FUZZY LOGIC CONTROLLER BASED MPPT METHODS FOR THE MULTILEVEL INVERTERS TO THE ELECTRIC VEHICLES

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Abstract - The effective and conservative design of Multi level inverters (MLI) spurs different applications, for example, solar powered PV and electric vehicles (EV). This paper proposes a staggered inverter geography in light of an exchanged capacitor (SC) approach. The quantity of degrees of MLI is planned in light of the fountain association of the quantity of SC cells. The proposed structure is direct and simple to carry out for the more significant levels. As the quantity of dynamic switches is less, the driver circuits are diminished. This lessens the gadget count, cost, and size of the MLI. This paper presents the plan and displaying of a fluffy regulator for following the greatest power point of a PV Framework. PV module, buck converter and fluffy regulator; featuring as principal curiosity the utilization of a numerical model for the PV module, which, not at all like diode based models, just has to work out the bend fitting boundary. A P&O regulator to contrast the outcomes got and the fluffy control was planned. The reenactment results exhibited the predominance of the fluffy regulator concerning settling time, power misfortune and motions at the working point. Near examination of the decreased switch inverter geographies in view of the part count, all out consonant twisting of result voltage, and effectiveness is additionally introduced in this paper. The sunlight powered chargers, alongside a Molecule swarm Enhancement (PSO) calculation, give a steady DC voltage and is helped over the DC connect voltage utilizing a solitary info and multi-yield converter (SIMO). A Recreation model is carried out and confirmed tentatively under powerful burden varieties, though the reenactments are finished in MATLAB/Simulink.

Key Words: multilevel inverters (MLI), solar PV and electric vehicles (EV), switched capacitor (SC) maximum power point, fuzzy, single input and multi-output converter (SIMO).

1. INTRODUCTION

With the interest for an expansion in the necessities of high-power quality in modern applications and sun based PV Systems, the traditional inverters in gathering the ideal circumstances like an unadulterated sine-wave yield and less consonant contortions is a difficult errand. The staggered inverters get more consideration in arriving at the ideal prerequisites and goes about as an option in conveying a nature of force. It gives a few benefits, for example, decreased gadget count, works in low exchanging recurrence, diminished dv/dt stress, less consonant twists, and so on [1]. The new staggered inverter geographies contain fewer parts utilized in the circuit contrasted and the ordinary inverters, for example, flying capacitor type (FC) [2], flowed H-span type (CHB) [3], and the impartial point clipped type (NPC) [4]. The quantity of parts in the circuit is straightforwardly corresponding to the quantity of levels in MLI, which inflates cost and complex design [5]. In both the FC MLI and NPC MLI, the capacitor voltage adjusting is a difficult undertaking with which these are restricted to five-level and unfit to flow.

For a PV took care of inverter, in delivering a steady DC voltage, there is a requirement for a control procedure. A standard PI regulator acknowledged in the independent PV framework to choose a legitimate obligation pattern of the DC converter by contrasting the converter result and reference [6]. It isn't alluring to have command over the DC converter with the MPPT strategy, and thus different geographies are proposed to tackle this issue for the independent planetary group. In the new past, a few high level methods like computerized reasoning (computer based intelligence), functional multitude enhancement (PSO), fluffy and hereditary calculation (GA) to have an auto-control with respect to the preparation information to manage voltage [7]. The determination of the MPPT strategy for a reasonable application is a shocking undertaking where each technique has its own benefits and faults. For instance, slope climbing (HC), bother, and noticing (P&O) and are broadly utilized MPPT techniques on account of their straightforward execution. Under fractional concealing circumstances, the regular strategies like fluffy, P&O, INC calculations can't remove worldwide MPP (GMPP) [8 Both sun oriented irradiance and temperature change during day time for climatic circumstances and contingent upon the season. Thus, it is imperative to follow this multitude of boundaries and get greatest power point.

In this paper, a sun based PV framework is executed utilizing a 17 level staggered inverter coordinated with a solitary info, and different result DC support converter is introduced. P&O controlled MPPT procedure is executed in the proposed framework to separate pinnacle energy from the sunlight powered chargers. DC voltage from the between the sunlight powered chargers took care of to the single info and different result support converter where the voltage gets helped to the ideal level and given to the 17-level inverter. The SC units are flowed to accomplish 17 degree of result voltages. Execution of these MLIs in view of numerous such boundaries like gadget count, power misfortunes, proficiency, THD is contrasted and different MLI geographies and addressed. The carried out framework is tried in MATLAB/Simulink, though it is tried tentatively with an equipment arrangement.

Closest level control (NLC) tweak is utilized for the inverter control. As the HFL is bidirectional, the inverter shows magnificent execution during regenerative slowing down of the EV. The switches of the principal converter work at the essential recurrence, and subsequently, the exchanging misfortunes are significantly diminished. It is appropriate for medium-and hard core EV applications. Ounejjar et al.30 presented a stuffed U cells seven-level inverter that consolidated the benefits of FC MLI and CHB MLI. A solitary stage PUC MLI contains six switches, one DC source, and one capacitor. Figure 5 portrays the circuit chart of a solitary stage PUC MLI. The result voltage had seven levels with yield voltage contortion of 25.23% and a result current twisting of 4.96%. This geography is just liked for low-power applications and isn't reasonable for high-power applications where a high-voltage yield is gotten with low information DC voltage. Besides, as the capacitor has only one charging way, the DC-connect voltage doesn't stay steady when the capacitor is released for quite a while. This is the fundamental restriction of PUC MLI. The exchanging example of a seven-level PUC MLI. It is reasonable for medium-and uncompromising EV applications.

2. MODELLING OF PV AND DC-DC BOOST CONVERTER

2.1 MODELLING OF SOLAR PV

The modeling of a solar cell is an important segment of analyzing a solar PV system. The overall proposed circuit comprises solar panels, a three-level DC-DC boost converter fed to 17-level MLI shown in Figure 1. The solar PV can be modeled with three categories such as an equivalent circuit with current-voltage (I-V) and power-voltage (P-V) characteristics, the effect of solar irradiance and temperature, and the partial shading condition is taken into consideration.

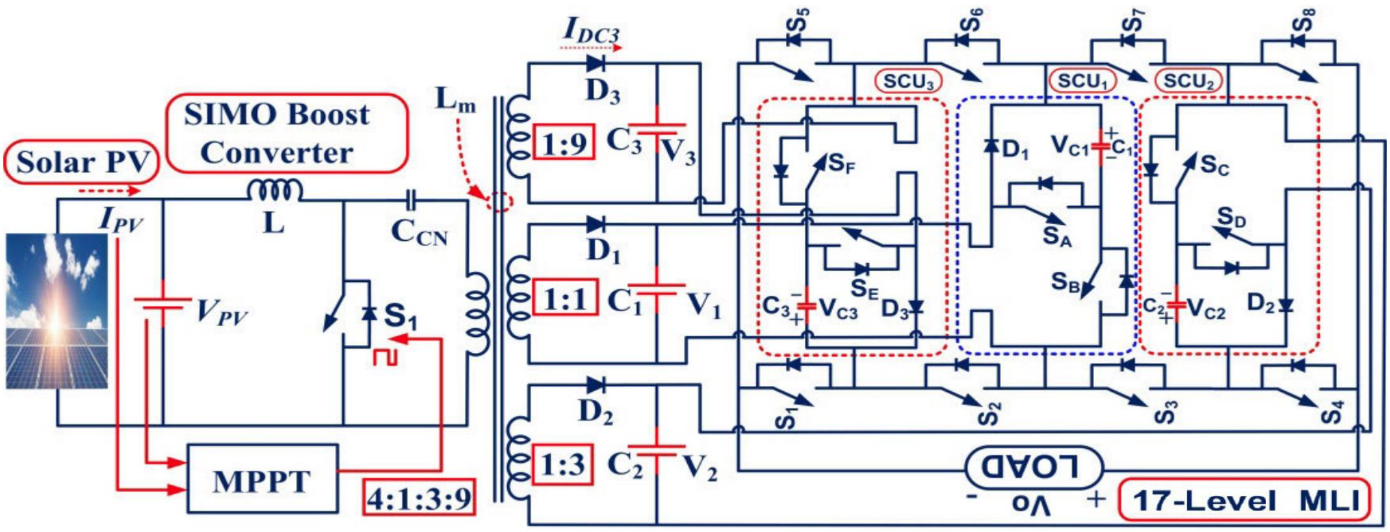

Figure 1. Overall structure of the proposed system.

PV resembles two words photo and voltaic: photo represents the photonic energy and voltaic represents the electrical energy, which implies that the energy conversion from photonic energy into electrical energy [1]. The designed solar PV has a behavior of changing its output with the variation of temperature and climatic conditions [2].

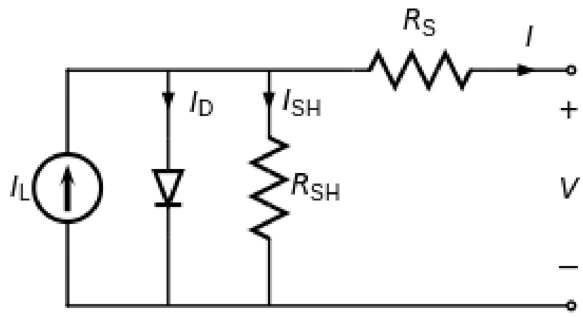

Figure 2. Equivalent circuit of solar cell.

2.2 SOLAR CELL: EQUIVALENT CIRCUIT AND I–V CHARACTERISTICS

The solar cell comprises internal resistance RSE and RSH connected to the diode in series and parallel combination, known to be an equivalent circuit shown in FIGURE 2. VPV and IPV are the output voltage and current of a solar cell, respectively. These are got from the series and parallel connection of several PV modules shown in equation (1),

$$I_{PV} = \left\{ I_{Ph} - I_0 \left[exp\left(\frac{q(V_{PV}+R_{SE}I_{PV})}{N_{SE}AKT}\right) - 1 \right] - \frac{(V_{PV}+R_{SE}I_{PV})}{N_{SE}R_{SH}} \right\} \quad (1)$$

where NSE and NSH are the number of PV cells in series and parallel connection. RSE is the series resistance, and RH is the parallel resistance. A is the ideality factor of a semiconductor device. K is Boltzmann's constant (1.3806503 × 10−23 J/K), T is 'he temperature. Ip is the current produced and is depends on the irradiation and temperature shown in equation (2)

$$I_P = [I_{SK-STM} + K_i (T - T_{STM})] - \left(\frac{G}{G_{STM}}\right) \quad (2)$$

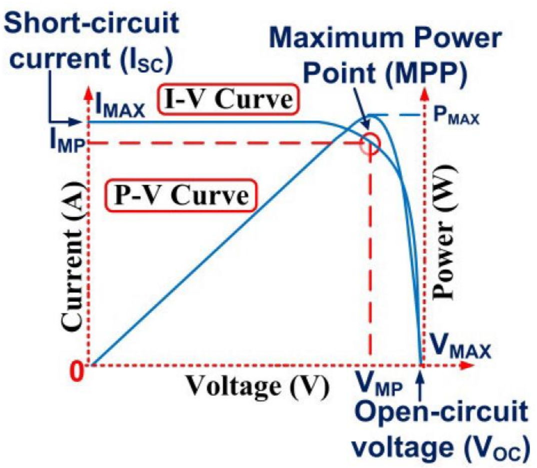

Figure 3. I-V Characteristics of solar cell.

where ISK−STM is a short-circuited current at standard testing cases (STM), Ki is the SCC coefficient, G (W/m2) is the irradiance on the surface of the cell, GSTM (1000W/m2) is the irradiance at STM, and the cell temperature is TSTM [13].

$$I_O = \left\{ \frac{I_{SK-STM} + K_i (T - T_{STM})}{exp\left[(V_{OK-STM} + K_{OV} (T - T_{SKC}) / AV_{Sth})\right]} \right\} \quad (3)$$

where VOK−STM is an open-circuited voltage at the standard testing case, KOV represents the open-circuit voltage coefficient, VSth is solar cell thermal voltage.

$$P_{PV} = V_{PV} \times N_{SH} \left(I_{Ph} - I_O exp\left(\frac{qV_{PV}}{N_{SE}AKT}\right) - \left(\frac{V_{PV}}{N_{SE}}\right)\right) \quad (4)$$

I-V/P-V curves represent the characteristics of a solar cell is shown in Figure 3 [4]. It is clear from the curve there is instability for the operating point of a PV; it varies continuously from null to open-circuit voltage. In this process, there is a single point that provides peak power for the design of solar PV at various irradiance. Here, the respective voltage and currents are VMPP, IMPP shown in Figure 3.

The values of current and voltage got from the solar PV depend on irradiance, temperature, number of series, and parallel connected strings. So, it is required to choose the solar panel wisely. In this paper, the 1Soltech 1STH-215- P panel is chosen from the list of given solar modules data in MATLAB with 2 series and parallel connected modules per string. The specifications of the selected solar panel and the readings for 1 parallel string and 1 series-connected module with a solar irradiance of 1000 W/m2 and 250oC temperature.

2.3 IRRADIANCE AND TEMPERATURE EFFECT

The solar PV output continuously varies with variation in climatic changes [9]. As the solar irradiance confides on the incidence angle of sun rays, this effect forces the I-V/P-V characteristics to change. The output current IPV varies with the variation of sunray incidence, making VPV constant and VPV also shifts its magnitude, making IPV constant [9]. Three factors are influencing the variation in temperature of a solar PV: The heat dissipated on its own during the functioning of PV, for the infrared wavelength started, which is a worn on the cell and the gradual increase in the sunbeam intensity [6]. The VOC and ISC are measured based on the equations (5) and (6) at variable irradiance.

$$V_{OC} = V'_{OC} + a_2 (T - T') - (I_{SC} - I'_{SC})R_{SE} \quad (5)$$

$$I_{SC} = I'_{SC}\left(\frac{G}{G'}\right) + a_1 (T - T') \quad (6)$$

From the above equations, the temperature coefficients are a1 and a2 of the PV cell, respectively [5]. V 0 OC and I 0 SC are the reference parameters at solar intensity G' and temperature T0. As the variations of climatic conditions are specific, it affects the output voltage and currents. At any point during the operation of solar PV, the maximum extraction of power can be done. This can be possible with an efficient MPPT technique that tracks the irradiation and temperature and provides a constant voltage at the output.

3. DC-DC BOOST CONVERTER

A single input multiple output DC-DC boost converter interfaced in between the solar panels and the proposed inverter is shown in Figure 1 [8]. This converter provides three isolated dc sources in the ratio of 4:1:3:9. The converter feeds on a single solar PV to eliminate the unequal voltages along with the variations in the step size based on several climatic conditions.

The magnitude of the inductance can be calculated using the relation:

$$L = \left(\frac{mV_{dc}}{4af_sI_r}\right) \quad (7)$$

where Vdc is the input dc voltage, m is the modulation index, and fs is the switching frequency, Ir is the ripple current, a is the overloading factor which is usually 1.25. The value of capacitance can be calculated using the relation

$$C = \left(\frac{DI_{dc}}{V_{dc}rf_s \times 0.5}\right) \quad (8)$$

where Idc is the dc current, fs is the switching frequency, r is the ripple voltage, Vdc is the input dc voltage, D is the duty cycle.

The duty cycle of the converter can be calculated using the following relation:

$$D = \left(\frac{V_O}{V_O + V_{dc}}\right) \quad (9)$$

The simulation and experimental results are shown in figure 4and figure 5, respectively. The specifications of the boost converter are represented requirement, and the upper limits of the additional ripple voltage. SC has the advantage of increasing the voltage level with its structural design. In general, a DC-DC converter is required to get a rated output fed to the inverter but irrespective of the converter rated output, in the proposed topology voltage gets boosted based on the SC design in its charging and discharging behaviour. The addition of several SC units results in the production of the various number of levels of multilevel inverters. Here, the SC units are cascaded to form 17 MLI.

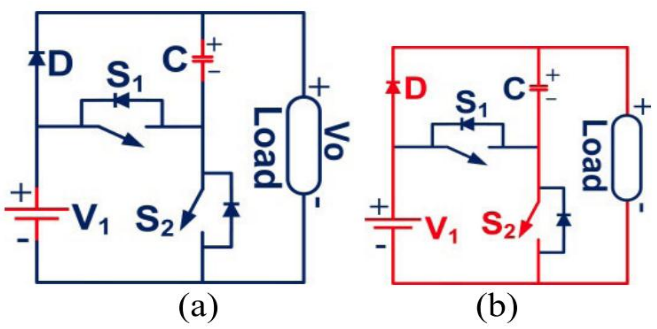

Figure 4. SCU (a) Basic SC unit: (b) Charging.

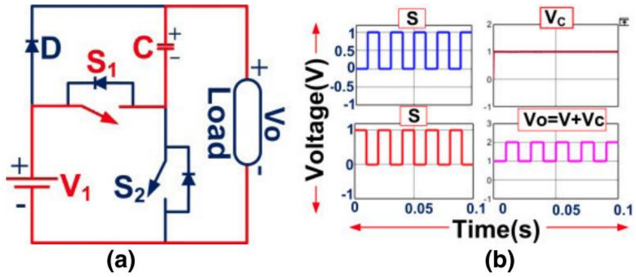

Figure 5. Capacitor in SC unit: (a) Discharging, (b) Simulation output

Figure 4(a) & Figure 5(a), under optimal conditions, during each half-cycle, the capacitor C is charged through S2 switch during V0 = ±Vc1. The discharging of the capacitor C is started when the switch S1 is in conduction at the front end of the proposed MLI topology. During the discharging period, the diode D and switch S2 gets turned off. V1 and VC1 supply energy to the load and the respective maximum load current is known where

$$\mathrm{V_0} = \mathrm{V_1} + \mathrm{V_{C1}} \quad (10)$$

The discharging period can be used for obtaining the optimum value of SC for obtained ripple voltages. The simulation output waveform shown in Figure 5(b).

Let QC be the charge released by C1 during the period, then

$$Q_C = \int_{td1}^{td2} [I_0 sin\,(2\pi fst - \varphi)\, dt] \quad (11)$$

where td1, td2 is the period of discharging, I0 is maximum output current, fs is the fundamental frequency, and ϕ is the phase difference among the voltage and current. 1VC is the ripple voltage and can be calculated using the angles computed using

$$\Delta VC = \frac{1}{2\pi fsC}\int_{\theta}^{\pi-\theta} I0\sin(2\pi fst - \varphi)d\omega t \quad (12)$$

where θ is the angle where the capacitor discharges and πθ is the angle where the capacitor is discharging stops.

Design and Modelling of PV System

Figure 1 shows the general diagram of the PV system, which is composed of the 65 W PV module, the buck converter, the battery and the MPPT algorithm (fuzzy or P&O)

4. Fuzzy Controller

4.1 Membership Functions

Triangular membership functions for the fuzzification process were used. For the inputs E, CE and for the output ΔD, 5 membership functions were defined in terms of the following linguistic variables: Very Low (MB), Low (B), Neutral (N), High (A) and Very High (MA). The range for the error is (−60 to 100), for the change of error is (−10 to 10) and for the increment in duty cycle is (−0.01 to 0.01). Figure 7 shows the membership functions for the inputs and outputs of the controllers.

4.2 Fuzzy Controller Modelling

The controller was modelled with the Matlab Fuzzy Logic Toolbox (Math Works, Natick, MA, USA). A Mamdani controller with the centroid defuzzification method was used. This procedure was carried out using the fuzzy inference system editor (FIS editor) (Math Works, Natick, MA, USA). Figure 9 shows the controller modeled in Simulink, for which a subsystem was performed to calculate ΔV and ΔP in order to obtain the inputs E and ΔE.

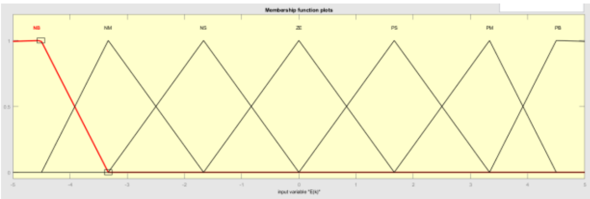

Figure 6. Membership Functions of the Fuzzy input E.

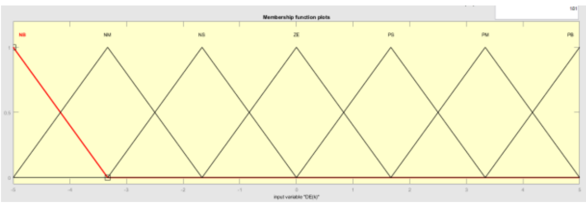

Figure 7. Membership Functions of the Fuzzy input ΔE.

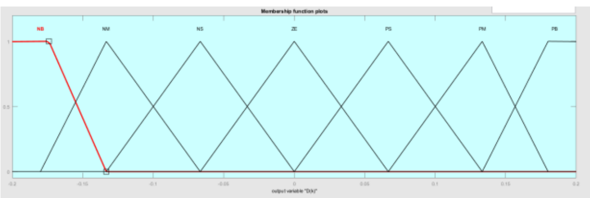

Figure 8. Membership Functions of the Fuzzy output.

4.3 PV System Modelling

The PV system implemented in Matlab/Simulink, which is composed of the PV module, the buck converter and the fuzzy/P&O controller. The signal builder block was used to generate the temperature and irradiance signals in order to evaluate the controller performance. Additionally, this system was used to evaluate the standard P&O controller and perform the comparison with the fuzzy controller.

4.4 Limitations

The dc-dc converter and fuzzy control were designed based on the electrical parameters of the PV module under study; for this reason, the calculations made apply to PV modules with powers up to 65 W. One of the inputs of the fuzzy controller is the change of error, which requires a differentiation operation that increases the complexity in the calculations and can generate errors when measuring small powers that are sensitive to noise.

5. Simulation Results

17-LEVEL MLI

A 17-level MLI is designed with the two SC units connected in cascade with a smaller number of components is shown in FIGURE 9. The proposed MLI topology comprises 10 controlled switches with two asymmetric DC sources with the absence of inductors.

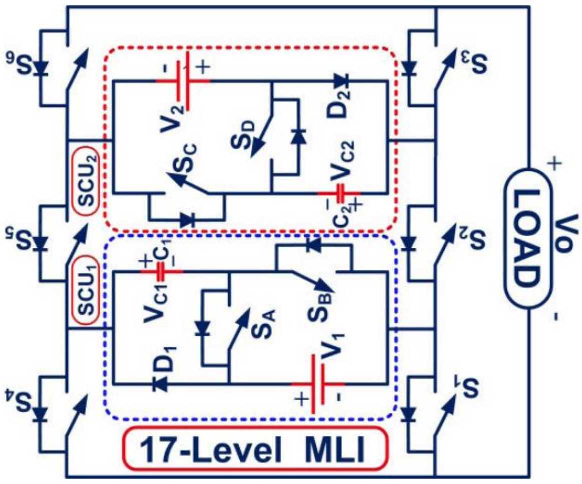

Figure 9. Developed structure of 17-level MLI.

The two DC sources are of unequal voltage levels formed to be an asymmetrical configuration. Several power quality issues like total standing voltage (TSV), cost factor, and cost per unit with various values of the weight factor, THD, switch count, component count level, voltage stress is minimized with this MLI topology. This topology achieves less TSV and is compared with various topologies. The path of the load current through the switches.

The developed 17-level MLI is operated in various modes of operation. In mode-1 operation of the circuit, the switches

SA, S5, SD, S3, S1 turn on forming a load current path, where V1, VC1, V2, and VC2 sources act in the circuit and produce a voltage of 50V, 150V, 50V, 150V respectively to get a maximum voltage of 400V. In mode-4 operation, the switches SA, S5, D2, S3, S1 turn on with the voltages V1, VC1, and V2 sources act in the circuit and produce a voltage of 50V, 150V, and 50V respectively and get a voltage of 5Vdc which is equal to 250V. In mode5 operation, the switches D1, S5, D2, S3, S1 turn on with the voltages V1 and V2 sources act in the circuit and produces a voltage of 50V and 150V respectively and get a voltage of 4Vdc equal to 200V. In mode-6 operation, the switches D2, S3, S4, S5, turn on with the voltage V2 source act in the circuit and produce a voltage of 50V and get a voltage of 3Vdc which is equal to 150V. In mode-7 operation, the switches SA, S5, S6, S1, turn on with the voltages V1 andVC1 sources act in the circuit and produces a voltage of 50V and 150V respectively and get a voltage of 2Vdc equal to 100V.

In mode-8 operation, the switches D1, S5, S6, S1 turn on with the voltages V1 source act in the circuit and produces a voltage of 50V respectively and get a voltage of Vdc which is equal to 50V.

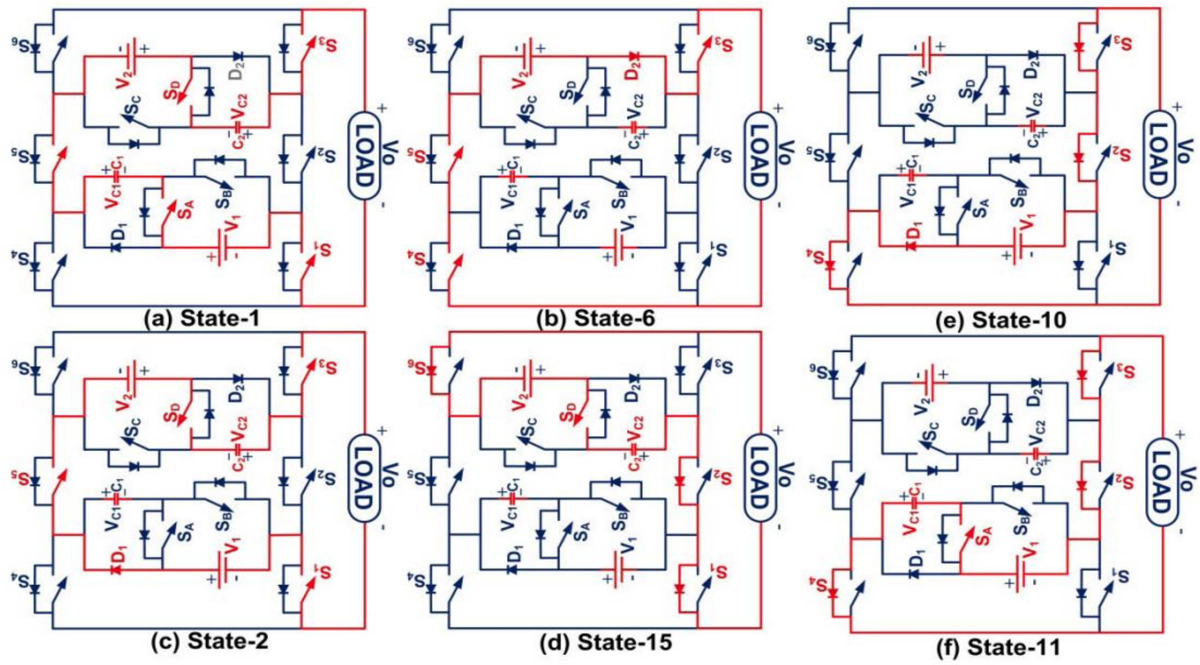

Figure 10. Modes of operation of the proposed 17-Level MLI topology.

In mode-9 operation, the switches S1, S2, S3, turn on with no voltages acts in the circuit and produces a voltage of 0V. Hence the positive cycle is created. The negative cycle is implemented with the negative modes of operation, along with the switching states.

The output waveform for output voltage and currents are shown in figure 14, and figure 15. The experimental output voltage and output current are represented in FIGURE 16. The MLI is tested with R-load, and the obtained voltage and currents are 400V and 4A.

17-LEVEL MLI

A 17-level MLI is designed with the two SC units connected in cascade with a smaller number of components is shown in FIGURE 9. The proposed MLI topology comprises 10 controlled switches with two asymmetric DC sources with the FIGURE 9. Developed structure of 17-level MLI. Absence of inductors. The two DC sources are of unequal voltage levels formed to be an asymmetrical configuration. Several power quality issues like total standing voltage (TSV), cost factor, and cost per unit with various values of the weight factor, THD, switch count, component count level, voltage stress is minimized with this MLI topology. In mode-1 operation of the circuit, the switches SA, S5, SD, S3, S1 turn on forming a load current path, where V1, VC1, V2, and VC2 sources act in the circuit and produce a voltage of 0respectively to get a maximum voltage of 80V. In mode-2 operation, the switches D1, S5, SD, S3, S1 turn on where V1, V2, and VC2 sources act in the circuit and produce a voltage of 80V respectively and get a voltage of 8Vdc which is equal to 80V. In mode-3 operation, the switches SD, S3, S6, S5 turn on forming a load current path where V2, VC2 sources act in the circuit and produce a voltage respectively and get a voltage of 5Vdc equal to 80V.

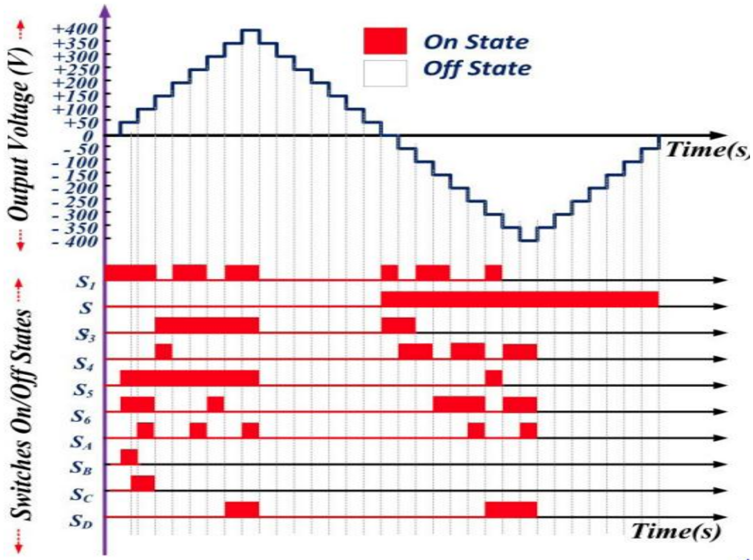

Figure 11. 17-Level expected output voltage waveform with switching pulses.

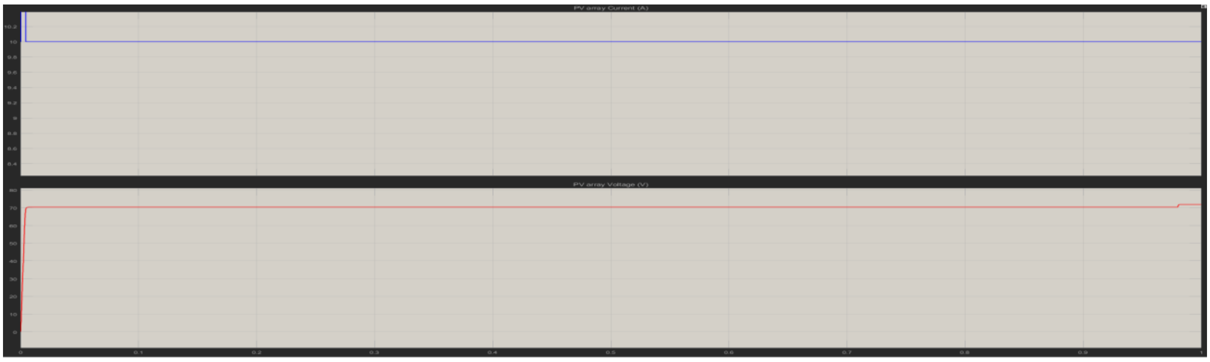

Figure 12. PV array Output current and Voltage with the Fuzzy MPPT technique.

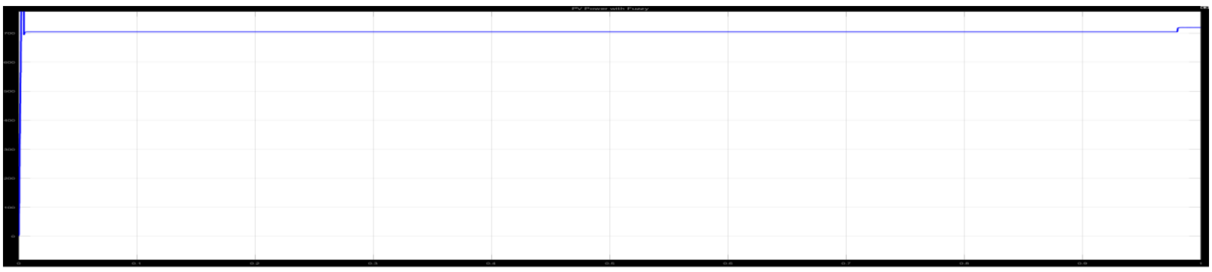

Figure 13. PV array Output Power 700W with the Fuzzy MPPT technique.

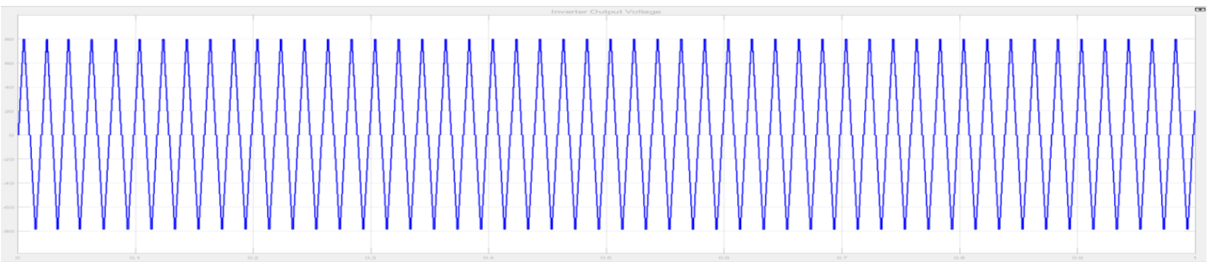

Figure 14. 17 Level Voltage output of the Inverter Voltage of 80v

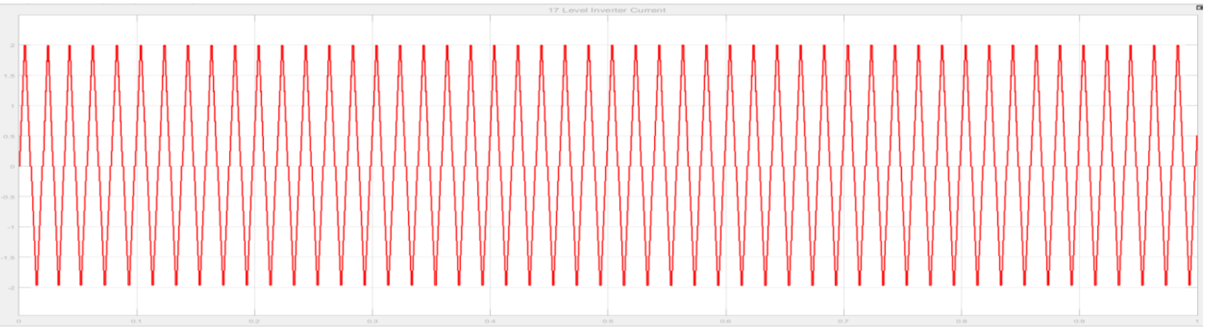

Figure 15. 17 Level Current output of the Inverter Current of 2A

CONCLUSION

The proposed switched-capacitor based 17-level MLI topology for electric vehicle applications is designed and implemented for the solar PV energy system with lesser semiconductor devices to reduce the cost and size of the inverter, improving efficiency and reliability. Fuzzy based MPPT technique is used, the stable output is achieved under all circumstances. The proposed MLI is implemented with various combinations of SC connections. A basic two units are cascaded and obtained a 17-level MLI configuration. All the MLIs are designed and compared with various topologies based on several parameters like devices level count. It was demonstrated that the fuzzy controller has an excellent performance when there are sudden changes in the operating temperature of the PV module, in contrast with P&O control that is considerably affected, presenting power losses. In this way, the main contribution of this manuscript is the guarantee of supplying the maximum possible power to a battery in an off-grid PV system, using a fuzzy controller. As future work, in the second stage of the project, the fuzzy controller will be implemented The proposed MLI is tested under multiple dynamic load variations. This topology is most suited for renewable energy applications along with the EV applications.

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