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Cascaded Multi-Level Inverter for Grid Integration of Solar System

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ABSTRACT
Multi-Level Inverter (MLI) are becoming popular for all type of inversion application. They inherently generates low harmonics, produces output near to sine-wave, low switching losses and zero magnetic interferences. All these features are increasing there wide-spread usage. This paper presents the application of MLI for grid integration of solar energy. The output of solar is not always constant, it depends upon the environmental conditions like solar irradiance. It is very difficult to obtain constant output as well synchronization with the grid from solar. MLI can integrate the solar with the grid effectively and can also regulate the output voltage to compensate for variable irradiance. Also, THD is very low as well as it retains the unity power factor under normal as well as harmonized loading conditions. In this paper cascaded 5-level MLI is presented for grid integration of 2 panels of 1.5KW of rating each for solar.

Keywords – Cascaded 5-level MLI (C-5-L-MLI) Multi-Level Inverter (MLI), Power Electronics Converters, PV-Panel, Voltage Source Inverter (VSI), Total Harmonic Distortion (THD).

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I. INTRODUCTION

The For integrating RR with the utility system either 2-level or multi-level inverter (MLI) is employed. 2-level inverter has high THD content as compared to MLI in the AC output voltage hence MLIs are preferred. Tremendous research work is available to improve the performance of the system in a way to reduce losses, distortion and to enhance the efficiency by using different topologies of MLIs. In general MLIs are broadly classified as flying capacitor type, neutral point clamped and cascade H-bridge. The classification of MLIs is shown in Fig. 1. In the first two types the series of switches shares the common DC supply while cascaded type required separate DC sources for individual units which is shared according to the generated output voltages. The two most favored topologies are neutral point clamped (NPC) and cascade H-bridge (CHB) since these topologies can be effectively interfaced with RR and gives better execution proficiency when contrasted with flying capacitors type.. The NPC-MLI discover applications in Static VAR pay, Variable speed engine drives, High voltage DC-AC transmission lines and uses of CHB-MLI are Motor drives, Active channels, Electric vehicle drives, DC power source use, Power factor compensators, Back-back recurrence connect frameworks and Interfacing with sustainable power source assets. In this segment previously mentioned topologies are examined in a word.

Other than the above discussed traditional topologies there are a few topologies likewise been accounted for as of late in writing which are explicitly planned according to the application necessities and are for the most part mix of any of the two previously mentioned topologies with some change. These topologies are named as half and half topologies of MLIs.

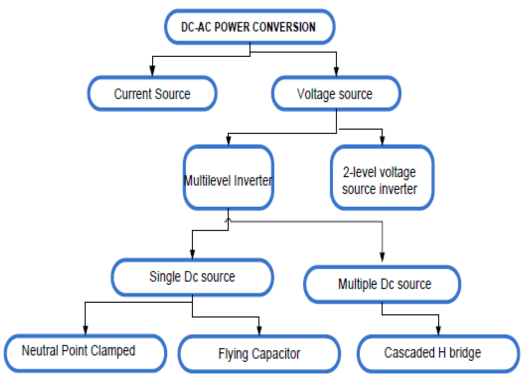

Fig. 1. Classifications of inverters

History of MLIs started in 1975 with Baker and Banister. This first patent depicted a converter topology fit for creating staggered voltage by associating single stage inverter in arrangement. The MLI offers a few element which raises its interest in present situation, for example, conceivable association of arrangement changing gadgets to get a high voltage yield without the need of snubber circuit, fundamentally low THD in yield waveforms, utilization of IGBT as changing gadget at high recurrence to decrease misfortunes, diminished torque swell in enlistment machine and so forth. MLI is favored over customary converter in light of various points of interest which are condensed as pursues [10-13]:

- Harmonic bending: MLI utilizes small voltage ventures for creating the ideal yield consequently it contains less consonant twisting [14].

- Staircase waveform quality: what's more of producing the yield voltages with decreased bending, MLI can likewise lessen the dv/dt stresses; consequently, bringing down the Electromagnetic Compatibility (EMC).

- Common-Mode (CM) voltage: MLI creates littler CM voltage; thus, the worry in the course of an engine associated with a staggered drive can be dense. Additionally, CM voltage can be invalidated by utilizing propelled adjustment systems [15].

- Input current: MLI draws input current with low contortion.

- Switching recurrence: MLI works with crucial exchanging recurrence just as high exchanging recurrence PWM [16-17].

Inferable from the previously mentioned points of interest, these converters have been broadly applied in PV framework for high power generation and power quality improvement [18, 19].

II. CASCADED MLI

In medium and high-power range utilizations, MLI with grid technology is a very efficient alternative as the heart of interfacing systems for integration of PV systems into utility grid. In this work a 5-level CHB-MLI (C-5-L-MLI) is designed with two solar system which replaces the DC batteries. The Cascaded H-Bridge inverter utilizes arrangement strings of single-stage full-bridge inverters to build multilevel stage legs with independent dc sources. CHB-MLI uses a very less numbers component as compared to other conventional topologies. The typical arrangement CHB-MLI is presented in fig. 2. The most important work in designing an MLI is to develop the switching strategy. In this work a phase shifted sinusoidal carrier wave PWM technique is used to trigger the switching devices of CHB-MLI. In this strategy of modulation, the carrier signals are shifted in phase with respect to each other which are then compared with the reference signal as shown in fig. 3. The simulation model of the proposed CHB-MLI with its output is presented in figure 4. and 5 respectively.

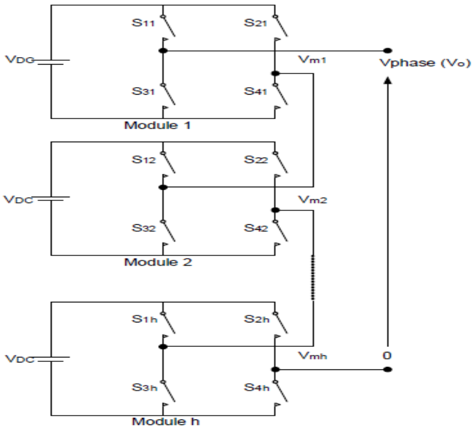

Fig. 2. n-level CHB-MLI.

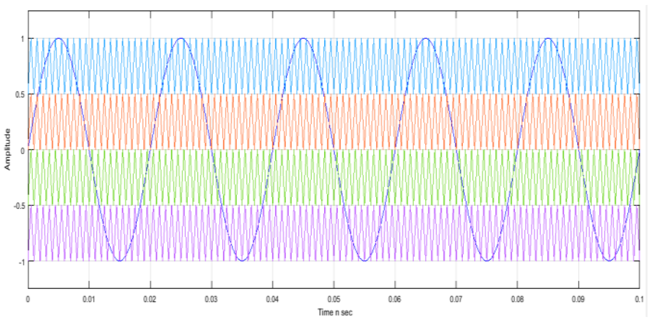

Fig. 3. Sinusoidal PWM

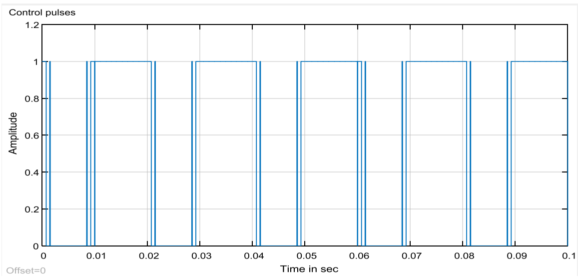

Fig. 4. Control pulse signals for switches states

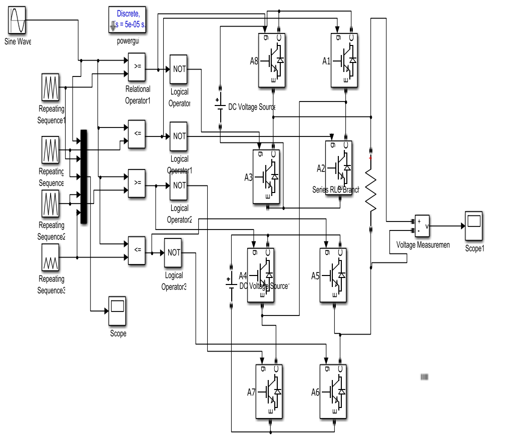

Fig. 5. Simulation model of proposed CHB-MLI

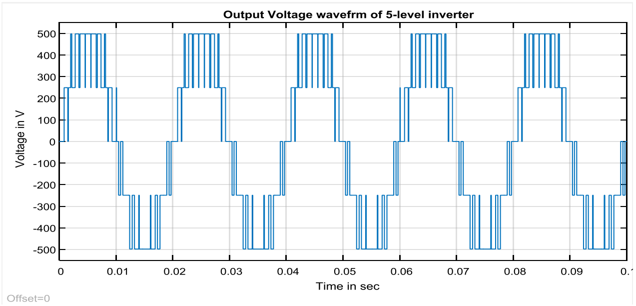

Fig. 6. Output voltage of single phase 5 level CHB-MLI

III. MODELING OF SOLAR PV-ARRAY

In this work grid integration of PV panel is presented for utility grid applications. A PV system is designed, two PV-array having 20 parallel strings and 8 Series-connected modules in each array for single phase. The simulation model of the proposed topology for PV-CHB-MLI as shown in fig. 7 The rated capacity of each PV panel is 50 kW. Overall 300KW power can be generated from the solar system for three phase system. The PV-VI characteristics of the designed PV system is shown in figure 8. To obtain the constant DC output from Solar system a DC-DC boost converter is designed with switching frequency 5 kHz. The output voltage of the boost converter is approx. 400 V as shown in figure 9. To integrate the PV system with the grid a DC/AC inverter is simulated. The inverter is designed using 5-level CHB-MLI which is synchronized using PLL and PI controller. The design parameters for PV module is presented in Table-1.

The CHB required multiple sources for each H-bridge unit. In this work 5-level CHB is designed hence two PV module is connected. The pulse input of the IGBT for CHB is controlled via PWM technique whose switching response is shown in figure 10. The output voltage waveform of single phase proposed CHBMLI for the PV is shown in Figure 11 whose THD analysis is shown in Figure 12. Since the THD of the system is very high hence a filtering unit has to be installed to maintain the grid requirement of the system. The complete simulation model of the of the grid connected system is presented in next section.

Table 1 Basic parameters for PV module

Symbol	Parameter
I_{PH}	Solar current
q	Electron charge; 1.6×10^{-19}C
k	Boltzmann's constant; 1.38×10^{-23}J/K
T_C	25° C cell's working temperature
A	Ideality Factor;1.3
R_{SH}	Shunt resistance; 142.84
R_S	Series resistance; 0.1059

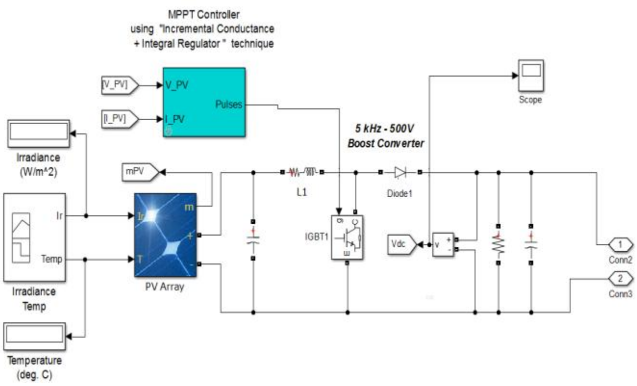

Fig. 7. Circuit of dc-dc converter for driving LED string [5]

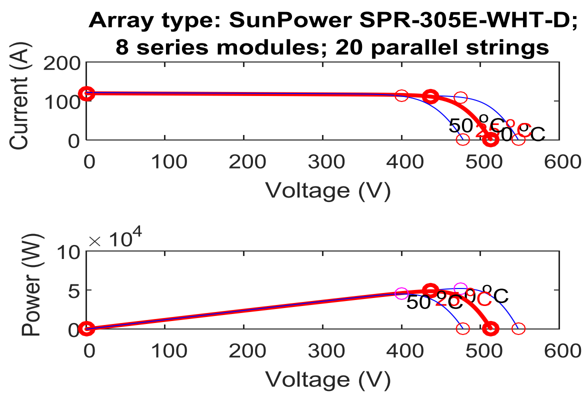

Fig. 8. PV-VI characteristics of PV system

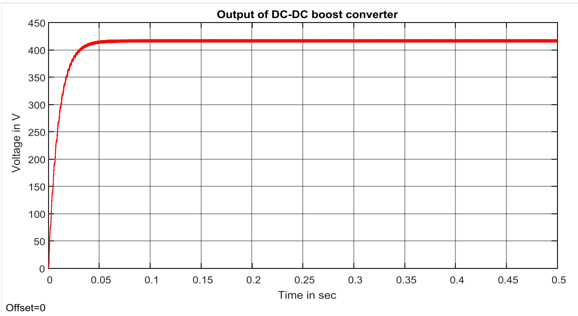

Fig. 9. Output of DC-DC boost converter

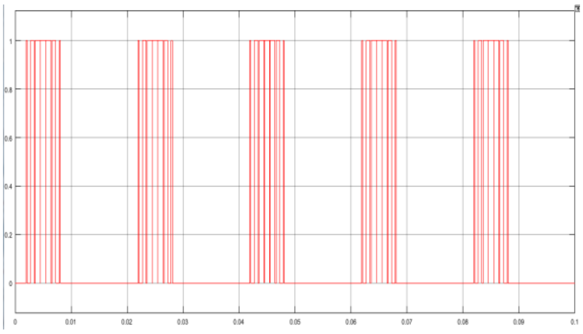

Fig.10. Switching responses of In Phase Disposition PWM (IPDPWM)

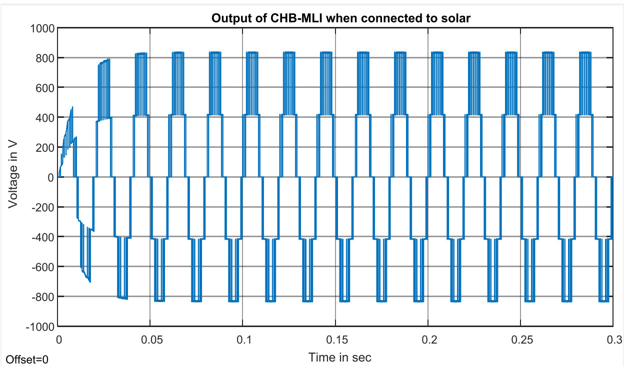

Fig. 11. Output voltage of single phase 5-level CHB-MLI for using PV system

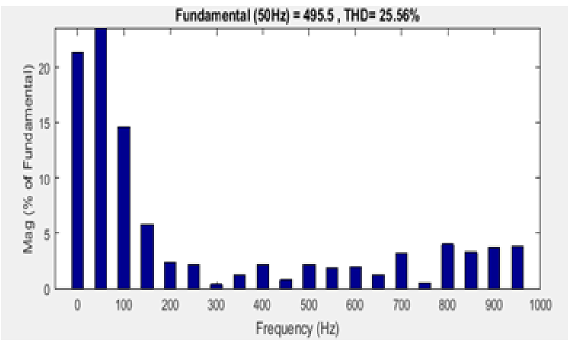

Fig. 12. THD of voltage outtput of CHB MLI

IV. Simulation Model and Result

This section presents modeling of PV with proposed topology system for various loading. A MATLA-Simulink model of the solar panel with 50KW rating has been developed whose DC output is regulated using DC-DC boost converter. To design a DC/AC converter a 5 level inverter is designed whose pulse width modulation technique is designed using level shifted carrier modulation technique.One side of the converter is connected to the synchronized AC output of the PV system and other side to the grid. The system is synchronized with the grid using PI controller and Phase Lock Loop. The complete simulation model of the proposed topology is given in fig 15. The simulation model of the subsystem is shown in figure 16. The parameter considered in designing the proposed system with various loading condition is presented in table 2.

Table-2 System parameter design

Parameter	Values
Switching frequency	5kHz
C_{dc}	12000 µF
L1	1e mH
Inverter parameter	
Effective nominal voltage of the utility (RMS) VS	415 V
Nominal utility grid frequency fS	50Hz
Switching frequency of the converters fch	5khz
inductance of filter	10 mH
Series resistance converter	0.01 ohms
Capacitances of the parallel filters	1000µF
Resistances of the converter filter	0.01 ohms
dc-bus voltage Vdc	400V

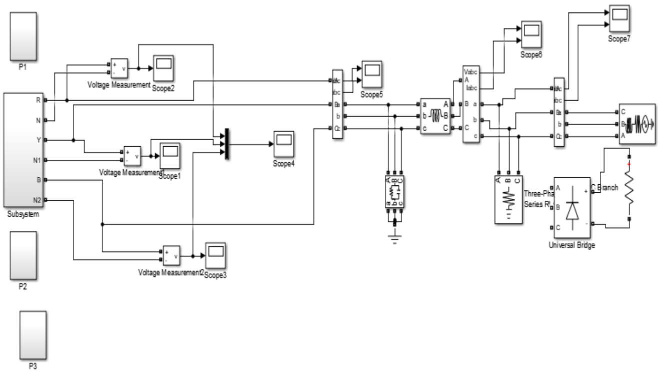

Fig. 15. Simulation model of CHB-MLI based PV system

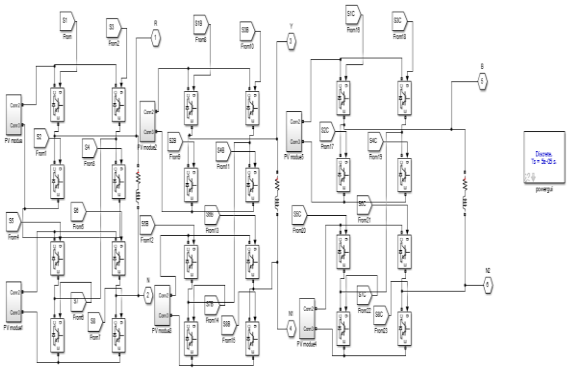

Fig. 16. Simulation model of PV connected across CHB-unit

The simulation results for grid side and load side has been given. The output voltage and current waveforms for both load side and at point of common coupling is shown with THD analysis to verify the efficiency of the system. Fig. 17 presents the Inverter phase-to-phase output voltage and its fundamental component with proposed topology for unbalanced linear load. The output of the CHB-MLI when applied synchronization via PLL and PI To obtain the smooth sinusoidal current and voltage waveform a proper filter is connected which helps in filtering the harmonics as shown in fig. 18 and 19 As soon as the filter connected with the proposed topology a complete synchronized and sinusoidal output is obtained with low THD of 0.03 and 0.8% as shown in figure 20 and figutre 21 respectively. If both switches operate then converter works in boost mode and if auxiliary switch is turned off and only main switch conducts then converter works in buck mode.

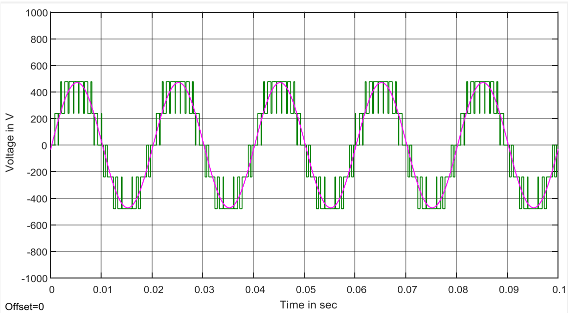

Fig. 17. Inverter phase-to-phase output voltage and its fundamental component

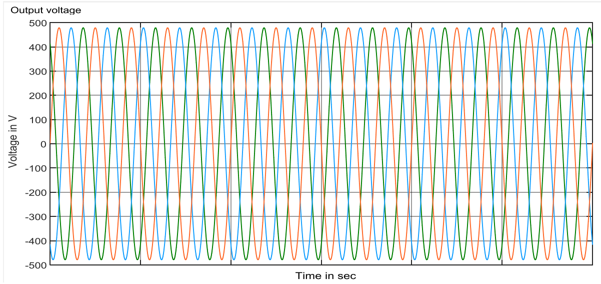

Fig. 18. Output Voltage at with proposed topology.

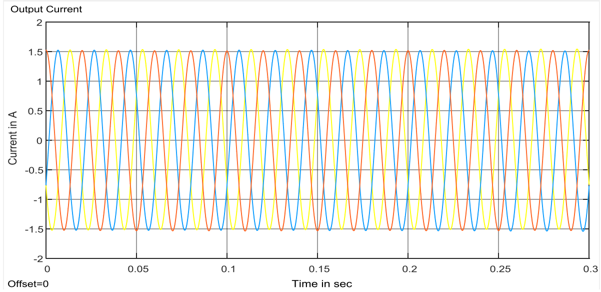

Fig. 19. Output Current of Solar system grid side with proposed topology

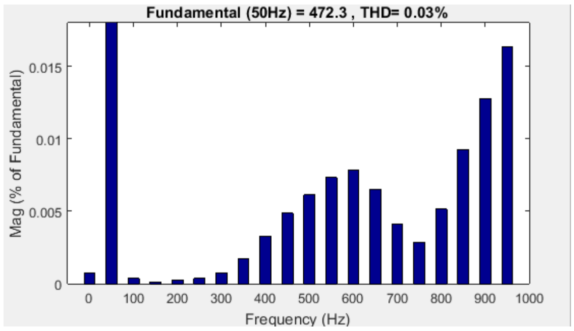

Fig. 20 THD analysis of Output voltage of Solar system grid.

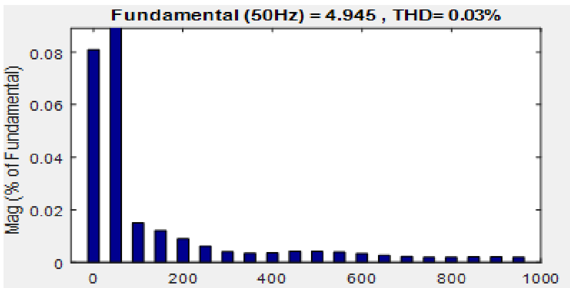

Fig. 21 THD analysis of Output Current at grid side

V. CONCLUSION

A robust 5 level CHBMLI is proposed for grid connected operation of PV system. The efficacy of the proposed topology is verified by employing level shifted PWM techniques under the condition of linear and non-linear load. To increase the number of levels by this topology is easily possible to large extends which is a new direction in this field. The THD analysis of the various loading conditions is performed by connecting filter elements.

The scope of the work is to integrate the PV system with grid using CHB-MLI. In addition with grid integration it must also maintain the quality of supply hence a multi-functionality is required. A lot of ongoing research has been reported in literature for auxiliary services on power quality improvement through multi-functional grid-tied (MFGT) converters. These converters can perform dual work of interfacing solar system with the grid and also conditions the power at point of common coupling.

The system has been analysed for linear resistive and inductive loading and THD analysis of the output voltage waveform is carried. The proposed converter topology is compatible to follow grid code for grid connected operation of solar panel. It not only maintains the voltage profile but also eliminate the harmonic content in load current. Hence the topology can be applicable for bulk power integration from solar panel with the grid to improve power quality of the system.

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