

A REVIEW ON EVALUATION OF PV MODELS BASED ON AN INTEGRATION USING A NEW CONFIGURATION OF A THREE-LEVEL INVERTER

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ABSTRACT

The effect of linear imbalances and nonlinear loads on the voltage balance of the neutral-point-clamped converters is described in this paper. The Neutral-Point-Clamped inverters are used in the multilevel inverters for high power applications. In this paper a three level NPC inverter that couple accommodate with solar photovoltaic (PV) and battery storage in grid connected system. The three level space vector modulation technique (SVPWM) is proposed. The SVPWM correct the ac voltage under unbalance dc voltage condition. SV-PWM strategy makes it possible to control the neutral point voltage by optimum choice of switch sequence for any position and length of output voltage vector. The control scheme has capability to control the power delivery between the solar PV, battery, and grid, it simultaneously provides maximum power point tracking (MPPT) operation for the solar PV. The results of matlab modeling of the system detail the comparative operation of inverter topologies which are the conventional two level inverters and multilevel inverter topology to reduce total harmonic distortions in grid voltage and electromagnetic interference. 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. The effectiveness of the proposed methodology is investigated by the simulation of several scenarios, including battery charging and discharging with different levels of solar irradiation.

KEYWORDS - Solar photovoltaic (PV), Battery storage, Space vector modulation (SVM), three level NPC inverter.

INTRODUCTION

Nowadays the demand for power is increases all over the world and this cannot be met by the conventional sources because it going to be vanishes. And also there are so many environmental problems, energy crises due to the conventional power generation [1]. This can be replace by using the renewable energy sources like solar photovoltaic (PV) wind sources etc. for generation of electricity.

Advance power electronic configuration are to be used for developing energy from the renewable energy sources. The maximum energy from solar PV are utilize by using the power electronic systems [2]-[3]. For three phase application, two types of power electronic configuration are required to transfer the power to the grid: 1) single stage conversion 2) double stage conversion.

In single stage conversion, only one converter is sufficient to fulfil the requirement of double stage converter. Hence this system will have lower cost and higher efficiency but the complex method is required. For three phase high power applications in industry, single stage conversion of solar PV is achieved by using the voltage source converter (VSC)[4].

In double stage conversion for solar PV two steps are applied i.e. firstly dc/dc converter is used and second stage is dc/ac inverter. In first stage the function of dc/dc converter is to facilitate the maximum power point tracking (MPPT) of the PV array to produce the appropriate dc voltage for dc/ac inverter. In second stage i.e. inversion stage, the inverter produce the three phase sinusoidal voltage and current and also reduces the harmonic content in the grid injected voltage and current afterwards it transfer power to load connected grid.

Due to the unpredictable and fluctuating nature of solar PV the output of this system is never be constant. To overcome this difficulty a battery storage system is employed. It can boost the system flexibility and also increase the availability of the system [2]. Generally the grid connected solar PV system require a two converters first which control the charging and discharging of the battery storage system and another converter is required to convert dc/ac power conversion for grid. This paper is concern with the design and study of a grid connected three phase solar PV system integrated with battery storage by using single three level NPC inverter having the capability of MPPT and ac side current control and also having the ability of controlling the charging and discharging of battery storage.

Since the introduction in 1981 [5] three level neutral point clamped (NPC) voltage source inverter are widely used in high power applications, it having the advantages over the conventional two level inverter for high power applications. To increase the performance of this converter, the voltages of two series connected dc link capacitors must be cramped to one half the level of dc link voltage. Most of the industry need to increase the efficiency and ants to reduce the production costs and this can be achieve by increasing the installation of high power electrical equipment and another way is to develop the multilevel inverter in the system.

STRUCTURE OF NEW CONTROL STRATEGY

A. Three Level Inverter

Fig. 1 shows the typical three level neutral point clamped NPC inverter, they have been widely used in several application such as motor drives, STATCOM, HVDC, Pulsewidth modulation (PWM), active power filters (APF), renewable energy applications, etc. The main advantages of these inverters are improving quality of voltage waveforms and an increase in the dc-link voltage for a given blocking voltage capacity of the semiconductors. The converter has two capacitors in the DC side to produce the three-level AC side phase voltages. Normally, the capacitor voltages are assumed to be balanced, since it has been reported that unbalance capacitor voltages can affect the AC side voltages and can produce unexpected behavior on system parameters such as even-harmonic injection and power ripple [6].

Several methods have been introduced to balance the capacitor voltage [5], [6], [7]. They are as follows:

Various strategies have been proposed to balance the capacitor voltages using modulation algorithms; one among them is sinusoidal carrier-based PWM (SPWM) or Space Vector Pulse-Width Modulation (SVPWM) [8], it is explain in next section.

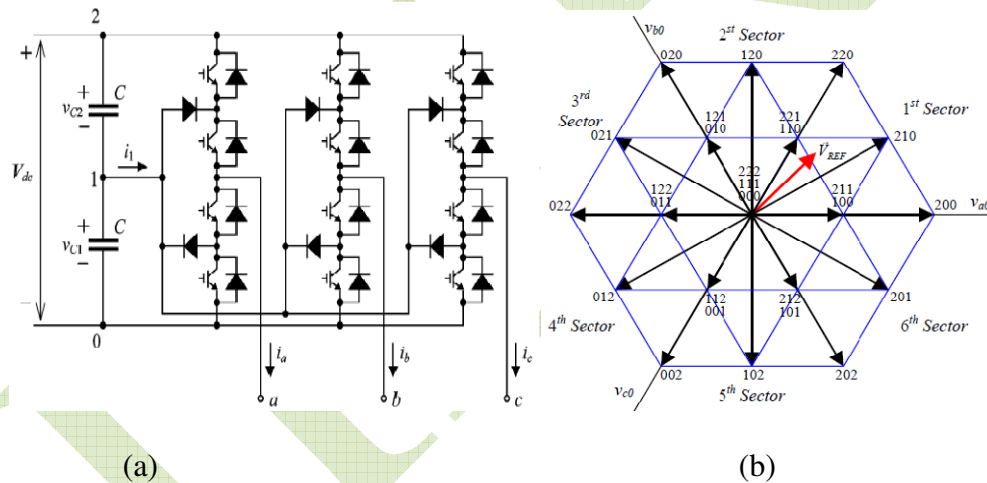


Fig.1 (a) A Typical three level NPC inverter, (b) Space vector diagram of the NPC inverter

B. Different Capacitors Voltages

In SVPWM, most of the strategies are based on injecting the appropriate zero-sequence signal in to the modulation signals to balance the DC-link capacitors [9].

In vector control theory, ideally, the inverter must be able to generate the voltage output instantaneously, following the reference vector (\vec{v}_{ref}), generated by the control system. However, because of the limitation of the switches in the inverter, it is not possible to guarantee that any requested vector can be generated; as a matter of fact, only a limited number of vectors (27 vectors for three-level inverter) can be generated.

To overcome such difficulties, in any space vector modulation scheme such as SVPWM and SVPWM, the reference vector, is generated by selecting the appropriate available vectors in each

time frame in such a way that the average of the applied vectors must be equal to the reference vector.

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

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

Where T_s is the time frame and preferred to be as short as possible. T_i is the corresponding time segment for selected inverter vector V_i and n is the number of applied vectors.

Generally, the reference vector is generated by the three nearest different vector ($n = 3$), and (1) can be converted to three different equation with three variables T_1 , T_2 , and T_3 to be calculated.

Fig. 1(b) shows the space vector diagram of a three-level inverter for balanced dc-link capacitors [5] this diagram shows, the numbers associated with each vectors represent the commutation state of the inverter for phase a, b and c respectively; 0 indicates that the corresponding phase is connected to the bottom of the DC-link, 1 to the NP and a 2 to the top.

It consist of four sets of vectors having their effect on different capacitor voltages. There are six large vectors (200, 220, 020, 022, 002, and 202), six medium vectors (210, 120, 021, 012, 102, and 201), the short or redundant vectors (100-211, 110- 221, 010-121, 011-122, 001-112, and 101-212), and three zero vectors (000, 111, and 222). Unlike the zero and large vectors, the medium vectors produce voltage imbalances on the capacitors caused by the connection of one phase to the NP. Proper selection of the short vectors can contribute to compensate for such imbalances.

For generating \vec{V}_{ref} , when one of the selections (\vec{V}_i), is a short vector, then there are two choices that can be made which can produce exactly the same effect on the ac side of the inverter in the three wire connection (if voltages are balanced). Capacitor balancing in most reported three-level NPC inverter applications is achieved by the proper selection of the short vectors.

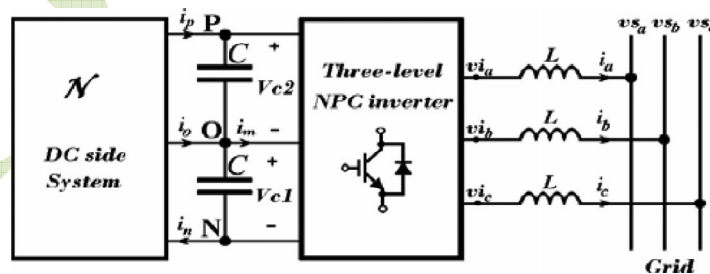


Fig.2 A grid connected three-wire three-level inverter.

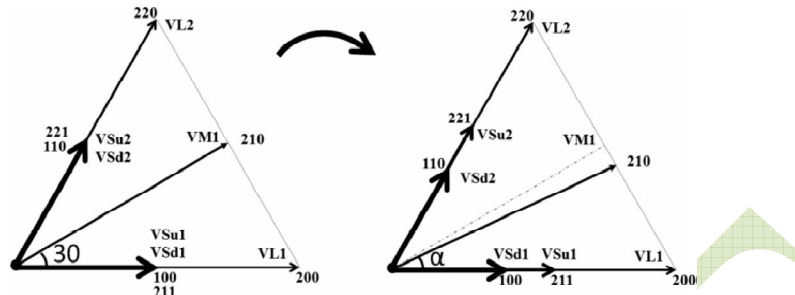


Fig. 3. Vector diagram in the first sector of Fig. 1 (b) showing the change of the vectors using balanced dc and unbalanced dc assuming $V_{c1} < V_{c2}$.

Fig.2 shows dc and ac side of inverter which is connected to the grid through three level NPC inverter. The dc side system shown by N consists of solar PV, a rectifying circuit, a battery storage. The unbalancing of capacitor voltages causes the short and medium vector is of different magnitude and angles as shown in fig. 1(b). Fig.3 shows the case where $V_{c1} < V_{c2}$. The vector \vec{V}_{i1} is related to the switching stage, it can be calculated as:

$$\vec{V}_I = \frac{2}{3} (V_{aN} + \vec{a} V_{bN} + \vec{a}^2 V_{cN}) \quad (2)$$

Where $\vec{a} = e^{j\frac{2\pi}{3}}$ and V_{aN} , V_{bN} and V_{cN} are the voltages of each phase with respect to N. The vectors in the first sector is calculated by using equation (2) and the result are given from in (3) – (9) these equation shows that the magnitude and angles of the vector is depending on the value of capacitor voltages, similarly the vectors in the other sector is also calculated.

$$\vec{V}_{sd1} = h \quad (3)$$

$$\vec{V}_{su1} = 1 - h \quad (4)$$

$$\vec{V}_{l1} = 1$$

$$\vec{V}_{l2} = \frac{1}{2} + \frac{\sqrt{3}}{2}j \quad (6)$$

$$\vec{V}_{sd2} = h \left(\frac{1}{2} + \frac{\sqrt{3}}{2}j \right) \quad (7)$$

$$\vec{V}_{su2} = (1 - h) \left(\frac{1}{2} + \frac{\sqrt{3}}{2}j \right) \quad (8)$$

$$\vec{V}_{m1} = \left(1 - \frac{h}{2} \right) + h \frac{\sqrt{3}}{2}j \quad (9)$$

PROPOSED TOPOLOGY TO INTEGRATE SOLAR PV AND BATTERY STORAGE

The two new configuration of a three level NPC inverter is integrated with battery storage and solar PV as shown in fig. (4). Fig shows that there is no extra converter is required and this can increase the overall efficiency of the system for both high and low power applications. Fig 4(a) shows the basic configuration of the grid connected three level NPC inverter with battery storage and solar PV. The power is transfer from system to the grid allowing the charging and discharging of the battery by the control system.

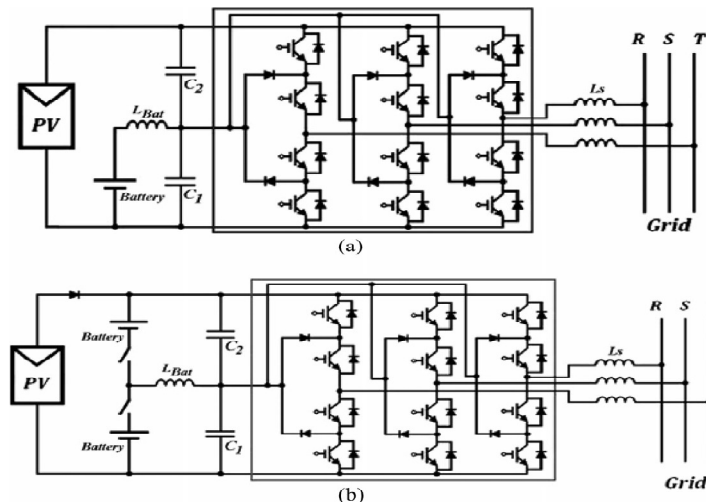


Fig. (4) Integration of solar PV and the Battery Storage. (a) Basic configuration (b) Improved configuration

Fig.4(b) shows the improved configuration of the system, in this the two batteries are connected across the capacitors through two relay. When the renewable energy is not available both the relay will remain close and allow the dc bus to transfer or absorb the active and reactive power to or from grid. In this there is no PWM control is used. When one battery is charge then relay will be open and another relay will remain close allowing the second battery to charge.

SIMULATION RESULT OF THE PROPOSED TOPOLOGY

Simulation is being carried out by using MATLAB/ Simulink. An LCL filter is used to connect inverter to the grid. Fig (5). The values used for the simulation are given in the Table I.

A grid connected to the Inverters takes a variable voltage from a DC source, such as solar panels array or a wind system, and inverts it to AC. It can provide power to your loads and feed an excess of the electricity into the grid. Depending on power and voltage levels Grid connected three level Inverters circuits normally have from one to three stages. G1 must be more than G2 to achieve the MPPT condition and having the flexibility to charge and discharge the battery. G1 and G2 are the gain associated with the relative error of the capacitor voltages. The role of L_{BAT} is to smooth the battery current, especially in the transient conditions and the value is dependent on the adjacent capacitor value and its transient voltage.

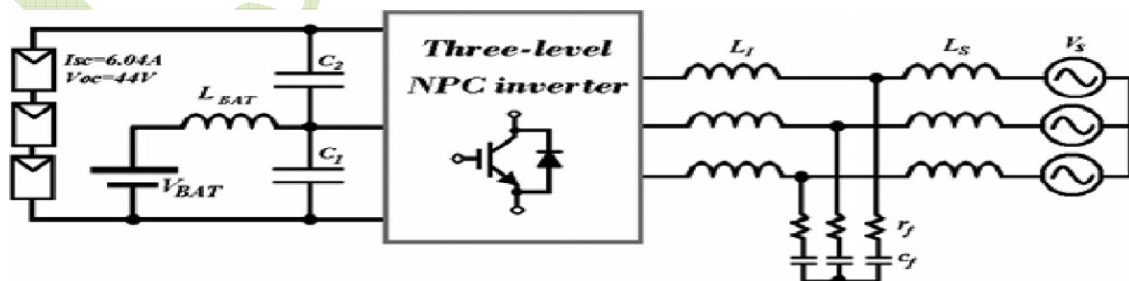


Fig. (5) Block diagram of the Simulated system.
TABLE I

PARAMETERS OF THE SIMULATED SYSTEM

V_{BAT}	V_s (line)	L_{BAT}	C_1, C_2	L_I	L_S
60 V	50 V	5 mH	1000 uF	500 uH	900 uH
r_f	C_f	K_p	K_i	G_1	G_2
3 Ω	14 uF	2.9	1700	1	200

Fig. (6) shows the inverter waveforms with respect to phase and reference. Fig.6(a) shows the line to line voltage V_{ab} , fig.6(b) shows the phase to midpoint voltage V_{ao} , fig. 6(c), (d) and (e) shows the reference voltage to neutral.

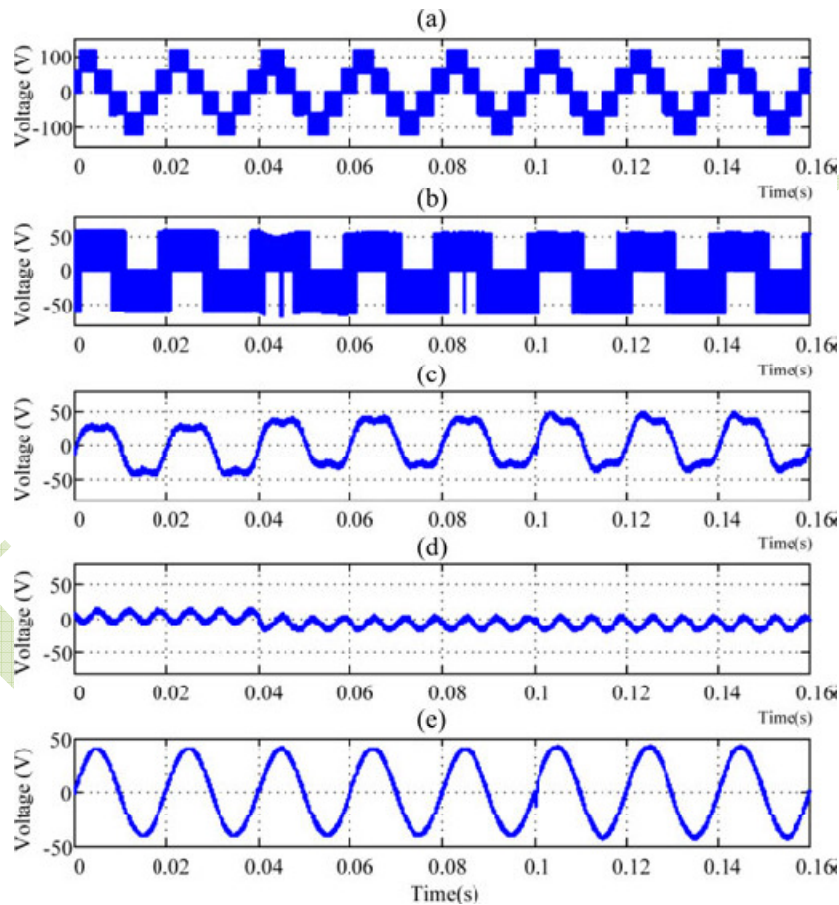


Fig. (6) Simulated inverter waveforms. (a) V_{ab} -Phase to phase inverter voltage. (b) V_{ao} -Inverter phase voltage reference to midpoint. (c) Filtered V_{oN} - Filtered inverter phase voltage reference to midpoint. (d) Filtered V_{oN} -Filtered midpoint voltage reference to neutral. (e) Filtered V_{aN} - Filtered phase voltage reference to neutral.

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. An unbalance three level vector modulation technique is used that can generate the correct ac voltage under any unbalanced conditions. A new algorithm is proposed to control the power flow between the solar PV, grid, and battery storage. The MPPT is used for the smooth and reliable operation for the solar PV. The results show the proposed system will control the balance and unbalance voltage levels from the solar irradiance.

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