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RESEARCH ARTICLE OPEN ACCESS

Multi-Level Cascaded Modular Inverter Topology for Solar Grid Integration

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ABSTRACT
Solar technology has matured to great extent and its installation for utility usage has increased to many folds. Though researchers find a lot of scope for maintenance free high efficiency Solar Utility Generation System (SUGS). Solar has wide spread usage in standalone mode like solar heating, cooking, lightening and pumping etc. But for wide spread installation it should be operated in grid integration mode. Another aspect of solar is its has high performance characteristics when installed near load center unlike conventional generation which required large installation area and has to be installed near the resource like coal or water. Hence this work presents a single-phase grid connected SUGS for low voltage distribution system. For DC-AC conversion Multi-Level Cascaded Modular (MLCM) Topology is proposed. Multi-Level Inverter (MLI) are high efficiency inverters, but with increase in level its circuit becomes complicated and bulky as well as performance of the inverter also degrades. Hence an 11-level MLCM topology is presented with reduced switch count. Conventional cascaded requires 20 switches, in this work modified modular structure is presented which require only 8 switches.

Keywords - Multi-Level Inverter (MLI), conversion Multi-Level Cascaded Modular (MLCM), MPPT, Logic gates, Solar Utility Generation System (SUGS), Sinusoidal PWM.

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I. INTRODUCTION

The deployment of solar generation is at peak. All around the world, power engineer trying to consolidate it with the main system. Solar power utilization can be in various form like heating, cooking and electricity generation. Among these heating and cooking are dispersed uses and has no effect on utility system. While electricity generation via solar has brought new dimension for power network. It had given new definition to conventional generation and has advantages like green form of energy and available in abundant. Hence generation of electricity from solar is transforming the conventional electricity network into the green network with zero carbon emission. Solar generation can be isolated one like standalone system, where solar can be installed as rooftop generation or near the vicinity of the consumer where generated power can be directly utilized by the consumer without any interaction with the distribution network. It can also be installed in grid connected form where via an interfacing medium link it with the grid. This type of topology is Solar Utility Generation System (SUGS), which has a great impact on the utility system. Like it shares the load supplied by the utility, increases the power transfer capability of the system, as well as available transfer capability can be enhanced by utilizing solar system as a compensating device. Now a days solar forms a lot of applications in utility system as a power conditioning device.

In this work SUGS is designed for single phase system. The interfacing of the SUGS is done using Multi-Level Cascaded Modular (MLCM). MLCM is a Multi-Level Inverter (MLI) with less switch count. MLI are the class of inverters where DC is converted into AC in small stepped output waveform. In conventional inverter only two level AC output is obtained with +Vdc and -Vdc. In MLI topology AC is obtained in multiple of Vdc as stair-case type waveform. MLI is preferred since it AC output resembles the sine wave hence losses are reduced with increased efficiency. MLI are designed with series and parallel combinations of semiconductor switches which helps in generating the AC output. But, as the no. of output level increases, no. of switches requirement also increases. For example, in case of 5-level output, eight semiconductor switches are required and it goes on with 4 switches per odd levels. Hence for higher level like 9 or 11, 16 and 20 switches respectively are required which continues for

further. This makes the system very complex and uneconomical. To overcome this Reduced Switch Count (RSC) topologies are introduced. In this work such topology is presented for 11-level output. In which only 8 switches are required to design the single-phase MLI topology.

II. SOLAR UTILITY GENERATION SYSTEM (SUGS)

In India, about 39 % of the total generation is renewable based and solar shares 13.2 %. Solar has the highest share in renewable for power production. Solar power is obtained from sun rays which is converted into electricity using various stages of conversion via power converters. the converted power can be directly used by consumers without any grid involvement or can be transferred to the utility system using grid interference. For widespread use of solar it should be used in grid interfacing mode as it can provide reliability as well as stability to the grid by increasing its power generation limit.

In this work solar generated electricity is examined in Solar Utility Generation System (SUGS). The simulation analysis is carried out in MATLAB environment. A PV-array block is available in renewable library of simulink. 5KW of solar power is generated per module with 4-series and 4-parallel array connection. The DC-output voltage of 220 V is obtained as shown in figure 1, which is regulated and boosted to 280 V using DC-DC boost converter as shown in figure 2.

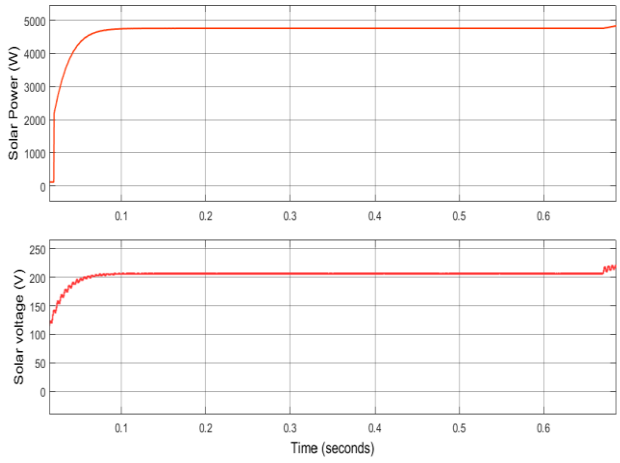

Fig. 1 Solar power and voltage output

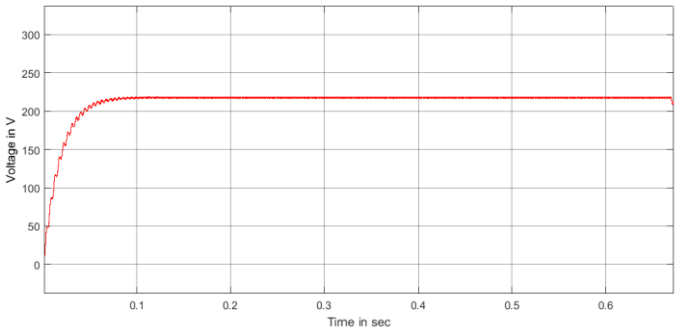

Fig. 2 DC-DC converter voltage output

TABLE 1 Parameter used for solar cell:

Parameter	Value
V_{PV}	0.6 V
I_L	6.0092 A
Irradiance used for measurements I_{r0} (Standard)	1000 W/m^2
Operating Irradiance I_r	1000 W/m^2
Quality factor, N	1.5
Series resistance, R_s	0
Energy gap, E_g	1.12
No of cell connected in series, Ns	4
No of cell connected in parallel, Ns	4
Cell reference Temp,T_{r0}	25^{0}C
Cell operating Temp, T_r	25^{0}C
V_{oc} for module	64.2 V
I_{sc} for module	5.96A

III. MODULAR CASCADED MLI (MC-MLI)

Cascaded structure in power electronics means arrangement of switches in a succession or series through which each stage derives from or acts upon the output on previous stage [18].

In this work MLI is designed in cascaded structure where output of each stage is summed to generate a cumulative output. Hence in conventional topology of MLI, for basic three level output 4 switches are required and the number of switches increases as per the no. of output [19].

This work presents a modular type structure where switch requirement decreases dramatically.

An eleven-level output is obtained just utilizing eight switches where as in conventional topology 20 switches are required. The Modular Cascaded MLI (MC-MLI) has successive series parallel combination and in each row DC-source is connected across the two switches as shown in figure 3. The conventional C-MLI is shown in figure 4. For all five H-shaped unit a constant DC-source is required with equal value. And in case of MC-MLI, only three Dc-source is required. The outer two source in the cascaded structure are connected in forward direction and the inner source is connected in reverse direction. The rating of the inner-source is twice that of the outer one. For example if the outer source has rating Vdc, then inner-source will be rated as 2Vdc. In this work level shifted SPWM technique is used to design the driver circuit for the switches of the MLI. In this type of PWM technique a carrier wave is sinusoidal wave and the modulated wave is triangular wave. The frequencies of the modulated wave is shifted in multiple of 2 where as for carrier wave a fixed frequency particularly fundamental one is considered.

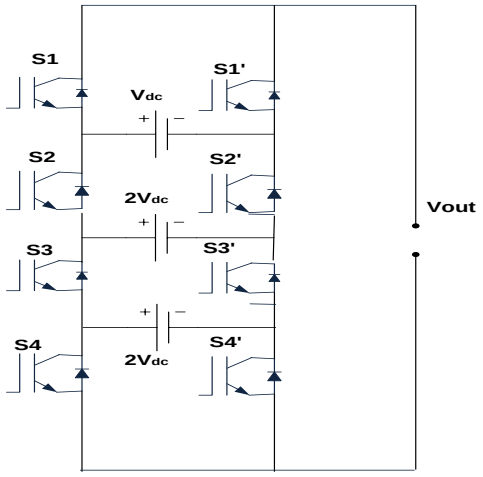

Fig. 3 Proposed 11-level MC-MLI topology

IV. SIMULATION RESULTS

A MATLAB simulation model is developed for MC-MLI based SUGS system as shown in figure 5. From the figure 3 it can be seen that for obtaining 11-level output three voltage sources are required, in SUGS system DC-voltage is replaced by solar with fixed DC voltage. The 11-level voltage output is shown in figure 6. From the figure it can be observed that the output obtained resembles too much to the sine wave, hence it has very less THD of 2.57 % as shown in figure 7. Hence a small filter is required with RL series branch having 0.1 Ω resistance and 25 mH inductance and RC parallel branch with 0.09 Ω resistance and 400 μF capacitance. This filter unit helps in obtaining sine wave as shown in figure 8 with 0 % THD as shown in figure 9. The grid side voltage is also sinusoidal as shown in figure 10 which shows that with the proposed MC-MLI topology PQ problems which generally arises due to solar interference is also take care well. The current flowing in the circuit is shown in figure 11 which also have 0% THD as shown in figure 12.

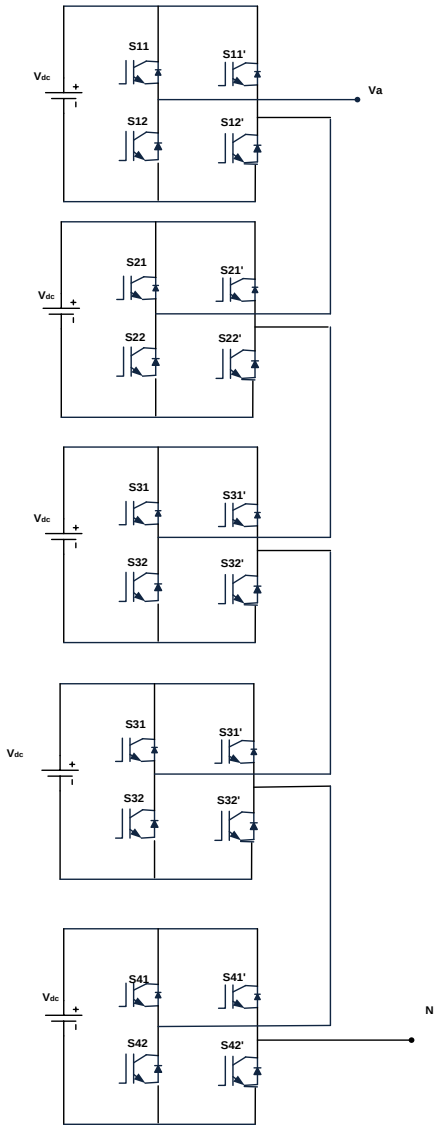

Fig. 4 Conventional 11-level MLI topology

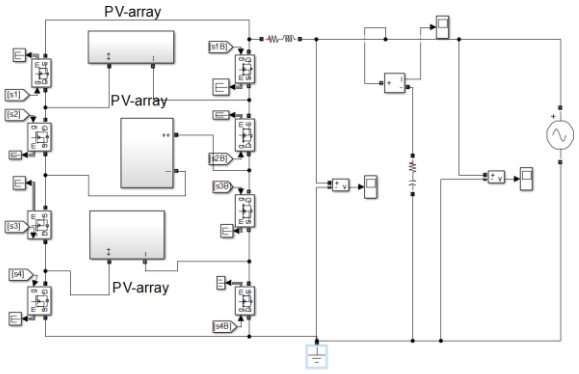

Fig. 5 MATLAB simulation model of MC-MLI based SUGS system

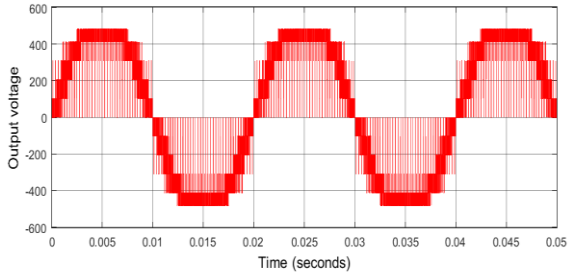

Fig. 6. Output voltage of 11-level proposed MC-MLI

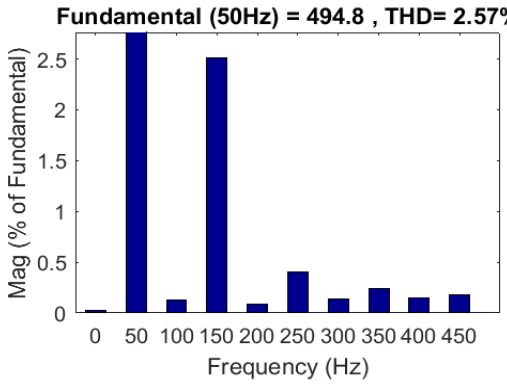

Fig. 7. THD of voltage of 11-level proposed MC-MLI

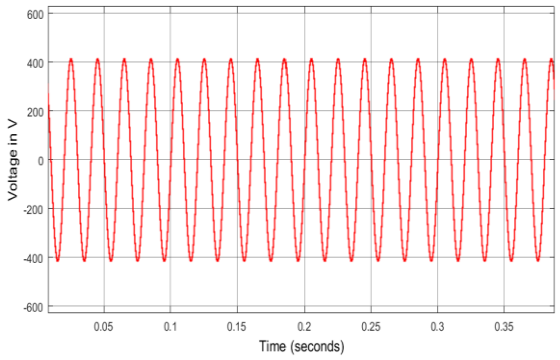

Fig. 8. Sinusoidal Output voltage of 11-level proposed MC-MLI

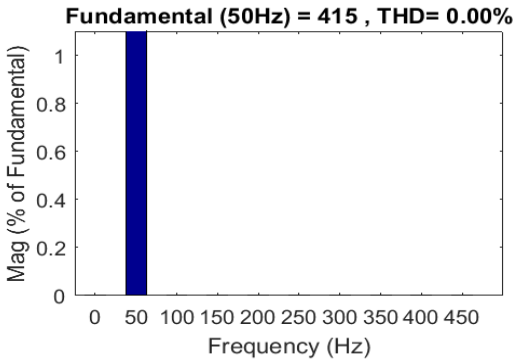

Fig. 9. THD of voltage of 11-level proposed MC-MLI after filter unit

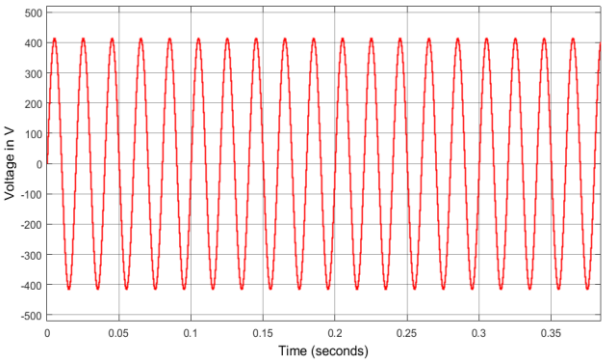

Fig. 10. Output voltage at grid side for SUGS

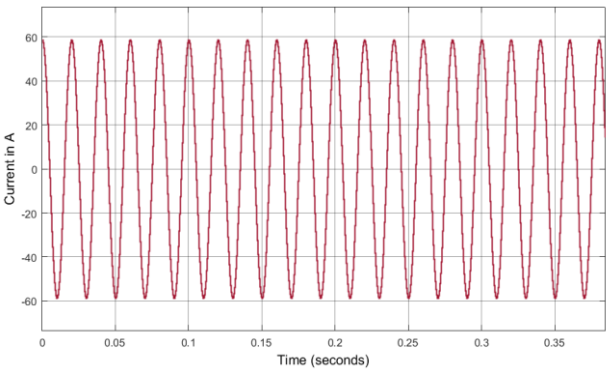

Fig. 11. Output current at grid side for SUGS

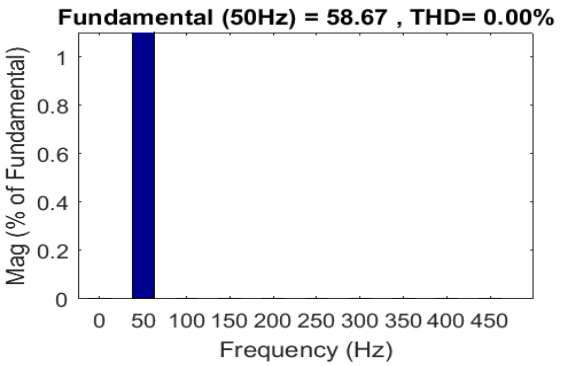

Fig. 12. THD of current after filter unit for 11-level proposed MC-MLI

V. CONCLUSION

A solar system with grid integration is presented for single phase utility system. For promoting the solar installation at low voltage level for residential consumer solar power generation system is presented. For increasing the efficiency of the system designed and reducing the losses and harmonics generated due to power electronic converters a modular cascaded multi-level inverter topology for 11-level output is presented. The presented topology has very less component requirement as well as it is compact in design. Also it has high efficiency with 0.0% THD in output voltages and currents.

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