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An Advanced Control Strategy For Solar PV And Battery Storage Integration System Using A Three Level NPC Inverter

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Abstract-
In this venture, another design of a three-level impartial point-braced (NPC) inverter that can incorporate sunlight based photovoltaic (PV) with battery stockpiling in a lattice associated framework is proposed. The quality of the proposed topology lies in a novel, developed unbalance three-level vector adjustment strategy that can create the right air conditioning voltage under lopsided dc voltage conditions. This venture shows the plan investigation of the proposed design and the hypothetical structure of the proposed regulation system. Another control calculation for the proposed framework is additionally exhibited with a specific end goal to control the power conveyance between the sun based PV, battery, and matrix, which at the same time gives greatest power point following (MPPT) operation for the sun based PV. In this venture fluffy controller used to lessened the music when contrasted with the PI controller. The adequacy of the proposed procedure is examined by the recreation of a few situations, including battery accusing and releasing of various levels of sun oriented illumination. The reenactment performed in MATLAB/SIMULINK condition.

***Index Terms*— Battery storage, solar photovoltaic (PV), space vector modulation (SVM), three-level inverter, fuzzy controller.**

INTRODUCTION

Because of the world vitality emergency and natural issues brought about by ordinary power era, sustainable power sources, for example, photovoltaic (PV) and wind era frameworks are ending up noticeably all the more encouraging contrasting options to swap regular era units for power era. Propelled control electronic frameworks are expected to use and create sustainable power sources. In sun based PV or wind vitality applications, using greatest power from the source is a standout amongst the most essential elements of the power electronic frameworks . In three-stage applications, two sorts of energy electronic arrangements are usually used to exchange control from the sustainable power source asset to the framework: single-stage and twofold phase transformation. In the twofold phase change for a PV framework, the principal stage is normally a dc/dc converter and the second stage is a dc/air conditioning inverter. The capacity of the dc/dc

converter is to encourage the greatest power point following (MPPT) of the PV cluster and to deliver the suitable dc voltage for the dc/air conditioning inverter. The capacity of the inverter is to create three-stage sinusoidal voltages or streams to exchange the ability to the network in a framework associated sunlight based PV framework or to the heap in a remain solitary framework . In the single-stage association, just a single converter is expected to satisfy the twofold phase capacities, and subsequently the framework will have a lower cost and higher proficiency, be that as it may, a more mind boggling control technique will be required. The present standard of the business for high power applications is a three-stage, single stage PV vitality frameworks by utilizing a voltage-source converter (VSC) for power transformation . One of the real worries of sun based and wind vitality frameworks is their unusual and fluctuating nature. Lattice associated sustainable power source frameworks joined by battery vitality stockpiling can conquer this worry. This additionally can build the adaptability of energy framework control and raise the general accessibility of the framework . More often than not, a converter is required to control the charging and releasing of the battery stockpiling framework and another converter is required for dc/air conditioning power transformation; therefore, a three stage PV framework associated with battery stockpiling will require two converters. This paper is worried with the outline and investigation of a matrix associated three-stage sun based PV framework coordinated with battery stockpiling utilizing just a single three-level converter having the capacity of MPPT and air conditioning side current control, and furthermore the capacity of controlling the battery charging and releasing. This will bring about lower cost, better effectiveness and expanded adaptability of energy stream control.

II. STRUCTURE OF A THREE-LEVEL INVERTER AND ITS CAPACITOR VOLTAGE CONSIDERATIONS

A. Three-Level Inverter

Since the presentation of three-level inverters , they have been broadly utilized as a part of a few applications, for example, engine drives, STATCOM, HVDC, pulsewidth tweak (PWM) rectifiers, dynamic power channels (APFs), and sustainable power source applications . Fig. 1(a) demonstrates an average threephase three-level impartial point-clasped (NPC) inverter circuit topology. The converter has two capacitors in the dc side to deliver the three-level air conditioning side stage voltages. Regularly, the

capacitor voltages are thought to be adjusted, since it has been accounted for that unbalance capacitor voltages can influence the acside voltages and can deliver surprising conduct on framework parameters, for example, even-symphonious infusion and power swell . A few papers have talked about techniques for adjusting these capacitor voltages in different applications .

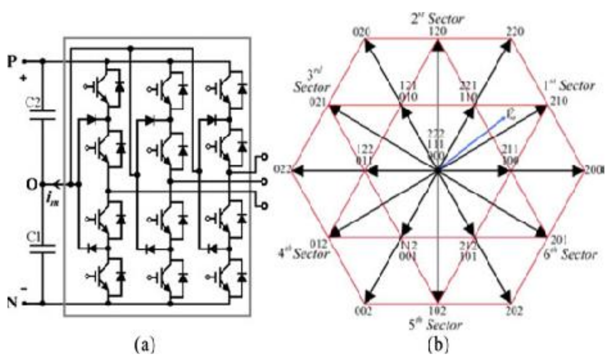

Fig. 1. Typical three-level inverter (a) structure of circuit, and (b) three-level inverter space vector diagram for balanced dc-link capacitors .

B. Adjusted Capacitors Voltage

Different systems have been proposed to adjust the capacitor voltages usingmodulation calculations, for example, sinusoidal carrierbased PWM (SPWM) or space vector pulsewidth regulation (SVPWM) . In SPWM applications, the majority of the procedures depend on infusing the suitable zero-grouping signal into the adjustment signs to adjust the dc-connect capacitors . In SVPWM applications, a superior comprehension of the impacts of the exchanging choices on the capacitor voltages in the vector space has brought about numerous techniques proposed to adjust capacitors voltages in the three-level NPC inverter. These incorporate capacitor adjusting utilizing regular SVPWM, virtual SVPWM (VSVPWM) and their mix . In vector control hypothesis, in a perfect world, the inverter must have the capacity to create the voltage yield promptly, taking after the reference vector (_Vref), produced by the control framework. Be that as it may, due to the constraint of the switches in the inverter, it is unrealistic to ensure that any asked for vector can be produced; indeed, just a set number of vectors (27 vectors for three-level inverter) can be created. To conquer such troubles, in any space vector adjustment (SVM) plan, for example, SVPWM and VSVPWM, the reference vector _Vref is produced by choosing the suitable accessible vectors in each time span such that the normal of the connected vectors must be equivalent to the reference vector.

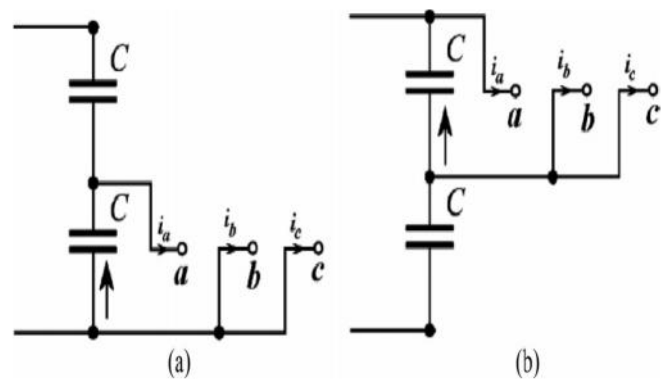

Fig. 2. Equivalent circuit and capacitors current with two different short vector. (a) Short vector—100. (b) Short vector—211.

Equation (1) shows the mathematical relation between the timing of the applied vectors and the reference vector

$$\begin{cases} T_s \vec{V}_{\text{ref}} = \sum_{i=1}^{n} T_i \vec{V}_i \\ T_s = \sum_{i=1}^{n} T_i \end{cases} \qquad (1)$$

where Ts is the time span and liked to be as short as would be prudent. It can be considered as a control refresh period where a normal vector will be numerically produced amid this time term. Ti is the comparing time fragment for chose inverter vector _Vi and n is the quantity of connected vectors. For the most part, the reference vector is created by three distinctive vector (n = 3), and (1) can be changed over to three diverse condition with three factors T1, T2 , and T3 to be figured. A few vector PWM systems displayed in [6], [7], [9]–[11], and [13]–[15] apply comparative procedure of timing count. Fig. 1(b) demonstrates the space vector chart of a three-level inverter for adjusted dc-interface capacitors [6]. It is comprised of 27 exchanging states, from which 19 diverse voltage vectors can be chosen. The number related with every vector in Fig. 1(b) speaks to the exchanging condition of the inverter stages individually. The voltage vectors can be ordered into five gatherings, in connection to their amplitudes and their consequences for various capacitor voltages from the perspective of the inverter air conditioning side. They are six long vectors (200, 220, 020, 022, 002, and 202), three zero vectors (000, 111, and 222), six medium vectors (210, 120, 021, 012,102, and 201), six upper short vectors (211, 221, 121, 122, 112,and 212), and six lower short vectors (100, 110, 010, 011, 001, and 101). For creating _Vref , when one of the determinations (_Vi), is a short vector, then there are two decisions that can be made which can deliver the very same impact on the air conditioner side of the inverter

in the three wire association (if voltages are adjusted). For instance, the short vector "211" will have an indistinguishable impact from "100" on the air conditioner side of the inverter. In any case, this decision will have distinctive impact on the dc side, as it will make an alternate dc capacitor be decided for the exchange of energy from or to the air conditioner side, and an alternate capacitor will be charged or released relying upon the exchanging states and the course of the air conditioner side current. For instance, Fig. 2 demonstrates the association of the capacitors when "100"or "211" is chosen, exhibiting how distinctive capacitors are included in the exchange of energy. Capacitor adjusting in most announced three-level NPC inverter applications is accomplished by the best possible choice of the short vectors. So as to create the air conditioner side waveform, the vector outline of Fig. 1(b) is utilized, where the dc capacitor voltages are thought to be adjusted.

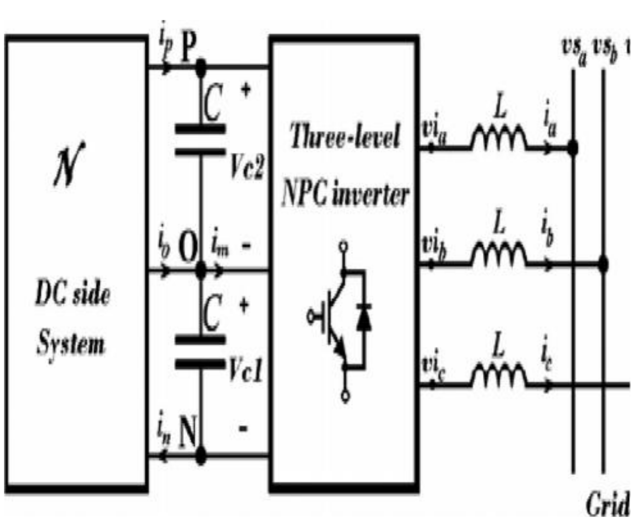

Fig. 1(b) can then be utilized to decide the suitable vectors to be chosen and to ascertain their relating timing (Ti) for executing the required reference vector in view of the expression given in (1). In spite of the fact that the control framework is attempting to guarantee adjusted capacitor voltages, ought to any unbalance happen amid a transient or an unforeseen operation, the above strategy will deliver a mistaken air conditioning side waveform which can be not the same as the genuine asked for vector by the control framework. This can bring about the generation of even-sounds, lopsided present and unpredicted dynamic

conduct. In any case, in a few applications, the prerequisite of having adjusted capacitor voltages might be excessively prohibitive. It is conceivable to work with either adjusted or unequal capacitor voltages. The strategy proposed in this paper depends on the opportunity of having parity or unequal capacitor voltages. In such applications, it is essential to have the capacity to create an exact reference vector in view of (1), independent of whether the capacitor voltages are adjusted or not, to accomplish the coveted targets of the framework.

C. Lopsided Capacitor Voltages

Fig. 3 demonstrates a general structure of a framework associated threelevel inverter demonstrating the dc and air conditioning sides of the inverter. The

dc-side framework, appeared as "N" can be comprised of many circuit setups, contingent upon the utilization of the inverter.

For example, the dc-side framework can be a sun based PV, a twist generator with an amending circuit, a battery stockpiling framework or a mix of these frameworks where the dc voltage over every capacitor can be distinctive or level with. One of the primary thoughts of this paper is to have a general perspective of the exchanging consequences for a three-wire association of a three-level NPC inverter with a mix of these frameworks on the dc side. Scientifically, in a three-wire association of a two-level inverter, the dq0 field, vd, vq , and v0 of the inverter in vector control can be considered as having two degrees of opportunity in the control framework; in light of the fact that the zero grouping voltage, v0 will have no impact on the framework conduct in both the dc and the air conditioner side of the inverter. Be that as it may, in the three-level three-wire application shown in Fig. 3, with settled vd and vq in spite of the fact that v0 will have no impact on the air conditioner side conduct, it can be valuable to exploit v0 to give another level of flexibility to control the sharing of the capacitor voltages in the dc transport of the inverter. By doing this, it is currently conceivable to work and control the inverter under both adjusted and uneven capacitor voltages while proceeding to produce the right voltages in the air conditioner side. This component is especially valuable in applications where the two capacitor voltages can be distinctive, for example, while associating two PV modules with various MPPT focuses, or interfacing a PV module over the two capacitors and including battery stockpiling at the midpoint of the two capacitors, or interfacing battery stockpiling to each of the capacitors with the capacity to exchange diverse power from every battery stockpiling.

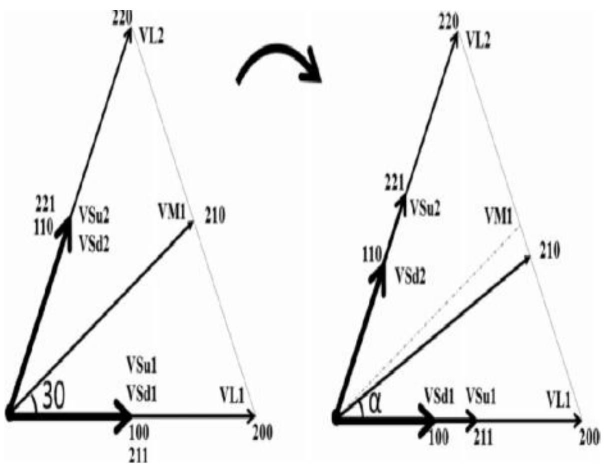

Fig. 4. Vector diagram in the first sector of Fig. 1(b) showing the change of the vectors using balanced dc and unbalanced dc assuming $Vc1 < Vc2$.

D. Effect of Unbalanced Capacitor Voltages on the Vector Diagram

In the vector diagram shown in Fig. 1(b), capacitor voltage unbalance causes the short and medium vectors to have different magnitudes and angles compared to the case when the capacitor voltages are balanced. Fig. 4 shows the differences between two cases as highlighted in the first sector of the Fig. 1(b) for $VC1 < VC2$. Vector related to the switching state _VI can be calculated from the reference paper[1].

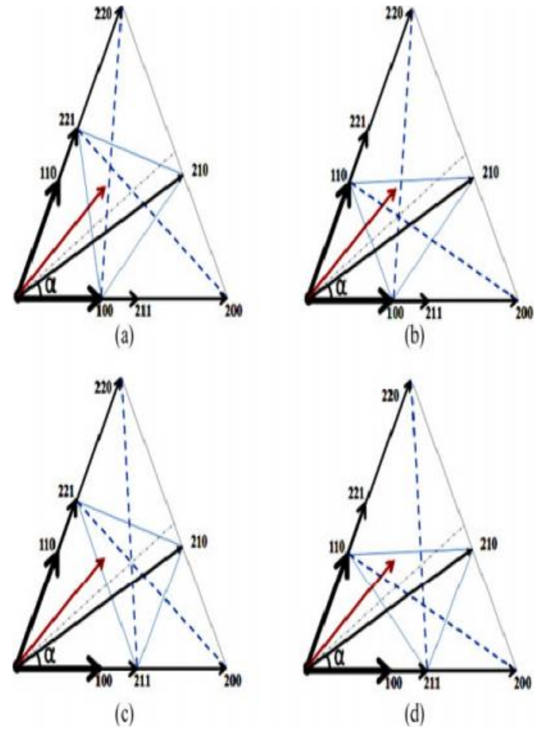

Fig. 5. Different possible vector selection ideas.

Generally, each combine of short vectors is thought to be excess, as the determination of any of the short vectors at any occurrence will have a similar impact on the air conditioner side. Be that as it may, when the two capacitor voltages are distinctive, the short vectors can't be thought to be repetitive any more. In this way, when h _= 0.5, each unique short vector needs extraordinary planning to

create the asked for vector in light of (1).

E. Choosing Vectors Under Unbalanced DC Voltage Condition and Their Effects on the AC Side of Inverter

To create a reference vector in light of (1), unique blends can be actualized. Fig. 5 demonstrates diverse conceivable vector choices to produce a reference vector (_V ∗) in the principal part in view of the choices of various short vectors. For instance, to create _V ∗ in view of Fig. 5(a), one of taking after blends can be chosen with appropriate planning in light of (1). The blends are: (221–210–100), (221–220–100), (221– 200–100), (221–200–Zero), (000–220–Zero), (220–200–Zero), where "Zero" can be "000" or "111" or "222". This shows there is adaptability in picking the right vector determinations. Albeit these choices with reasonable planning can create a similar reference vector, they impactsly affect the dc and air conditioning side of the inverter in their momentary conduct. To explore the air conditioner side conduct, the precision of the produced voltage must be inspected. To the extent the air conditioner side is concerned, in a perfect world the asked for voltage_V ∗ (t) ought to be precisely and all the while created in the three periods of the inverter to have the right quick current in the air conditioner side of the framework. Notwithstanding, in light of the constraint of the inverter to create the correct estimation of the asked for voltage in each stage, in the brief span Ts , just the normal estimation of the asked for vector _V ∗ for the predefined time window of Ts can be delivered. To research the constant time conduct of the air conditioner side voltages, the blunder vector _e (t) can be figured with a specific end goal to decide how far the created voltage veers off from the asked for vector as takes after:

$$\vec{e}(t) = \vec{V}^{*}(t) - \vec{V}_{\mathrm{apl}}(t)$$
$$E(t) \triangleq \left| \int_0^t \vec{e}(t)dt \right|; \qquad 0 \le t \le T_s \tag{2}$$

where _Vapl(t) is the connected vector at the time "t". This mistake can bring about consonant current over the impedance associated between the inverter and the matrix. On the off chance that this impedance is an inductor then the swell in the inductors current _IrL can be communicated as To determine (13), it is expected that the asked for vector _V ∗ (t) will create sinusoidal current in the inductor, which is typically adequate in the persistent time conduct of the framework. In light of (11) and (12), the outright estimation of blunder E(t) is specifically identified with the greatness of the inductors current swell. Albeit in view of (1) and (11), E (Ts) = 0 or the total of mistakes amid the period Ts is zero; however to lessen the greatness of high recurrence swells, it is vital to limit the blunder at each time moment. To accomplish this, the three closest vectors (TNV) are normally utilized. For instance, in Fig. 5(a), to create the asked for vector _V ∗, in the TNV technique, the gathering (221, 210, 100, or 211) gives off an impression of being the best three closest vectors to be picked. Likewise, to reduceE (t), a savvy timing calculation for every vector in the TNV technique has been proposed, for example, isolating an opportunity to apply every vector into at least two shorter circumstances. Be that as it may, this will have the impact of expanding exchanging misfortunes. Separating by two is normal, adequate arrangement. Additionally, decreasing Ts will diminish the blunder E (t) while enhancing the precision of the asked for vector created by the control framework. Agreeing tothe fundamental run of computerized control, exactness of the asked for vector figuring can be enhanced by diminishment of the examining time and the vector computation time.

F. Choosing Vectors Under Unbalanced DC Voltage Conditions and Their Effects on DC Side of the Inverter

To the extent the dc side is concerned, diverse vectors effectsly affect the capacitor voltages which rely on upon the

entirety of the approaching streams from the dc side and the inverter side. Fig. 3 indicates ip, io , and in as dc-side framework streams which are reliant on the dc-side framework circuit topology and capacitor voltages. The streams originating from the inverter are identified with the inverter exchanging and the air conditioner side of inverter ebbs and flows which can be straightforwardly influenced by the actualized vectors in the inverter. Choosing diverse vectors will exchange air conditioning side streams and power contrastingly to the capacitors .These vector determination conditions are depicted in the paper[1].

III .Fuzzy controller:

Fluffy rationale has two unique implications. In a restricted sense, fluffy rationale is a consistent framework, which is an expansion of multivalve rationale. Be that as it may, in a more extensive sense fluffy rationale (FL) is practically synonymous with the hypothesis of fluffy sets, a hypothesis which identifies with classes of items with unsharp limits in which participation involves degree. In this point of view, fluffy rationale in its thin sense is a branch of fl. Indeed, even in its more tight definition, fluffy rationale contrasts both in idea and substance from customary multivalve consistent frameworks.

In fluffy Logic Toolbox programming, fluffy rationale ought to be deciphered as FL, that is, fluffy rationale in its wide sense. The fundamental thoughts basic FL are clarified plainly and wisely in Foundations of Fuzzy Logic. What may be included is that the fundamental idea basic FL is that of a semantic variable, that is, a variable whose qualities are words instead of numbers. As a result, a lot of FL might be seen as a technique for figuring with words as opposed to numbers. Despite the fact that words are innately less exact than numbers, their utilization is nearer to human instinct. Moreover, registering with words abuses the resistance for imprecision and along these lines brings down the cost of arrangement.

Another essential idea in FL, which assumes a focal part in a large portion of its applications, is that of a fluffy if-then administer or, just, fluffy run the show. Despite the fact that lead based frameworks have a long history of utilization in Artificial Intelligence (AI), what is absent in such frameworks is a system for managing fluffy consequents and fluffy precursors. In fluffy rationale, this instrument is given by the analytics of fluffy guidelines. The analytics of fluffy guidelines fills in as a reason for what may be known as the Fuzzy Dependency and Command Language (FDCL).

IV.SIMULATION CIRCUITS AND RESULTS

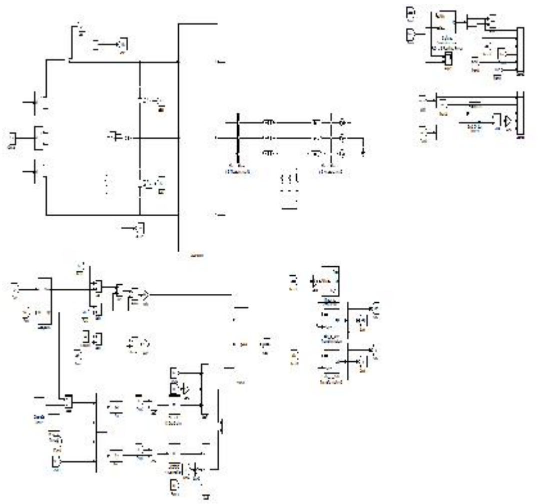

FIG6: Control system diagram to integrate PV and battery storage.

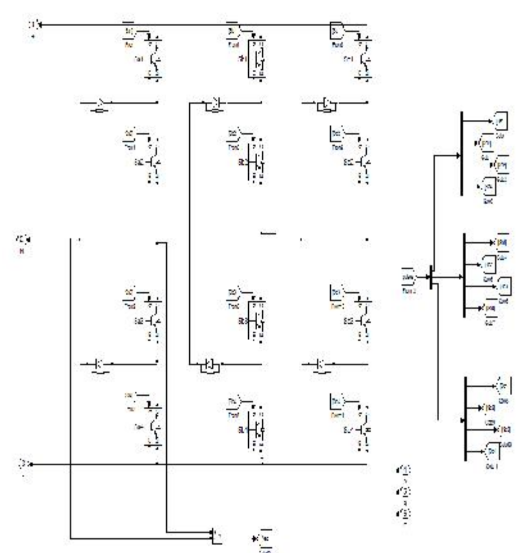

FIG7:NPC INVERTER

A. First Theoretical Scenario

In the principal situation, it is expected that the sunlight based light will create ISC = 5.61 An in the PV module as per (21). The MPPT control square, appeared in Fig. 6, decides the asked for PV module voltage V ∗ dc , which is 117.3 V to accomplish the greatest power from the PV framework that can create 558 W of electrical power. The asked for dynamic energy to be transmitted to the framework is at first set at 662Wand is changed to 445Wat time t = 40 ms and the responsive power changes from zero to 250 VAr at timet = 100 ms. Fig. 8 demonstrates the aftereffects of the main situation reproduction. Fig. 8(a) and (b) demonstrates that the proposed control framework has accurately taken after the asked for dynamic and receptive power, and Fig. 8(c) demonstrates that the PV voltage has been controlled precisely (to be 177.3 V) to acquire the greatest power from the PV module. Fig. 8(d) demonstrates that battery is releasing when the lattice power is more than the PV power, and it is charging when the PV power is more than the network control. Fig. 8(d) demonstrates that before time t = 40 ms, the battery releases at 1.8 A since the power produced by the PV is inadequate. After time t = 40 ms, the battery current is about –1.8 An, implying that the battery is being charged from the additional energy of the PV module. Fig. 8(e) demonstrates the inverter air conditioning side streams, and Fig. 8(f) demonstrates the framework side streams with a THD under 1.29% due to the LCL channel. The reenactment brings about Fig. 8 demonstrate that the entire framework creates a decent powerful reaction. Fig. 10 demonstrates the inverter waveforms for a similar situation. Fig. 9(a) demonstrates the line-to-line voltage Vab , and Fig. 9(b) demonstrates the stage to midpoint voltage of the inverter Vao . Fig. 9(c) and (e) indicates Vao, Von, and Van after scientific sifting to decide the normal estimation of the PWM waveforms.

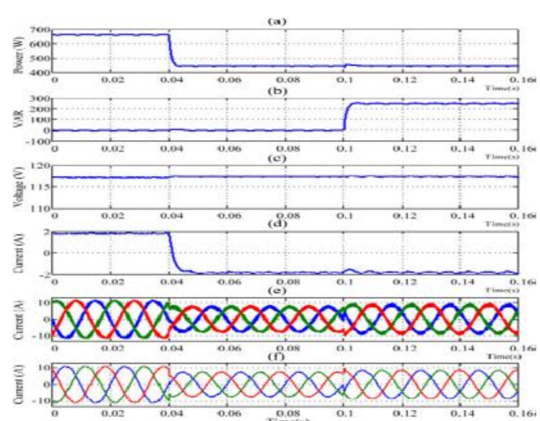

Fig. 8. Simulated results for the first scenario. (a) Active power injected to the grid. (b) Reactive power injected to the grid. (c) PV module DC voltage.

(d) Battery current. (e) Inverter AC current. (f) Grid current.

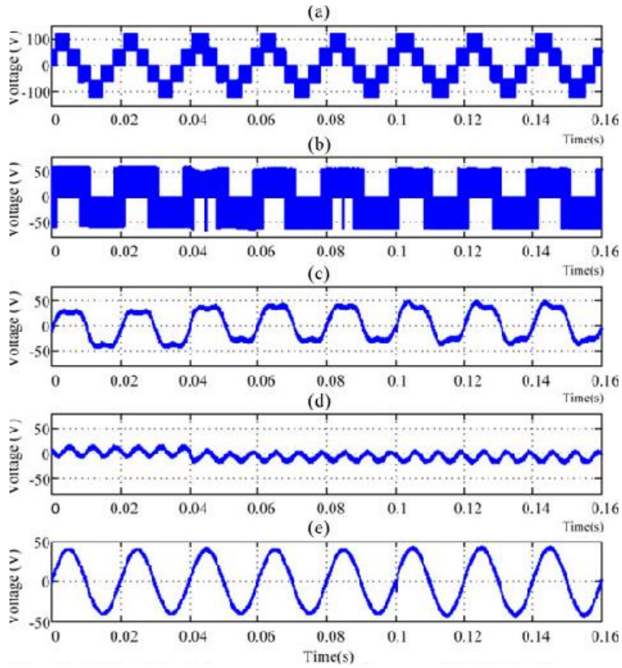

Fig. 9. Mimicked inverter waveforms. (a) Vab-Phase to stage inverter voltage. (b) Vao-Inverter stage voltage reference to midpoint. (c) Filtered Von-

Separated inverter stage voltage reference to midpoint. (d) Filtered Von-Filtered midpoint voltage reference to nonpartisan. (e) Filtered Van-Filtered stage voltage reference to impartial.

B. Second Theoretical Scenario

In the second situation, it is accepted that the sunlight based light will change with the end goal that the PV module will produceISC = 4.8, 4, and 5.61 A. The MPPT control piece confirms that V ∗ dc should be 115.6, 114.1, and 117.3 V to accomplish the greatest power from the PV units which can produce 485, 404, and 558 W, individually. The asked for dynamic energy to be transmitted to the framework is set at a steady 480 W and the responsive power is set to zero amid the reenactment time. Fig. 10 demonstrates the aftereffects of the second situation reenactment. Fig. 10(a) demonstrates that the inverter can produce the asked dynamic power. Fig. 10(b) demonstrates that the PV voltage was controlled precisely for various sun based light values to get the applicable greatest power from the PV modules. Fig. 10(c) demonstrates that the charging and releasing of the battery are accurately performed. The battery has supplemented the PV control era to take care of the asked for demand by the matrix. Fig. 10(d) represents that the nature of the waveforms of the matrix side streams are adequate, which connotes that the right PWM vectors are created by the proposed control methodology. By utilizing the proposed system, the inverter can give a quick transient reaction. Fig. 10(e) demonstrates the a-stage voltage and current of the matrix, which are dependably in-stage meaning that the receptive power is zero at all circumstances.

Table1:comparison of PI and FUZZY controller thd for different scenario's

THD FOR	1^{ST} SCENARIO	2^{ND} SCENARIO	3^{RD} SCENARIO
INPUT VOLTAGE	4.16%	4.13%	4.19%
INPUT CURRENT	3.58%	3.29%	7.66%

THD FOR	1^{ST} SCENARIO	2^{ND} SCENARIO	3^{RD} SCENARIO
INPUT VOLTAGE	0.38%	0.28%	0.30%
INPUT CURRENT	0.20%	0.18%	2.68%

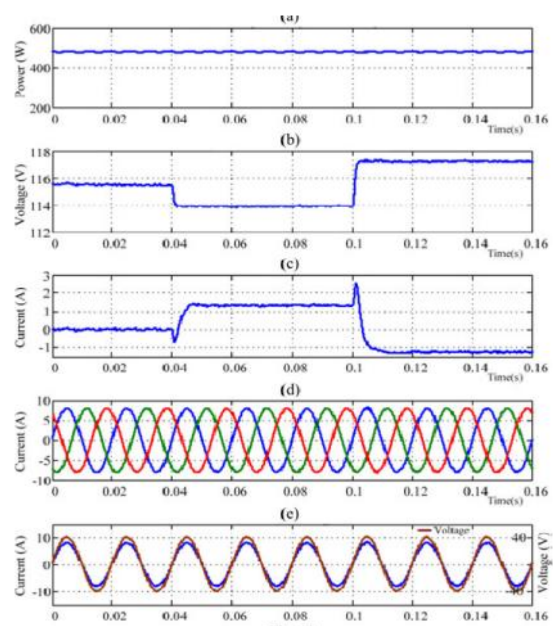

Fig. 10. Simulated results for the second scenario. (a) Active power injected to the grid. (b) PV module DC voltage. (c) Battery currents. (d) Grid side currents. (e) Grid side Phase (a) voltage and its current.

V. CONCLUSION

A novel topology for a three-level NPC voltage source inverter that can integrate both renewable energy and battery storage on the dc side of the inverter has been presented. A theoretical framework of a novel extended unbalance three-level vector modulation technique that can generate the correct ac voltage under unbalanced dc voltage conditions has been proposed. A new control algorithm for the proposed system has also been presented in order to control power flow between solar PV, battery, and grid system, while MPPT operation for the solar PV is achieved simultaneously. The effectiveness of the proposed topology and control algorithm was tested using simulations and results are presented. The results demonstrate that the proposed system is able to control ac-side current, and battery charging and discharging currents at different levels of solar irradiation. In this project fuzzy controller used to reduced the harmonics when compared to the PI controller. The simulation performed in MATLAB/SIMULINK environment**.**

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