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A Novel Solar Based Three-Level Neutral-Point-Clamped (NPC) Grid-Tied Inverter with Integrated Battery Storage

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ABSTRACT:

The unbalance of the neutral point voltage is an inherent problem of three-levelneutral-point-clamped (NPC) inverter, the effect of neutral point voltage balancingwhich is caused by voltage vector is analyzed, and the relationship of the voltage offset and neutral point voltage is studied in this paper. This paper proposes a novel neutral point balance strategy for three-level NPC inverter based on space vector pulse width modulation (SVPWM). A voltage offset is added to the modulation wave, and a closed-loop neutral point voltage balance control system is designed. In the control system, the dwellingtime of synthesis voltage vectors for SVPWM is varied to solve the problem of the unbalance of the neutral point voltage, the sequence of the voltage vectors maintains unchanging.Simulation results show the neutral point voltage balancingcontrol strategy based on SVPWM is effective.

Key words:

space vector PWM, neutral point voltage.

I.INTRODUCTION:

DUE to the world energy crisis and environmental problemscaused by conventional power generation, renewable energysources such as photovoltaic (PV) and wind generationsystems are becoming more promising alternatives to replaceconventional generation units for electricity generation [1], [2].Advanced power electronic systems are needed to utilize anddevelop renewable energy sources. In solar PV or wind energyapplications, utilizing maximum power from the source is oneof the most important functions of the power electronic systems[3]–[5]. In three-phase applications, two types of power electronic configurations are commonly used to transfer powerfrom the renewable energy resource to the grid: single-stage anddouble-stage conversion. In the double-stage conversion for a PV system, the first stage is usually a dc/dc converter and second stage is a dc/ac inverter. The function of the dc/dc converter is to facilitate themaximum power point tracking (MPPT) of the PV array and to produce the appropriate dc voltage for the dc/ac inverter. The function of the inverter is to generate three-phase sinusoidal voltages or currents to transfer the power to the grid in a grid-connected solar PV system or to the load in a stand-alone system [3]–[5].In the single-stage connection, only one converter is needed to fulfill the double-stage functions, and hence the system will have a lower cost and higher efficiency, however, a more complex control method will be required. The current norm of the industry for high power applications is a three-phase, singlestage PV energy systems by using a voltage-source converter (VSC) for power conversion [4]. One of the major concerns of solar and wind energy systems is their unpredictable and fluctuating nature. Grid-connected renewable energy systems accompanied by battery energy storage can overcome this concern. This also can increase the flexibility of power system control and raise the overall availability of the system [2]. Usually, a converter is required to control the charging and discharging of the battery storage system and another converter is required for dc/ac power conversion; thus, a threephasePV system connected to battery storage will require two converters. This paper is concerned with the design and study of a grid-connected three-phase solar PV system integrated withbattery storage using only one three-level converter having thecapability of MPPT and ac-side current control, and also the ability of controlling the battery charging and discharging. This will result in lower cost, better efficiency and increased flexibility of power flow control.

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II.PROPOSED SYSTEM:

As the switch isfurther away from the centre tap the switching time is shorter.Another difference between theconventional 2-level and multilevel NPC is the clamping diode. In case of 3-level NPC inverter,clamping diode, D1 and D4 clamped the DC bus voltage into three voltage level, +Vdc/2, 0 and -Vdc/2 Diode, D4 balances out the voltage sharing between S4in and S4out, with S4in blocking the voltage acrossC1 and S4out blocking the voltage across C2 the use of different parameters in the calculations and the regulations of the zero sequencesignals complicate the control. The SVPWM scheme uses the nearest three vectors to synthesizethe reference vector. Two methods can overcome the neutral point voltage problems:changing the vector switching sequence and changing the dwell times of the redundant states[7, 8]. Redundant states of the small vectors can be selected to maintain the neutral pointvoltage balance. Each small vector has two redundant states: positive small vector and negative small vector. These two states generate the same output voltage vector, however, theyhave the opposite control effect on the neutral pointvoltage. Therefore, redundant small vectors are used for neutral point voltage control [9].

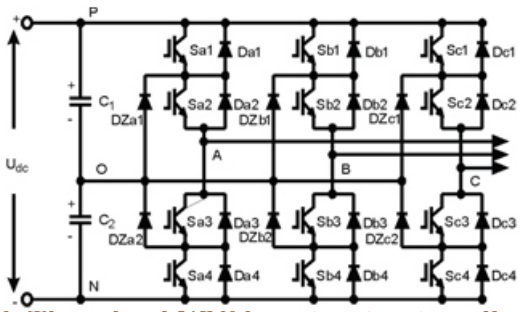

Fig. 1. Three-level NPC inverter structure diagram

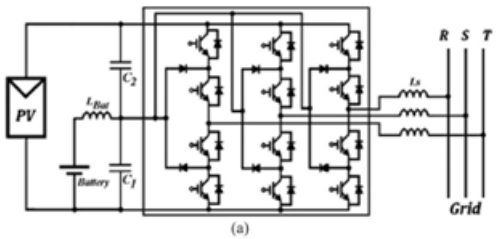

Fig. 2. Proposed configurations for integrating solar PV and battery storage:(a) basic configuration;

In the present paper, a neutral point voltage balance control strategy based on SVPWM isproposed. A voltage offset is added to the modulation wave in the regions of all the sectors asshown in Figure 2, and the neutral point voltage is controlled by changing the dwelling time ofthe synthesis voltage vectors. Simulation and experimental results show that the strategy hasgood capability for neutral point voltage balance.

III.CONTROL STRATEGY:

SVPWM scheme for NPC three-level inverter:

In the three-phase three-level NPC inverter, each phase has three output switching states"P", "O" and "N", which can be combined into a total of27 possible switching states, the total27 switching states correspond to 19 space voltage vectors, the space vector diagram is shownin Figure 2, it is composed of two hexagons.

The plane is divided into six 600 sectors (S1, S2,S3, S4, S5 and S6) by large vectors. And each sector can be divided into four regions (R1, R2,R3 and R4, R1 contains two small regions R11 and R12, R3 contains two small regions R31,R32). For the nearest three vectors (NTV) SVPWM strategy, reference output voltage issynthesized by the nearest three vectors according to the equivalence of the volt-second integral.

Based on the vector magnitude, space voltage vectors can be divided into four types: largevectors, medium vectors, small vectors and zero vectors. The lager vectors have the magnitudeof 2/3Udc, which are located at the vertices of the outer hexagon, the medium vectors have themagnitude of 3 / 3 Udc, which are located at the middle of the outer hexagon, the smallvectors have the magnitude of 1/3Udc, which are located at the vertices of the inner hexagon,and the zero vectors have the magnitude of zero. Each small vector has two switching states,one contains "P" state, which is called positive small vector, and the other contains "N" state,which is called negative small vector.

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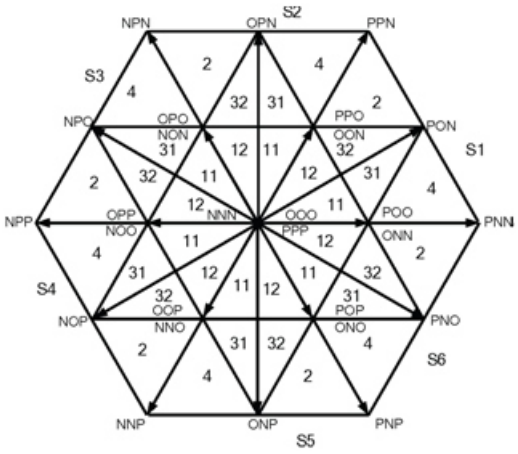

Fig. 2. Voltage space vector distribution

The four types of vectors have different effect on neutral point voltage deviation, it is summarized that the zero and large vectors do not affect the neutral point voltage; the mediumvectors affect the neutral point voltage, but the influence depends on the operation conditionsthe small vectors have specific effect on the neutral point voltage, the neutral point voltagewill rise when positive small vector operates, and the neutral point voltage will drop whennegative small vector operates in motoring mode. The power flow is from DC-link to the loadwhen the system is in motoring mode; and the power flow is from the load to DC-link whenthe system is in regenerative mode. The mode depends on the direction of the DC-link current. In contrary, the neutral point voltage will rise when positive small vector operates, and the neutral point voltage will drop when negative small vector operates in regenerative mode.

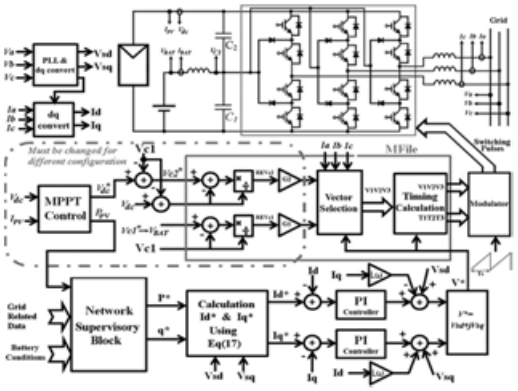

Fig. 3. Control system diagram to integrate PV and battery storage

3. Neutral point balance control based on SVPWM:

In this paper, a SVPWM strategy is proposed to maintain the neutral point voltage balance.The switching sequence of this strategy is the same as that of conventional NTV SVPWMalgorithm. The negative small vector is chosen to be the first given vector, Figure 3 shows thesynthesis vectors sequence when the reference voltage vector ref Vris located in S1, R11. Forthe proposed neutral point voltage balancing strategy, in each region of the sixsectors, a voltageoffset is add to the adjusting phase uk (k is a, b or c), and the dwelling times of operationvectors change. The adjusting phase uk is the phase whose absolute value is thelargest of threephases,

IV.SIMULATION RESULTS:

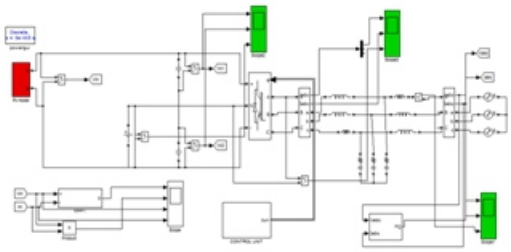

Fig.4 .Simulation circuit

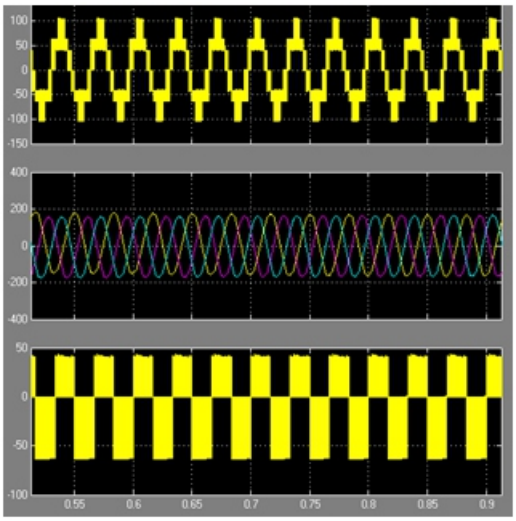

Fig.5 Phase-phase inverter voltage, inverter current and Va0

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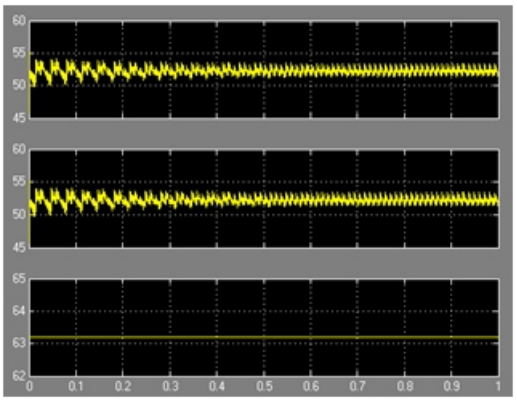

Fig.6 Dc capacitors and battery voltage

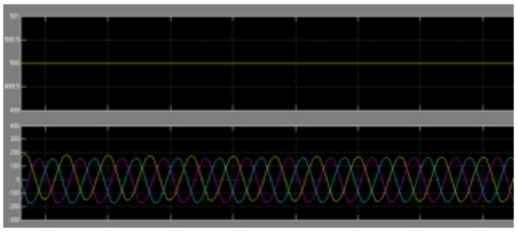

Fig.7 Output power and Grid Current

V. CONCLUSION:

In this paper, a neutral point voltage balance control strategy based on SVPWM for threelevelinverters is presented. This strategy maintains the neutral point voltage balance by addinga voltage offset to the modulation wave of the adjusting phase. The causes of the neutralpoint unbalance are studied in detail, and the influence of the voltage offset on neutral pointbalance is investigated, in motoring mode, when the voltage offset is positive, neutral pointvoltage will increase. In contrast, when the voltage offset is negative, neutral point voltagewill decrease. In regenerative mode, neutral point voltage will increase when voltage offset isnegative, and neutral point voltage will decrease when the voltage offset is positive. The newsimple and effective strategy for neutral point voltage control is verified by simulations results.

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