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A Novel Solar based NPC Grid-Tied Inverter with Integrated Battery Storage

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ABSTRACT:

A new configuration of a three level neutral point clamped inverter that can integrates solar photovoltaic withbattery storage in a grid connected system is proposed in this paper. The proposed system has capability of generating correct Ac voltage under unbalanced DC bus voltage conditions. This paper present the designphilosophy of proposed configuration and the theoretical frame work of proposed modulating technique. Thecontrol scheme has capability of 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 usefulness of the proposed methodology is investigated by the simulation of several scenarios, including battery charging and discharging with different levels of solar irradiation.

Keywords:
Battery Storage System, Solar Photovoltaic, Space Vector Pulse WidthModulation,Three- Level NPC Inverter.

I.INTRODUCTION:

Nowadays demand for power throughout the world increases and these demands cannot meet by conventionalsources (like thermal and hydro generation) because of limited availability of coal and water. Hence entire worldfoot forward to the renewable energy sources like wind and solar energy they never going to be vanish, and these are the most promising alternatives to replace conventional energy sources [1], [2]. But effectiveutilization of renewable sources and for getting maximum power output requires fast acting power electronicconverters [3]. For three-phase applications, two types of power electronic configurations are commonly used to transfer powerfrom the renewable energy resource to the grid: 1) single-stage and 2) double-stage conversion.

In the doublestageconversion for a PV system, the first stage is usually a dc/dc converter and the second stage is a dc/acinverter. In first stage the DC-DC converter provides maximum power tracking from PV module and alsoproduces appropriate DC voltage for stage-2 inversion. In stage-2 (inversion stage) inverter produces 3-øsinusoidal voltages or currents and it transfers power to load connected or to the grid.

In the case of single-stage connection, only one converter is desired to fulfill the double-stage functions, andhence the system will have a lower cost and higher efficiency, however, a more complex control method will be required. For industrial high power applications need a 3-ø system, single stage PV energy systems by using avoltage-source converter (VSC) for power conversion [4], [5].

Because of unpredictable and fluctuating nature of solar PV and wind energy systems the output of thesesystems not constant at terminal ends to overcome such difficulty a battery storage system is employed. Thisalso can boost the flexibility of power system control and increase the overall availability of the system [2].

Usually, a converter is essential to control the charging and discharging of the battery storage system andanother converter is required for dc/ac power conversion; thus, a three phase PV system connected to batterystorage will require two converters. This paper is concerned with the design and study of a grid-connected threephasesolar PV system integrated with battery storage using only one three-level NPC converter having thecapability of MPPT and ac-side current control, and also the ability of controlling the battery charging anddischarging.

All these will result the cost of conversion decreases, efficiency goes up and flexibility of power flow control increase.

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II.PROPOSED SYSTE:

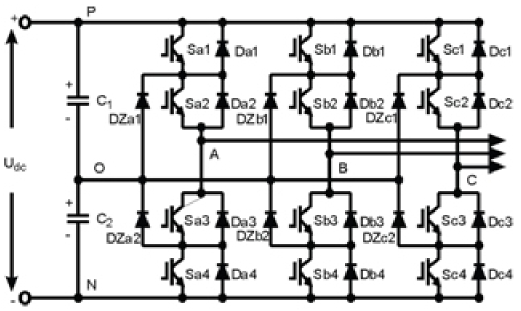

Fig. 1. Three-level NPC inverter structure diagram

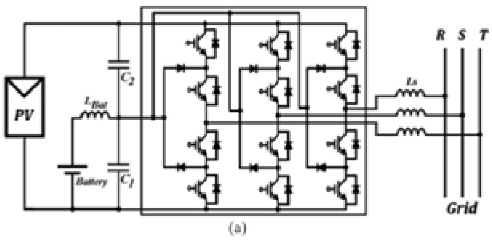

Fig. 2. Proposed configurations for integrating solar PV and battery storage:(a) basic configuration;

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.

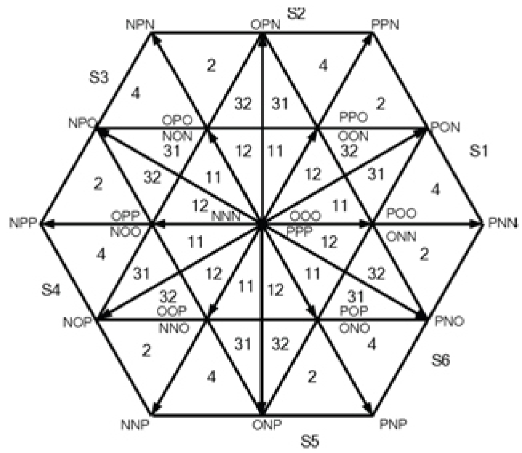

Fig.3. Voltage space vector distribution

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.

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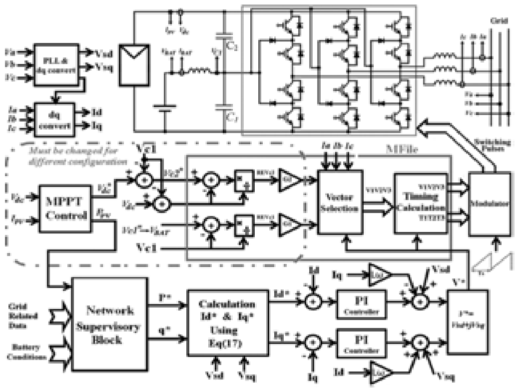

Fig. 3. Control system diagram to integrate PV and battery storage.

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:

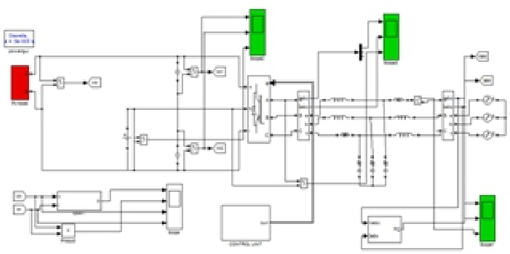

Fig.4 .Simulation circuit

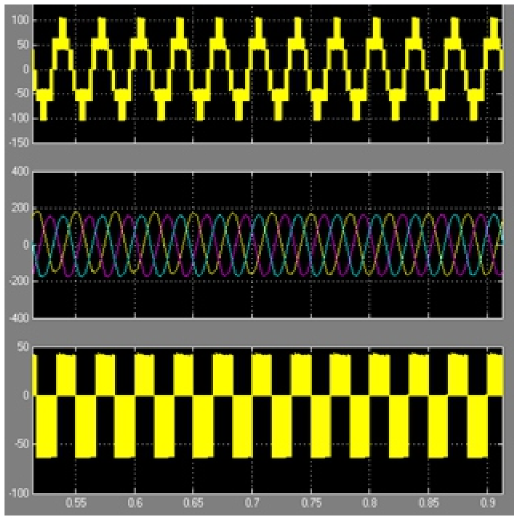

Fig.5 Phase-phase inverter voltage, inverter current and Va0

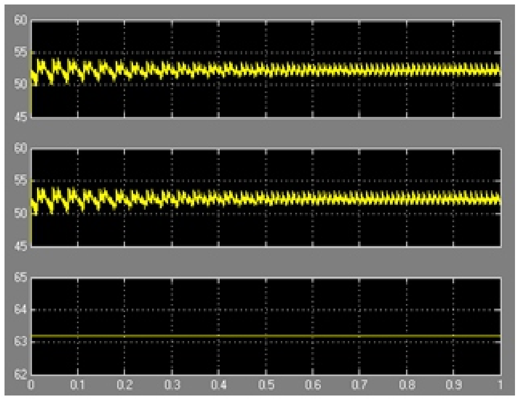

Fig.6 Dc capacitors and battery voltage

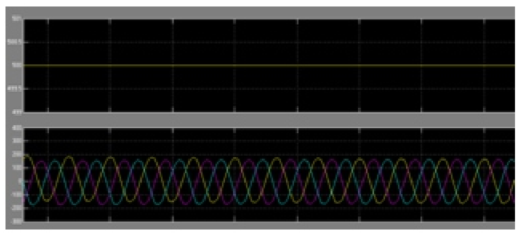

Fig.7 Output power and Grid Current

V. CONCLUSION:

A novel topology for a three-level NPC voltage source inverter that can integrate both renewable energy andbattery storage on the dc side of the inverter has been presented. A theoretical framework of a novel extendedunbalance three-level vector modulation technique that can generate the correct ac voltage under unbalanced dcvoltage conditions has been proposed.

A new control algorithm for the proposed system has also been presentedin order to control power flow between solar PV, battery, and grid system, while MPPT operation for the solarPV is achieved simultaneously. The effectiveness of the proposed topology and control algorithm was testedusing simulations and results are presented. The results demonstrate that the proposed system is able to controlac-side current, and battery charging and discharging currents at different levels of solar irradiation.

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