International Journal on Applications in Engineering and Technology
Volume 1: Issue 3: March 2015, pp 18-23. www.aetsjournal.com

Z-Source Multi Level Inverter with Genetic Algorithm

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Abstract-This project presents a Photovoltaic Multilevel Inverter based on Genetic Algorithm (GA). In the existing system, a novel switched capacitor based MLI is presented. The Symmetrical Phase Shift Modulation (PSM) technique is used and the active device present in the MLI produces a power loss with shoot-through problem. The proposed system consists of PV system, Z-source, MLI, Genetic Algorithm and PI controller. The Z-source is used to protect the MLI from the shoot-through problem and also to reduce the switching loss and switching stress of the device. A novel switched-capacitor-based cascaded multilevel inverter with Symmetrical Phase Shift Modulation (PSM) technique is used, which is constructed by a switched-capacitor frontend and H-Bridge backend. Through the conversion of series and parallel connections, the switched capacitor frontend increases the number of voltage levels. The output harmonics can be significantly reduced by the increasing number of voltage levels. Genetic algorithm and PI controller will be used to evaluate the performance of the proposed system and the output of both controllers will be compared. The salient features of the proposed nine level inverter are that reduced switching loss and switching stress and minimized THD value. A prototype will be developed and the performance of the system is analysed by using MATLAB/Simulink platform .

Index term - Multilevel Inverter ,Z-source, Genetic Algorithm(GA), Photovoltaic(PV),Phase Shift Modulation (PSM).

I.INTRODUCTION

Solar energy is one of the most important renewable energy sources that has been gaining increased attention in recent years. Solar energy is plentiful; it has the greatest availability compared to other energy sources. The amount of energy supplied to the earth in one day by the sun is sufficient to power the total energy needs of the earth for one year. Solar energy is clean and free of emissions, since it does not produce pollutants or by-products harmful to nature. So that here the PV is used as an input [12]. High-frequency ac (HFAC) power distribution system (PDS) potentially becomes an alternative to traditional dc distribution due to the fewer components and lower cost. So that in this project high frequency output is considered [14,15]. In recent years Multilevel power conversion has become increasingly popular because it have advantages of high power density and quality waveforms, low switching losses, and high-voltage capability. Multilevel inverter synthesizes staircase waveform with less harmonic content compared to three level waveform operating at same switching frequency. In a multilevel inverter the number of switching device was reduced [11]. But there is some switching loss and switching stress are present in a converter switches. The switching losses and switching stress will reduce by using Z-source multilevel inverter [13]. Automatically the THD value will be reduce because of multilevel inverter.

There are different types of multilevel circuits are available [7]. In that first MLI introduced was the series H-bridge design. Then the diode clamped converter was introduced, that utilized a lot of series capacitors. A later invention detailed the flying capacitor design in which the capacitors were floating rather than series-connected. Several combinational designs have also emerged some involving cascading the fundamental topologies. The multilevel inverters are mainly classified as diode clamped, Flying capacitor inverter and cascaded multilevel inverter. The cascaded multilevel control method is very easy when compare to other multilevel inverter because it doesn’t require any clamping diode and flying capacitor. It is impractical for HF inverter, because it is complicated to simultaneously synchronize both amplitude and phase with HF dynamics. Multilevel inverter is an effective solution to increase power capacity without synchronization consideration, so the higher power capacity is easy to be achieved by multilevel inverter with lower switch stress. Non polluted sinusoidal waveform with the lower total harmonic distortion (THD) is critically caused by long track distribution in HFAC PDS. A genetic algorithm (or GA) is a search technique used in computing to find true or approximate solutions to optimization and search problems[9].(GA)s are categorized as global search heuristics.(GA)s are a particular class of evolutionary algorithms that use techniques inspired by evolutionary biology such as inheritance, mutation, selection, and crossover (also called recombination)[5].

II. SWITCHED CAPACITOR BASED CASCADED INVERTER WITH NINE-LEVEL OUTPUT

The proposed circuit is made up of the SC frontend and cascaded H-Bridge backend. If the numbers of voltage levels obtained by SC frontend and cascaded H-

Bridge backend are N1 and N2, respectively, the number of voltage levels is 2 × N1×N2+1 in the entire operation cycle. Fig. 1 shows the circuit topology of solar input with nine-level inverter (N1 = 2, N2 = 2), where S1,S2,S1',S2' as the switching devices of SC circuits (SC1 and SC2) are used to convert the series or parallel connection of C1 and C2. S_{1a},S_{1b},S_{1c},S_{1d},S_{2a},S_{2b},S_{2c},S_{2d} are the switching devices of cascaded H-Bridge. PV1 and PV2 are solar input voltage. D1 and D2 are diodes to restrict the current direction. I_{out} and V_o are the output current and the output voltage, respectively. It is worth noting that the backend circuit of the proposed inverter is cascaded H-Bridges in series connection.

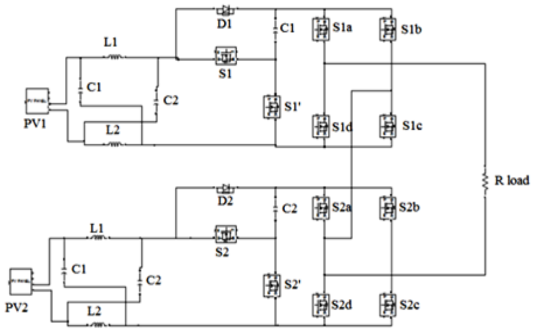

Fig.2.1 Circuit diagram of Z-source SC-based Cascaded Inverter

It is significant for H-Bridge to ensure the circuit conducting regardless of the directions of output voltage and current. In other words, H- Bridge has four conducting modes in the conditions of inductive and resistive load, i.e., forward conducting, reverse conducting, forward freewheeling, and reverse freewheeling.

A. Symmetrical Modulation

There are many modulation methods to regulate the multilevel inverter, the popular modulations are the space vector modulation , the multicarrier PWM , and the selective harmonic elimination , sub harmonic pulse width modulation , etc. However, most of them greatly increase the carrier frequency that is dozens times the frequency of reference or output. A symmetrical phase-shift modulation (PSM) is introduced into the proposed multilevel inverter. The symmetrical PSM ensures the output voltage of full bridge is symmetrical to the carrier, so voltage levels can be super imposed symmetrically and carrier frequency is twice as that of output frequency. A controlled PWM with pulse width δ is symmetrically generated by the comparisons of the triangle carrier V_c and modulation signal V_m. The rising edge matching of V_c and V_m triggers the polarity inversion of the leading bridge, while the falling edge matching of V_c and V_m triggers the polarity inversion of the lagging bridge.

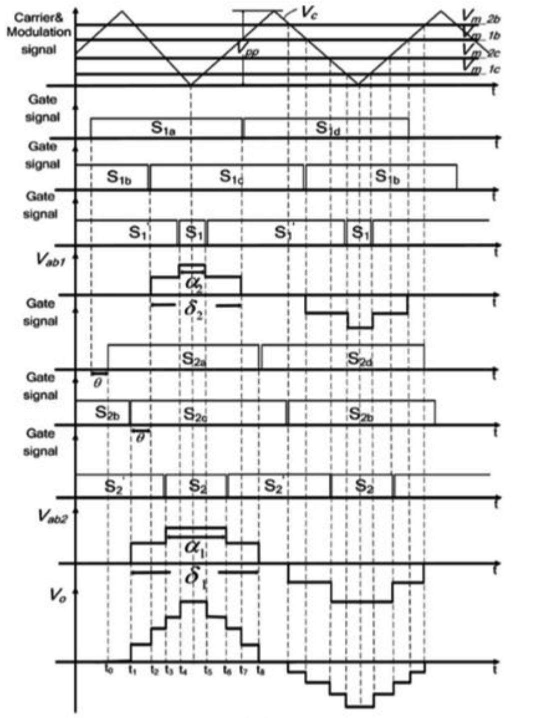

Fig.2.2 Operational waveforms of proposed Multi Level Inverter

When V_m has a change ΔV_m, this modulation simultaneously moves gate1 and gate3 in the opposite direction. Thus, the derived V_{ab} is symmetrical with respect to V_c.

B. Modes of operation

There are 8 modes of operations are available. First four modes of operations are explain by the following.

Mode1: The switches S_{1a},S_{1b},S_{2a},S_{2b} are driven by the gate-source voltage, respectively. H-Bridges 1 and 2 are in freewheeling state, and output voltage equals 0. Because S1' and S2' are on, the capacitors C1 and C2 are charged to Vin (Vdc1 = Vdc2 = V_{in}). The voltages on Bus 1 and Bus 2 are V_{in}.

Mode2: The switches S_{1a},S_{1b},S_{2a},S_{2c} are driven by the gate-source voltage, respectively. H-Bridge 1 is in freewheeling state, and H-Bridge 2 is in positive conducting state. Output voltage equals V_{in}. Because S1' and S2' are on the capacitors C1 and C2 keep charged to Vin (Vdc1 = Vdc2 = V_{in}). The voltages on Bus 1 and Bus 2 are V_{in}.

MODE3: The switches S_{1a},S_{1c},S_{2a},S_{2c} are driven by the gate-source voltage, respectively. H Bridges1 and 2 are in positive conducting state. Output voltage equals $2V_{in}$. Because S1' and S2' are on, the capacitors C1 and C2 keep charged to

V_{in} ($Vdc1 = Vdc2 = V_{in}$). The volt- ages on Bus 1 and Bus 2 are V_{in}.

Mode4: The switches $S_{1a}, S_{1c}, S_{2a}, S_{2c}$ are driven by the gate-source voltage, respectively.H-Bridges1and2areinpositiveconductingstate.Output voltage equals $3V_{in}$. Because S 1 and S2 are on, the capacitor C1 keeps charged to V_{in} ($Vdc1 = Vdc2 = V_{in}$), and the capacitor C2 is discharged. The voltages on Bus 1 and Bus 2 are V_{in} and $2V_{in}$, respectively. Mode 5,6,7,8 are same as mode 1,2,3,4.

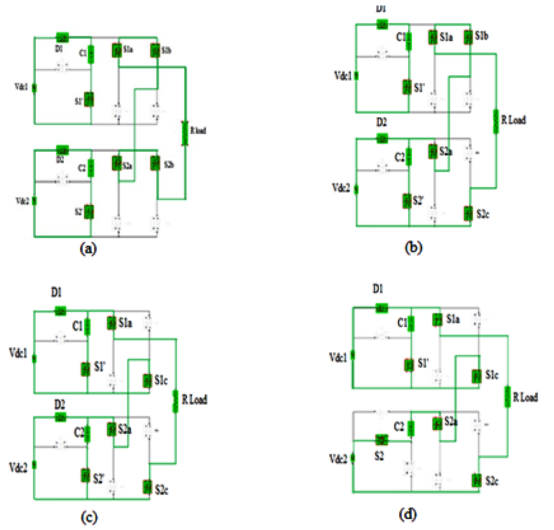

Fig.2.3(a) Operational mode 1,(b) Operational mode 2,(c)Operational mode 3,(d) Operational mode 4.

C. Z-Source Inverter

The basic Z-source converter structure proposed as shown in figure given below. It employs a unique impedance network (or circuit) to couple the converter main circuit to the power source, load, or another converter, for providing unique features that cannot be observed in the traditional V and I source converters where a capacitor and inductor are used, respectively. The Z-source converter overcomes the above-mentioned conceptual and theoretical barriers and limitations of the traditional V-source converter and I-source converter and provides a novel power conversion concept. It consist of a two port network that consists of a split-inductor and capacitors and connected in X shape is employed to provide an impedance source (Z-source) coupling the converter (or inverter) to the dc source, load, or another converter.

The dc source/or load can be either a voltage or a current source/or load. Therefore, the dc source can be a battery, diode rectifier, thyristor converter, fuel cell, an inductor, a capacitor, or a combination of those. Switches used in the converter can be a combination of switching devices and diodes such as the anti-parallel combination. The inductance and can be provided through a split inductor or two separate inductors. The Z-source concept can be applied to all dc-to-ac, ac-to-dc, ac-to-ac, and dc-to-dc power conversion. The figure 3 shows the traditional two-stage power conversion.

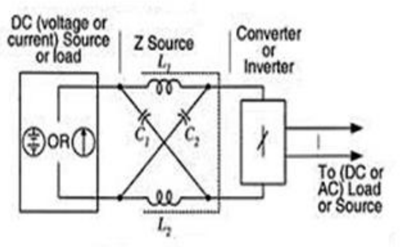

Fig.2.4. Equivalent circuit of Z-Source Inverter

The usually produce a voltage that changes widely (2:1 ratio) depending on current drawn from the source. For distributed power generation, a boost dc–dc converter is needed because the V source inverter cannot produce an ac voltage that is greater than the dc voltage. Z-source inverter for such applications, which can directly produce an ac voltage greater and less than the input voltage. The diode in series is usually needed for preventing reverse current flow.

D. Genetic Algorithms

GA encodes the problem within binary string individuals. Evolutionary pressure is applied in step 3, where the stochastic technique of roulette wheel parent selection is used to pick parents for the new population. The concept is

1. A population of μ random individuals is initialized.

2. Fitness scores are assigned to each individual.

3. Using roulette wheel parent selection μ/2 pairs of parents are chosen from the current population to form a new population.

4. With probability Pc, children are formed by performing crossover on the μ/2 pairs of parents. The children replace the parents in the new population.

5. With probability Pm, mutation is performed on the new population.

6. The new population becomes the current population.

7. If the termination conditions are satisfied exit, otherwise go to step 3.

III. PERFORMANCE EVALUATION

A. Simulation circuit of Genetic Algorithm based Z-source MLI

The Genetic Algorithm based Z-source MLI with R load simulation model is shown in the figure3.1.

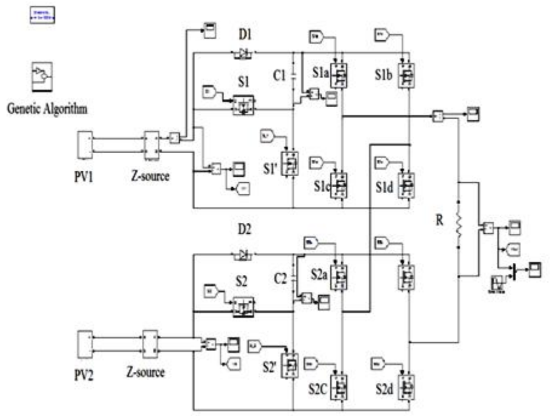

Fig.3.1 Simulation circuit of Genetic Algorithm based Z-source MLI

B. PV with boost converter output voltages waveforms

There are two PV system is used as a input to the Z-source cascaded MLI with R load and Genetic Algorithm . Input Voltage of the PV1 with boost converter is shown in Figure 3.2 Input Voltage of the PV2 with boost converter is shown in Figure 3.3 . This output can be characteristics between current v_s time.PV1 output voltage value is 94V and PV2 output voltage value is 120V.

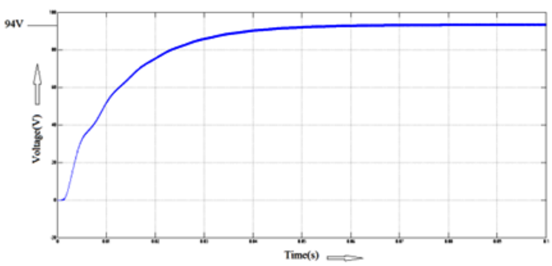

Fig.3.2 PV1 with boost converter output voltages

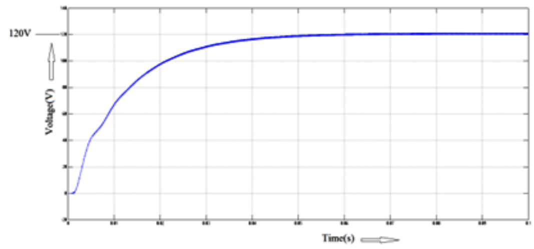

Fig.3.3 PV2 with boost converter output voltages

C. Output voltage of Genetic Algorithm based z-source MLI

Output load voltage waveform of Genetic Algorithm based Z-source MLI with R load is shown in the below Figure3.4. This voltage is taken across the R load. This output can be characteristics between voltage v_s time. Genetic Algorithm based z-source MLI with R load gives a nine level voltage output . Output voltage is 400V.

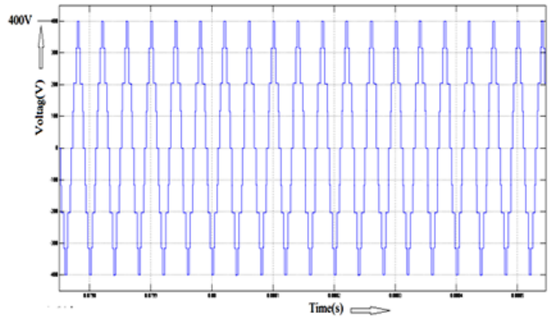

Fig.3.4 output voltage of genetic algorithm based z-source MLI with R load

D. THD value of output load voltage

THD value of output load voltage of Genetic Algorithm based Z-source MLI with R load is shown in the below figure3.5.

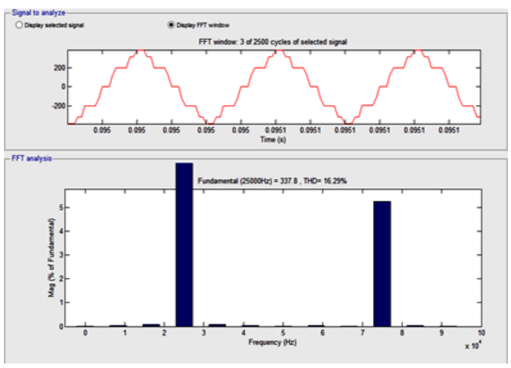

Fig.3.5 THD value of output load voltage

The THD value is calculated for output load voltage by using FFT window. Display FFT window calculated for 3 number of cycle and THD value is 16.29%.

IV. COMPARISON OF SIMULATION RESULTS

Simulation outputs are compared in the below table. Both R load and RL load output THD values are calculated by using FFT window in the MATLAB/Simulink.

SYSTEM	THD (R LOAD)	THD (RL LOAD)
EXISTING SYSTEM	19.10%	19.30%
PROPOSED SYSTEM WITH PI CONTROLLER	18.58%	18.77%
PROPOSED SYSTEM WITH GENETIC ALGORITHM	16.36%	16.71%

Fig.3.6 Outputs Comparison Table

The calculated values are compared with each other. From the output comparisons Genetic Algorithm gives reduced output load voltage THD value.

V. CONCLUSION

In this project, a novel Switched Capacitor based cascaded multilevel inverter was used. nine level circuit topology are examined .Compared with conventional cascaded multilevel inverter, these inverter can greatly decrease the number of switching devices. A symmetrical phase-shift modulation (PSM) is used in the proposed multilevel inverter. With the exponential increase in the number of voltage levels, the harmonics are significantly cut down in staircase output, which is particularly remarkable due to simple and flexible circuit topology. Meanwhile, the magnitude control can be accomplished by pulse width regulation of voltage level, so the proposed multilevel inverter can serve as HF power source with controlled magnitude and fewer harmonics. The genetic algorithm is used to find the optimum solution, From the simulation results genetic algorithm gives reduced THD value (16.36%) compare to PI controller. The output voltage will be increased by increasing the solar input voltage.

VI. FURTHER ENHANCEMENTS

The number of voltage levels can be further increased via two approaches. One is to increase the level number generated by SC circuit. the other one is to increase level number generated by cascaded H-Bridge. Hybrid renewable energy will be used as a input and different control algorithms are used to get the minimized THD values.

REFERENCES

[1] Adrian Ioinovici and On-cheong, (1998) , "Switched-Capacitor Inverter with High Power Density and Enhanced Regulation Capability", IEEE TRANSACTIONS ON CIRCUITS AND SYSTEMS, VOL. 45, NO. 4,PP.336-347.

[2] G.Chakradhar and B.M.manjunath,(2013)," Grid Connected PV system based on Z-source Inverter with Phase shifted PWM Technique", INTERNATIONAL JOURNAL OF EMERGING TRENDS IN ELECTRICAL AND ELECTRONICS, VOL.8, NO. 1,pp.39-44.

[3] Kalle Ilves and Antonios Antonopoulos ,(2012) "Steady-State Analysis of Interaction Between Harmonic Components of Arm and Line Quantities of Modular Multilevel Converters", IEEE TRANSACTIONS ON POWER ELECTRONICS, VOL. 27, NO. 1,pp.57-68.

[4] Kalle Ilves and Antonios Antonopoulos,(2012) "A New Modulation Method for the Modular Multilevel Converter Allowing Fundamental Switching Frequency", IEEE TRANSACTIONS ON POWER ELECTRONICS, VOL. 27, NO. 8,pp. 3482-3494.

[5] Kokila R and F. T. Josh ,(2014) "GA Based Selective Harmonic Minimization Of a 11 Level Cascaded Inverter Using PV Panels", INTERNATIONAL JOURNAL OF RESEARCH IN ENGINEERING AND TECHNOLOGY,VOL.03,NO. 7.pp.237-242.

[6] Leon M. Tolbert and Fang Zheng Peng , (2000) "Multilevel PWM Methods at Low Modulation Indices", IEEE TRANSACTIONS ON POWER ELECTRONICS, VOL. 15, NO. 4.pp.719-725.

[7] Mariusz Malinowski and K. Gopakumar (2010) "A Survey on Cascaded Multilevel Inverters", IEEE TRANSACTIONS ON INDUSTRIAL ELECTRONICS, VOL. 57, NO. 7.pp.2197-2206.

[8] Miaosen Shen and Jin Wang,(2004) "Maximum Constant Boost Control of the Z-

Source Inverter", IEEE TRANSACTIONS ON POWER ELECTRONICS, VOL. 15, NO. 4.pp.142-147.

[9] N. Veeramuthulingam and S. Sivajanani,(2013) "GA Based Performance Enhancement Of She Methods For Nine Level Inverter", INTERNATIONAL JOURNAL OF EMERGING TRENDS & TECHNOLOGY IN COMPUTER SCIENCE, VOL. 2,NO. 5.pp.146-151.

[10] Samir Kouro and Pablo Lezana (2008) "Multicarrier PWM With DC-Link Ripple Feedforward Compensation for Multilevel Inverters", IEEE TRANSACTIONS ON POWER ELECTRONICS, VOL. 23, NO. 1,pp.52-59.

[11] Samir Kour and Mariusz Malinowski,(2010) "Recent Advances and Industrial Applications of Multilevel Converters", IEEE TRANSACTIONS ON INDUSTRIAL ELECTRONICS, VOL. 57, NO. 8,pp,2553-2580.

[12] Selva santhose Kumar R and Priyaa Dharshini R S,(2014) "High Performance PV Power Generation Using Z Source Inverter", INTERNATIONAL JOURNAL OF ADVANCED RESEARCH IN ELECTRICAL AND ELECTRONICS ENGINEERING, VOL. 2,NO. 2,pp,68-78.

[13] Vrushali Suresh Neve and P.H. Zope , (2012) "A literature survey on z-source inverter", VSRD INTERNATIONAL JOURNAL OF ELECTRICAL, ELECTRONICS & COMMUNICATION ENGINEERING, VOL. 2 NO. 11.pp.889-896.

[14] Junfeng Liu, K. W. E. Cheng(2014) "A Cascaded Multilevel Inverter Based on Switched-Capacitor for High-Frequency AC Power Distribution System", IEEE TRANSACTIONS ON POWER ELECTRONICS, VOL. 29, NO. 8,pp.4219-4230.

[15] Zixin Li and Yaohua Li(2010) " Single-Loop Digital Control of High-Power 400-Hz Ground Power Unit for Airplanes", IEEE TRANSACTIONS ON INDUSTRIAL ELECTRONICS, VOL. 57, NO. 2,pp.532-543.