's improved design, the system's power quality is increased by lowering the THD level for both the current and the voltage waveform.

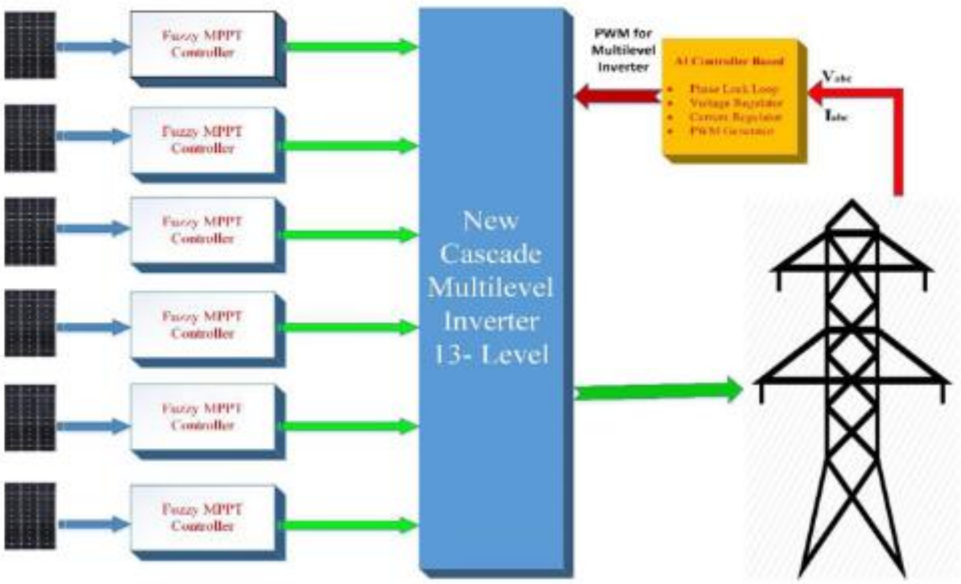

Figure 5- Grid integration of new cascade multilevel inverter for proposed PV system and its controller

(ii) Design of voltage source control unit- Three main sub divisions of the VSC unit are including a voltage regulator, phase-locked loop (PLL), and current regulator. Synchronising the frequency between two AC sources is aided by the phase-locked loop. The PV system is linked to a novel cascade multilevel inverter in this article, and the suggested inverter uses PLL to synchronise with the microgrid. The grid voltage, current, and frequency are monitored by this PLL loop. The grid voltage and current are translated into the ABC and d_q axes and sent to the current regulator for comparison with the characteristics of the inverter output. The voltage regulator controls an inverter's output voltage in relation to the grid voltage. In order to manage the inverter output voltage in relation to the reference voltage, a voltage regulator controller is used. The reference voltage and measured inverter input voltage are compared by the voltage regulator. The PI controller is coupled to a current regulator and produces direct axis reference current based on error signals. When the I_d current is positive, the current regulator will regulate the inverter operation of the proposed system. When the I_q current is positive, the inverter creates the active power and monitors the reactive power. The suggested multilevel inverter's output signal is produced by the PWM generation system in order to synchronise it with the power grid.

(iii) Fuzzy rules formation for current regulator- This study proposes a current regulator that makes use of fuzzy controller features. The fuzzy controller is connected to two input signals (direct axis and quadrature axis current) and two output signals (controlled direct axis and quadrature axis current), (Hemanand et al. 2018; Venkateshkumar and Raghavan 2015; Venkateshkumar 2019a, b, c, d). The centroid approach for defuzzification and the triangle method for fuzzification have served as the foundation for the formulation of the fuzzy membership function. While the current regulator produces a positive direct axis current, the converter exports active power to the grid. According to Venkateshkumar and Raghavan (2015), the current regulator produces a positive quadrature axis current, while the converter monitors reactive power from the grid. As shown, the input membership function of the quadrant axis current and the direct axis current has been divided into two ranges: low and high. Based on the membership functions of the input and output, fuzzy interference rules are formed and the output membership function of the regulated direct axis and quadrant axis current is categorised into two ranges: low and high.

CONCLUSION

Using MATLAB Simulink, the super lift Luo three-stage converter was built, and its output was tested in a range of operating scenarios. The purpose of the fuzzy logic controller was to assess the solar system's and the super lift Luo converter's performance in a range of meteorological conditions. MATLAB was used to model the proposed PV-new CMLI grid integration. As the quantity of new CMLI rises, more switches will be employed in the system, which will raise the PV system's harmonic content. IEEE 519 and 1547 were used to mimic the fuzzy logic controller's output in order to demonstrate the recommended system quality. This allowed for multi-level inverter grid integration. Lastly, for both grid and autonomous industrial applications, the proposed multilayer inverter and controller system is strongly advised hybrid sources of renewable energy. With the aid of a newly suggested cascade multilevel H-bridge inverter that requires fewer switch deployment, this research explores the operation and control techniques of grid integration of PV power systems. The MPPT system for the PV uses a fuzzy controller, which is modelled, simulated, and its performance is examined in different weather scenarios. MATLAB has been used to model the proposed grid integration of PV using a novel cascade inverter (13 level), with detailed illustrations of the findings. The circuit design complexity and number of switches employed in the system will both rise as we raise the levels of cascading MLI in the system. This will also increase the harmonic content found in photovoltaic systems. The fuzzy controller was created for PV multilevel inverter grid integration, and it evaluated the device's performance in a range of scenarios.

REFERENCES

[1] N. B. Deshmukh, R. D. Thombare, P. T. Jadhav and D. S. More, "MISO Luo DC-DC converter for renewable energy applications," International Conference on Energy Systems and Applications 2015, pp. 63-68. Pune (2015).

[2] J. R. Christina and J. Pradeep, "Design and implementation of wind energy based improved positive output super-lift Luo converter," Second International Conference on Science Technology Engineering and Management (ICONSTEM - 2016), pp. 287-292. Chennai, (2016).

[3] S. A. Nath and J. Pradeep, "PV based design of improved positive output super-lift Luo converter," Second International Conference on Science Technology Engineering and Management (ICONSTEM - 2016), pp. 293-297. Chennai, (2016).

[4] G. Anandhakumar, M. Venkateshkumar, and P. Shankar, "Intelligent controller based MPPT method for the Photovoltaic power system," International Conference on Human-Computer Interactions (ICHCI - 2013), pp. 1-6. Chennai, (2013).

[5] F. A. Silva, "Advanced DC\/AC Inverters: Applications in Renewable Energy (Luo, F.L. and Ye, H.; [Book News]," in IEEE Industrial Electronics Magazine, vol. 7, no. 4, pp. 68-69, Dec. (2013).

[6] E. Babaei, M. Sarbanzadeh, M. A. Hosseinzadeh, and C. Buccella, "A new topology for cascaded multilevel inverters with a reduced number of power electronic switches," 2016 7th Power Electronics and Drive Systems Technologies Conference (PEDSTC – 2016), pp. 165- 170. Tehran, (2016).

[7] K. Chen et al., "Cascaded iH6 multilevel inverter with leakage current reduction for transformerless grid-connected photovoltaic system," IEEE 12th International Conference on Power Electronics and Drive Systems (PEDS - 2017), pp. 613-617. Honolulu, HI,(2017).

[8] Venkateshkumar, M., Raghavan, R. and Kumarappan, N., Design of a New Multilevel Inverter Standalone Hybrid PV/FC Power System. Fuel Cells, 15: 862-875. (2015).

[9] E. Babaei, M. A. Hosseinzadeh, M. Sarbanzadeh, and C. Cecati, "A new basic unit for cascaded multilevel inverters with a reduced number of power electronic devices," 7th Power Electronics and Drive Systems Technologies Conference (PEDSTC – 2016) , pp. 185- 190. Tehran, (2016).

[10] M. Venkateshkumar and R. Raghavan, "Fuel cell power penetration into AC distribution grid by using new cascade multilevel inverter with minimum number of switches," 2015 International Conference on Smart Technologies and Management for Computing, Communication, Controls, Energy and Materials (ICSTM– 2015), pp. 568-574. Chennai, (2015).

[11] Mahendravarman, I., Elankurisil, S.A., Venkateshkumar, M. et al. Artificial intelligent controller-based power quality improvement for microgrid integration of photovoltaic system using new cascade multilevel inverter. Soft Computing (2020).

[12] Dr.M. Venkateshkumar (2020). AI based Hybrid PV – FC and Wind Power system using MLI ,MATLAB Central File Exchange. Retrieved July 31, 2020.

[13] Anandhakumar G, Venkateshkumar M, Shankar P (2013) Intelligent controller based MPPT method for the photovoltaic power system. In: 2013 international conference on human computer interactions (ICHCI), Chennai, pp 1–6.

[14] Babaei E, Hosseinzadeh MA, Sarbanzadeh M, Cecati C (2016a) A new basic unit for cascaded multilevel inverters with reduced number of power electronic devices. In: 2016 7th power electronics and drive systems technologies conference (PEDSTC), Tehran, pp 185–190.

[15] Babaei E, Sarbanzadeh M, Hosseinzadeh MA, Buccella C (2016b) A new topology for cascaded multilevel inverters with reduced number of power electronic switches. In: 2016 7th power electronics and drive systems technologies conference (PEDSTC), Tehran, pp 165–170.

[16] Chen K et al (2017) Cascaded iH6 multilevel inverter with leakage current reduction for transformerless grid-connected photo-voltaic system. In: 2017 IEEE 12th international conference on power electronics and drive systems (PEDS), Honolulu, HI, pp 613–617.

[17] Christina JR, Pradeep J (2016) Design and implementation of wind energy based improved positive output super-lift Luo converter. In: 2016 second international conference on science technology engineering and management (ICONSTEM), Chennai, pp 287–292.

[18] Venkateshkumar M, Raghavan R, Kumarappan N (2015) Design of a new multilevel inverter standalone hybrid PV/FC power system. Fuel Cells 15:862–875.