SIMULATION OF NQBI FOR HV APPLICATIONS IN POWER SYSTEMS

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Abstract- Multilevel inverters (MLI) with switching capacitors are becoming more common in high-voltage AC applications related to renewable energy. Using the switched capacitor (SC) method, the desired voltage amplitude is created by applying a small DC voltage across the capacitor. Creating an effective MLI takes more work and less space on the keyboard. This work presents a nine-phase, four-phase quad boost inverter (NQBI) topology driven by a single solar photovoltaic source that uses fewer capacitors, switches, and diodes than previous SC-MLI architectures. The voltage across the two capacitors can be measured to provide nine distinct outputs. To illustrate the benefits and drawbacks of the suggested nine-phase quadrupole boost inverter (NQBI) architecture, a comparison of several SC-MLIs has been conducted. Successful trials have been conducted in a variety of experimental settings to show the efficacy of solar photovoltaic-based NQBI without grid connection.
Keywords: Reduced switch count, SPWM method, NQBI, and switched capacitor inverter.

1. INTRODUCTION

Devices frequently used in fuel cells and photovoltaic (PV)-based sustainable or renewable energy (RES) to convert electricity directly from electricity to direct current. This is MLI or multi-level inverter. MLI has the advantages of reducing stress transfer, increasing output power, improving output power integration and reducing dv/dt. Three major types of MLI have emerged in recent years: diode-clamped neutral point coupling (NPC) topology, cascaded H-bridge (CHB) topology, and flying capacitor (FC) architecture. In FC-MLI and NPC-MLI topologies, complex control systems and additional power supply are required to stabilize the capacitor voltage. In CHB-MLI, DC power supply is mainly used to generate more power supply. Additional support is needed to achieve better results when using MLI with RES.

A DC-DC boost converter or transformer is required to obtain a high output voltage. Large, expensive and complex inverter systems are created from these components [1]-[5]. As a recent development, multiphase inverters based on the SC principle have been used to reduce the above limitations [6]-[18].

SC-MLI increases the input voltage as well as increasing the output voltage. When an isolated DC is used as suggested in [6], there is no need for an H-bridge. Although the stress on the transformer is small in [6], when the voltage increases, the capacitors and power transformers also increase.

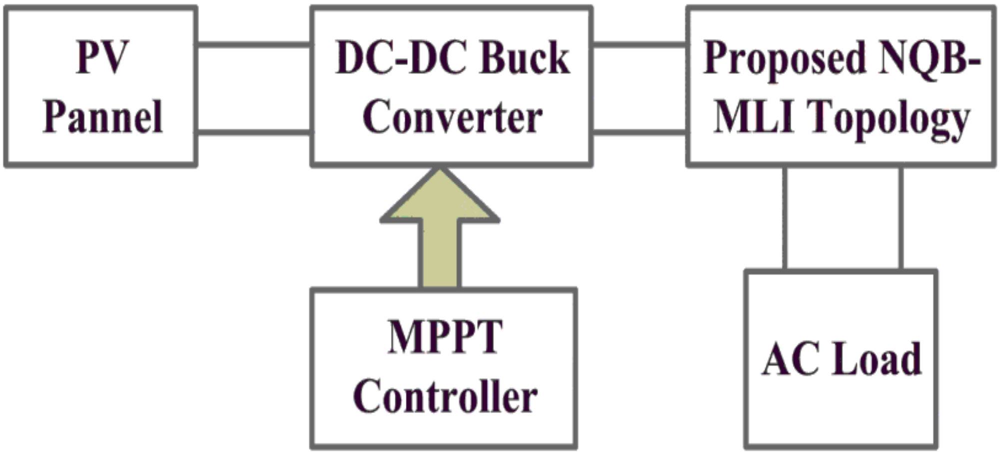

Fig. 1.1 A schematic diagram showing the suggested off-grid photovoltaic system with inverters and AC loads

Due to the low voltage stress and high voltage balance and support capacity, the SC-MLI topology introduced in [7], [8] is proposed for the conversion of renewable energy sources. Although it has the same number of output voltage levels and switches as [8], [7] uses a larger capacitor than [8] to provide power. A nine-phase H-bridge based three-phase switched capacitor inverter was also studied in [17]. A standard inverter can measure the voltage of its capacitors but cannot increase the voltage. In [9], [10], and [18], three SC-based nine-phase inverters with single-source architecture are proposed. These inverters provide capacitor voltage measurement without the need for connecting cables or additional power supplies. However, their potential balance of uses is two.

The equation of the variable mentioned in [11] is four. This architecture has a lot of diodes and capacitors but uses less power to convert electricity. To quadruple the output voltage, the SC-MLI in [12] uses an isolated DC power supply; however, these models require additional spare parts. References [13]-[16] discuss various topologies with various high-power consumption; However, additional hardware is needed to provide voltage (9-L) output. As the number of components increases, the cost related to inverter topology and loss also increases.

This work presents a nine-bit four-bit quad boost inverter (NQBI) architecture to solve the shortcomings of chemical topology found in previous works. The main advantages of this topology are listed below:

- The NQBI architecture has the ability to self-measure voltage and can achieve output voltage amplitudes up to four times the DC voltage amplitude.
- Therefore, there is no need for additional power supply to maintain the capacitor voltage.
- NQBI are much less versatile.
- NQBI architecture can be combined for loads with different power models.
- Proposed Nqbi Topology Based Pv System.

Maximum output is achieved by using Maximum Power Transformer (MPPT) and connecting the DC-DC converter to the PV system output. Fig. 1.2 shows the NQBI results.

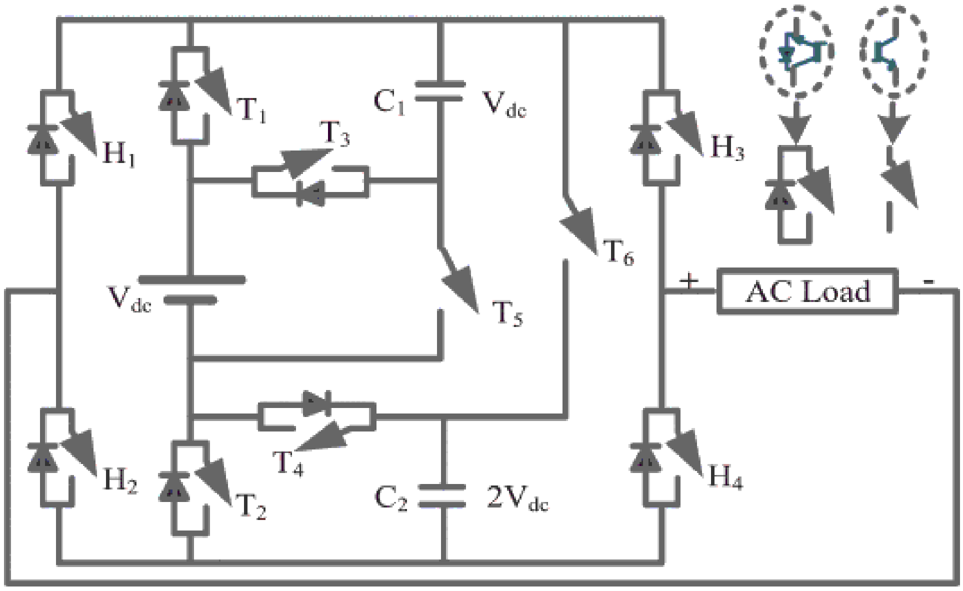

Fig. 1.2 Proposed NQBI Topology

The proposed MLI can be a nine-level quad power outlet with only 10 power switches. Fig 2 shows that the phase design section of this inverter model uses two capacitors with nominal values of V_{dc} and $2V_{dc}$ to increase the voltage by a quarter to create a four-phase voltage.

To stop the capacitors C_1 and C_2 from being discharged unnecessarily, the switches T_5 and T_6 are set up as reverse blocking switches. The polarity-generating portion, which is made up of the four switches H_1, H_2, H_3, and H_4, may produce alternating polarity. The capacitor switching states and modes that may be used to produce the nine-level AC output voltage are shown in Table 1.1.

Table-1.1 The proposed NQBI's capacitor condition, output voltage, and switching States

T 1	T2	T3	T4	T5	T6	H1	H2	H3	H4	Vo(xVdc)	C1	C2
0	0	1	1	0	0	0	1	1	0	4	D	D
1	0	0	1	1	0	0	1	1	0	3	C	D
0	1	1	0	0	1	0	1	1	0	2	D	C
1	1	0	0	1	0	0	1	1	0	1	C	-
1	0	0	0	1	0	1	0	1	0	Zero	C	
1	0	0	0	1	0	0	1	0	1			-
1	1	0	0	1	0	1	0	0	1	-1	C	-
0	1	1	0	0	1	1	0	0	1	-2	D	C
1	0	0	1	1	0	1	0	0	1	-3	C	D
0	0	1	1	0	0	1	0	0	1	-4	D	D

1.1 Evaluation of C1 And C2's Capacitance and Self-Voltage Balance

The NQBI concept can measure individual voltage while charging and discharging capacitors C_1 and C_2 using a series of parallel circuits. Capacitor C1 is connected to DC source and charged to Vdc, while T_1 and T_5 operate simultaneously at output voltage of ±0, $\pm V_{dc}$ and $\pm 3V_{dc}$ as shown in Table 1. Capacitors C_2 and C_1 are connected in series and DC supply respectively when T_2, T_3 and T6 are conducting. At $\pm V_{dc}$ output voltage level, capacitor C_1 is discharged and capacitor C_2 is charged to a maximum of 2 V_{dc}. When T_2 and T_4 are turned on at the same time, two capacitors (C1 and C_2) are connected to the DC source and the voltage becomes ± 4 V_{dc}. Fig.3 shows the value and output patterns of C_1 and C_2 during a single output voltage cycle

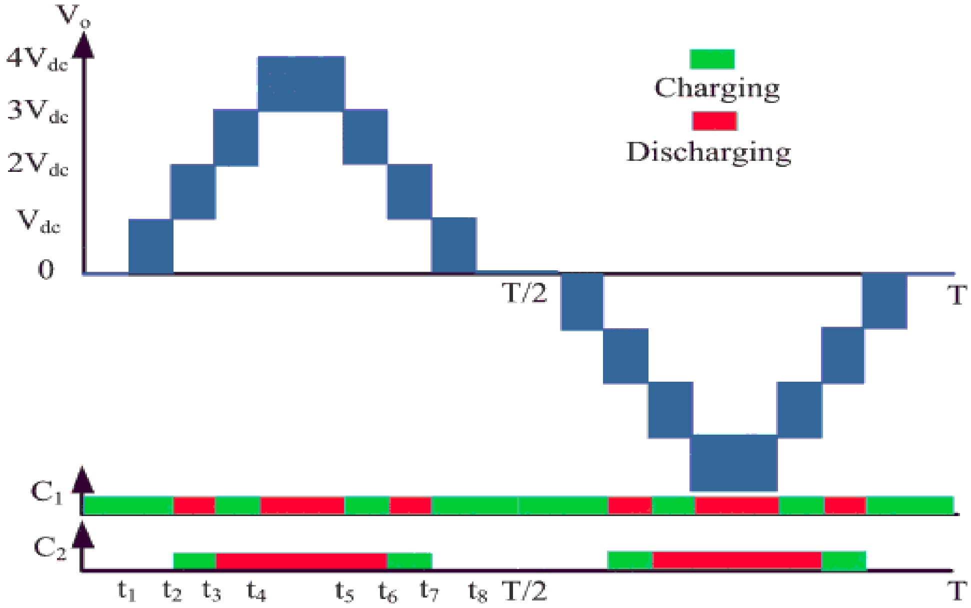

Fig. 1.3 Output voltage and charging pattern of capacitor

When capacitors C_1 and C_2 are closed, their voltage begins to decrease from the nominal value.the voltage of the capacitors C_1 and C_2 begins to drop from their nominal values. The total capacitance values, C_1 and C_2, required for the proper voltage ripple (ΔV), peak load current ($I_{o,\ peak}$), output voltage frequency, and matching maximum discharge time.

ΔT_1 and ΔT_2 are as follows:

where the voltage level interval of $4V_{dc}$ is represented by $\Delta T_1 = t_5 - t_4$, and the voltage level interval of $3V_{dc}$ and $4V_{dc}$ is represented by $\Delta T_2 = t_6 - t_3$ [11].

1.2 Technique of Pulsed-Width Modulation

Sinusoidal pulse width modulation compared to NQBI to generate a reference sine wave signal (v_{ref}) of appropriate amplitude (v_m). Eight-phase alternating current with the same amplitude (AC) is shown in Fig. 1.4.

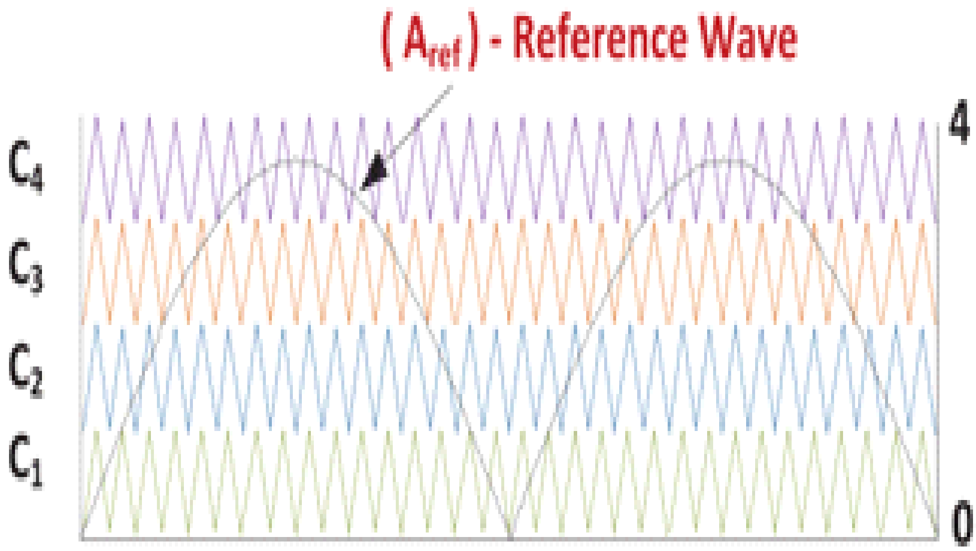

Fig. 1.4 shows the LS-PWM modulation method

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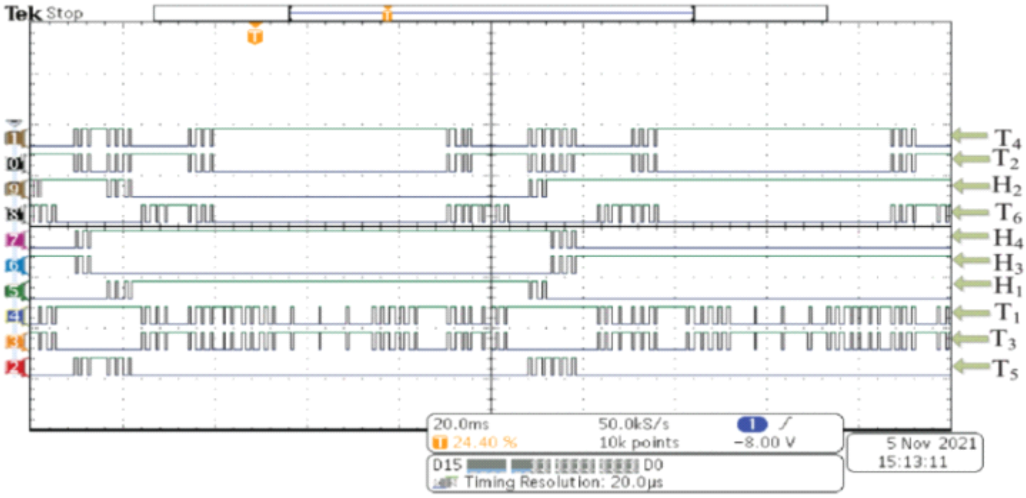

Fig. 1.5 The suggested nine-level inverter's gate pulses

The NQBI pulse gate is shown in Fig. 1.5. The meter measures the appropriate output voltage amplitude by the difference between the amplitude of the signal used. Instructions for using the tool are as follows:

1.3 Analysis of the Proposed NQBI Topology Power Loss

Nowadays, inverter equipment problems can cause inverter failure. The three main types of losses in the NQBI concept are substitution (P_{sw}), loss (P_c) and fluctuation losses (P_{ripple}). Therefore, the total power loss (P_{loss}) experienced by NQBI is Switching loss results from the voltage and current overlapping during each switching transition caused by intrinsic delays in the IGBT's switching. It is able to be stated as:

V_{on} is a representation of the voltage across the IGBT upon startup. I_{on} is the term for the current that is generated when electricity is transferred. ON state shift in tuning time.

The voltage across the power switch, the current passing through it while it is in the off state, and the long-term power change in the off state are represented by the symbols V_{off}, I_{off}, and T_{off}, respectively. The symbols f_0 and f_{fsw}, respectively, stand for the switching frequency and the output voltage frequency. When a switch is in conduction mode, conduction loss is the power loss resulting from internal work. The following can be listed among them:

I_{switch} is there to switch when Ron's internal struggle is present. The ripple loss during capacitor charging and discharging is a significant part of the total power loss in SC-MLI. Power loss occurs when measuring the charge of capacitors connected to a DC source. The ripple voltage ΔVC created by the difference between the capacitor and the capacitor charging current causes power loss. The ripple energy loss in the capacitor can be calculated by the formula:

Table 1.2 illustrates the energy loss of the different parts of the inverter concept using a 0.5 kW output power. The suggested NQB inverter has an efficiency of 97.3 at 0.5 kW of output power.

Table-1.2 Power loss profile with the proposed NQBI Topology

Power loss of	P_{sw}	P_{con}	P_{loss}
H1 (W)	0.015	0.62	0.635
H2 (W)	0.015	0.61	0.625
H3 (W)	0.0044	0.602	0.6064
H4 (W)	0.0044	0.603	0.6074
T1 (W)	0.047	1.11	1.157
T2 (W)	0.113	1.56	1.674
T3 (W)	0.136	1.56	1.696
T4 (W)	0.05	0.75	0.8
T5 (W)	0.074	0.55	0.624
T6 (W)	0.076	0.45	0.526
C1 (W)	1.11		
C2 (W)	3.44		
Power $_{total\ loss}$ (W)	13.5		
Output Power (W)	500		
Efficiency (%)	97.5		

2. COMPARATIVE ANALYSIS

It is a good choice to provide good power to the load or grid due to the design concept, support capacity and nine voltages at the output. Table 2.1 shows a comparison with various MLI topologies with the following feature.

Table-2.1 Different topologies are compared with the suggested NQB-MLI Topology

Topology	Nsw	Ngd	Nd	Ncom	No	Vc		Nsc	TSVp.u.			TCD			CF	(with value	of a and 8)		G
						Vdc	2Vdc			11st	22nd	+3rd	14th	TCD,	0.5.0.5	1.0.1.0	1.5.0.5	0.5. 1.5	
[6]	17	17	0	17	3	3	0	9	5.5	8	8	8	8	8	35.75	42.5	41.25	43.75	4
[11]	8	8	3	11	3	1	2	6	5.75	5	5	5	5	5	27.375	32.75	33.125	32.375	4
[12]	12	12	0	12	2	1	1	6	5.25	6	7	6	6.5	6.5	26.875	32.75	32.125	33.375	4
[13]	17	17	5	22	4	4	0	12	5.5	10	9.5	8.5	8.5	9	45.25	52.5	50.75	54.25	4
[14]	13	13	0	13	3	3	0	6	6.25	8	7	6	5	6.5	28.375	34.75	34.625	34.875	4
[15]	8	8	6	14	3	3	0	6	8	8	4	5	5	5.5	29.75	36.5	37.75	35.25	4
[16]	10	10	3	13	3	3	0	6	6.25	8	5	5	5	5.75	28	34	34.25	33.75	4
[9]	10	10	I	11	2	2	0	3	5.75	5	5	5	4	4.75	21.25	26.5	29.37	28.87	2
[17]	8	8	2	10	3	3	0	3	5	5	4	6	5	5	29.5	42	49.5	34.5	2
[18]	10	10	1	11	2	1	1	3	5.55	5	4	5	5	4.75	20.25	25.5	28.37	27.87	2
Proposed NQBI	10	10	0	10	2	1	1	3	6.25	5	5	5	4	4.75	20.25	25.5	28.37	27.87	4

N_{sw}=Quantity of power electronics switches, N_{gd}=Quantity of gate drivercircuits, N_d=Quantity of additional diodes, N_{com}=Sum of Nsw and N_d, N_c=Quantity of capacitor, V_c = Capacitor voltage rating, N_{SC} = Quantity of devices conducting in charging capacitors, TSV_{pu} = Total standing voltage in per unit, G= Gain, and TCD = Total conducting device.

The ability of their terminals to generate four times more voltage. The suggestion is that although the topologies proposed in [11] and [15] they need more diodes but less switching than the proposed NQBI architecture. Moreover, the architecture of [11] calls for two $2V_{dc}$-rated capacitors and one $2V_{dc}$-rated capacitor in order to achieve triple voltage gain, whereas the recommended design calls for two Vdc-rated capacitors and two $2V_{dc}$-rated capacitors.

The number of capacitors in MLI increases costs and makes charging and discharging more difficult. The inverter concept only requires 10 active switches, while the design in [12] calls for two capacitors in addition to a total of twelve active switches. The number of electronic components in the load capacity (NSC) is another essential factor for comparing SC topologies. The material used in the charging circuit must have a greater current rating in order to support the capacitor's charging current. At present, the suggested layout is available only on four products, all of which have superior ratings. In comparison to the architecture employed in this study, the topologies proposed in [6,], [9], [11], and [16] call for more hardware in the load loop, increasing the cost and loss.

For the purpose of comparison, the total number of electronic devices (TCD) per voltage level was determined. Table 3 also presents a comparison between the minimal number of points required at any given time for the proposed NQBI inverter to function and other criteria.The proposed inverter has higher average value per unit (TSVpu) than all other MLIs except [15]. The following are NQBI's loading functions where α and β are the weights of TSV_{pu} and TCD_{avg}, respectively. CF control value for gate driver circuits, capacitors and power transformers.

Table 2.1 lists different types of CFs with different weight coefficients (α and β). The proposed NQB-MLI was found to have lower CF values than other MLIs.

The PLECS program models various topologies with the following specifications: carrier frequency = 5 kHz, V_{dc} = 30V and C = 4700μF. Fig.6 shows the performance of various topologies under different conditions.

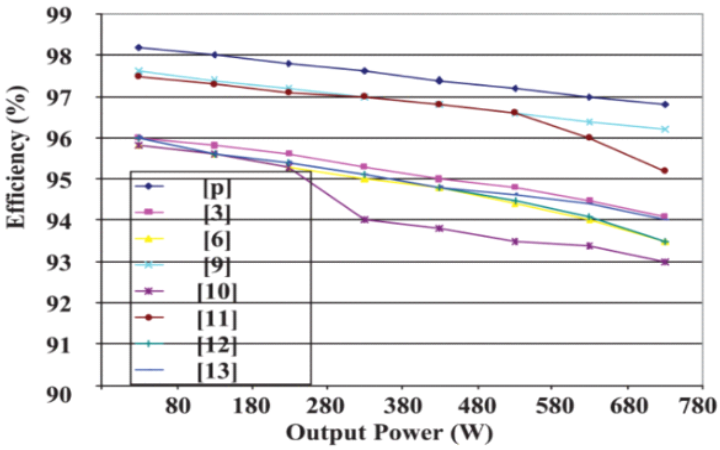

Fig. 3.1 shows the calculated efficiency comparison between the current inverter topologies and the proposed nine-level inverter

Fig. 3.1 clearly shows that the best performance of the design is 98.2%. Moreover, the proposed NQB-MLI outperforms all other topologies due to reduced component count, reduced power consumption, and reduced network complexity.

CONCLUSION

This work presents a low-reduction, nine-stage, switched-capacitor-based quadruple-boost inverter topology. Since two capacitors of different values are used in the inverter model, there is no difference in the voltage measurement required to complete the voltage measurement. Comparative analysis shows that the proposed nine-phase inverter topology outperforms other commonly used nine-phase switched-capacitor inverter topologies in terms of efficiency, total number of products and price accuracy.

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