Analysis and Performance of Solar based Transistor Clamped Five-Level Inverter using MATLAB simulation

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***Abstract*- In the proposed work, MATLAB simulation of Solar panel was done using Sim-Electronics. After that, MATLAB simulation of Five-Level Multilevel Inverter was made using Sim-Power system. Then the both the blocks of Solar panel and Multilevel inverter interfaced in MATLAB.**

Analysis and performance of complete circuit was done with Resistive load and R-L load. THD of output Voltage and current wave form was also obtained using MATLAB simulation.

I. INTRODUCTION

The multilevel inverter is the array of power semiconductor devices, Voltage sources, Capacitors and Diodes arranged in such a way that input is DC supply and output is stepped ac voltage. In the recent trends, input dc power to multilevel inverter is usually from the solar panel. In the proposed strategy MATLAB simulation of solar based Multi-level inverter was done. The analysis of circuit voltage and current at different parts of circuit was done for selecting the rating of Solar panel, IGBT, Diode and Load. The important feature of the proposed strategy is that we can obtain less harmonic content in the line current using a very simple Five-Level inverter circuit.

II. MATHMATICAL MODELING OF SOLAR PANEL & PROPOSED SYSTEM

As photovoltaic cells use light to generate electricity and that there are different types of photovoltaic cell technologies, including mono-crystalline, polycrystalline and thin-film cells which can all be used to produce Solar Panel. A single photovoltaic solar cell can produce an "Open Circuit Voltage" (Voc) of about 0.6 to 0.9 volts at 30 degree Celsius ambient temperature (typically around 0.98V). This cell voltage remains fairly constant just as long as there is sufficient irradiance light from dull to bright sunlight. In the proposed strategy, simulation of complete solar panel was done using Sim-Electronics of MATLAB. Here open circuit voltage means that there is no current flowing through the solar cell terminals. Simulation of solar panel initiated from its smallest element i.e. solar cell. The simulation parameters of elementary solar cell have its open circuit voltage and short-circuit current of 1.0 Volts and 7.34 Amps respectively. The elementary solar cell model in MATLAB, as shown in fig.1, has three terminals –two power terminals and third one terminal has to accept the energy from light which is irradiance (light intensity) in W/sqm falling on the cell. In the proposed strategy the value of irradiance set in the MATLAB simulation is 1000 W/sq-m.

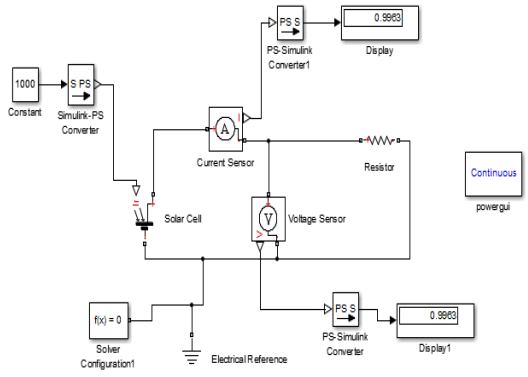


Fig.1: MATLAB simulation of elementary solar cell with resistor of 1 Ohms and irradiance of 1000 Watts/sq. meter

In the proposed strategy, the solar panel is formed in sim-electronics by the array of solar cells.

One solar panel contains ten solar cells in series then six such series modules are connected in parallel to form a solar panel of total 60 solar cells. The

simulation circuit of one such solar panel is shown in fig.2.

For simulating the per phase circuit of Five-level inverter, 9 such solar panels are connected in series to form a solar power module as shown in fig.3. The open circuit voltage of solar power module as shown in fig.3 is 90 Volts and short circuit current of same module is 44.04 Amps.

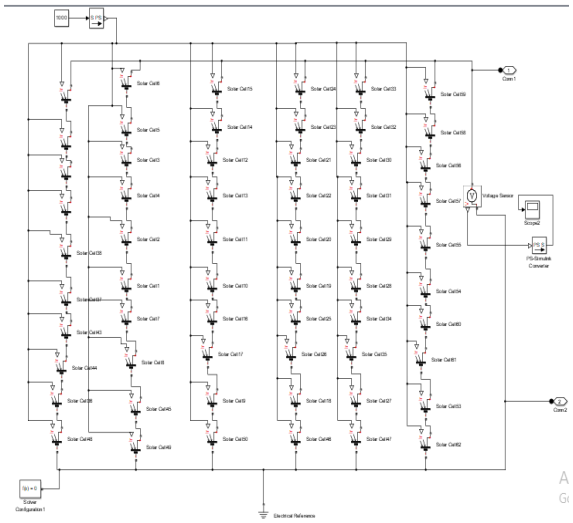


Fig 2: MATLAB Simulation of Solar panel in Sim-Electronics consist of 60 solar cells

The output voltage and current was also obtained using the simulation for Resistive load and R-L load as shown in fig. 3(a) & 3(b). In fig. 3(a), when the load resistance value is 1.4 ohm and in fig. 3(b), when R=1.4 Ohms and L=100µH,

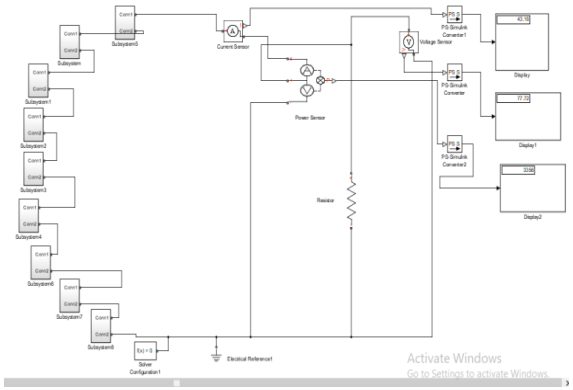


Fig 3(a): MATLAB Simulation of Solar power module in Sim-Electronics consist of 9 solar panels with R Load

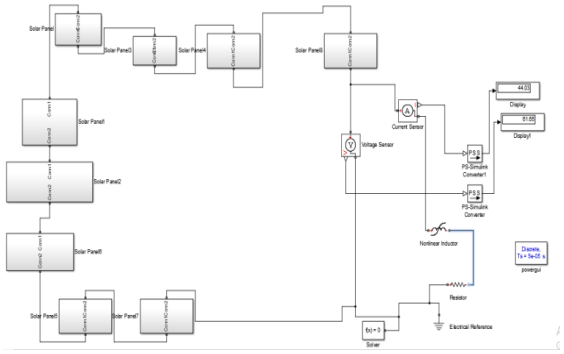


Fig 3(b):MATLAB Simulation of Solar power module in Sim-Electronics consist of 9 solar panels with R-L load

III. SIMULATION OF FIVE LEVEL TRANSISTOR CLAMPED MULTILEVEL INVERTER:

Multilevel inverters are DC to AC power conversion systems composed of an array of power semiconductors and capacitive voltage sources, arranged in such a way that when properly connected and controlled, can generate a multi-step voltage waveform with variable and controlled frequency, phase and amplitude.

The electric circuit configuration of 1-phase, Transistor clamped Five-Level Multi Level Inverter is shown in fig. 4. As shown in fig 4, the proposed inverter topology is the combination of staked capacitors (C1 & C2), switches (S1 to S5) and diodes (D1 to D4). The circuit uses 5-number of Power semiconductor switches, 4 numbers of Power Diodes, two capacitors & 1-DC Voltage source, which is actually the solar panel.

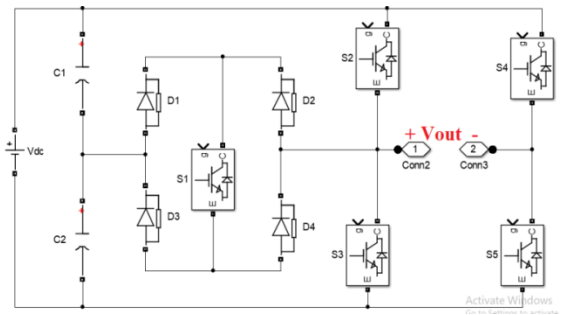


Fig. 4: Basic Electrical Circuit Diagram of 1-phase, solar based, 5-Level Transistor clamped Multilevel Inverter

For getting the output ac voltage waveform as shown in fig 5 across the terminals of Five-level inverter, the proper ON-OFF sequence of switches of above circuit

are mentioned in table 1. The time period of ac output voltage of 20 mili-sec is divided into 8 equal intervals, each of 2.5 mili-sec. From the table 1, it can be observed that the maximum switching frequency of any switch among all the switches is 4 times of frequency of output voltage i.e. 200 Hz.

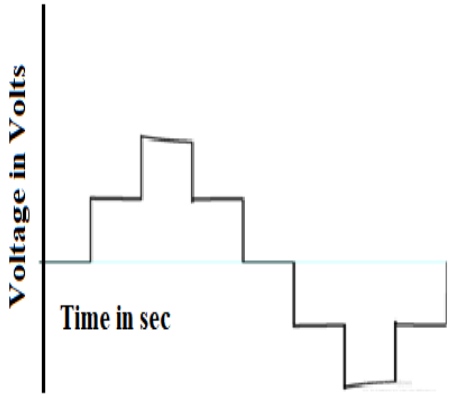


Fig.-5: Output voltage waveform of 5-Level Transistor Clamped Multilevel Inverter.

Table 1: Switching sequence of switches of 5-Level MLI

Time period of switching	S1	S2	S3	S4	S5	Output Voltage
0-45º	0	0	1	0	1	0
45-90º	1	0	0	0	1	+Vdc/2
90-135º	0	1	0	0	1	+Vdc
135-180º	1	0	0	0	1	+Vdc/2
180-225º	0	0	1	0	1	0
225-270º	1	0	0	1	0	-Vdc/2
270-315º	0	0	1	1	0	-Vdc
315-360º	1	0	0	1	0	-Vdc/2

IV. COMPLETE SIMULATION CIRCUIT & RESULTS

The complete simulation model of 1-phase, Five-level Inverter was made by interfacing the Solar panel and Transistor clamped Multi-Level Inverter and simulation circuit is shown in fig. 6. The parameters of different components selected for simulating the circuit shown in fig. 6 are mentioned in table-2.

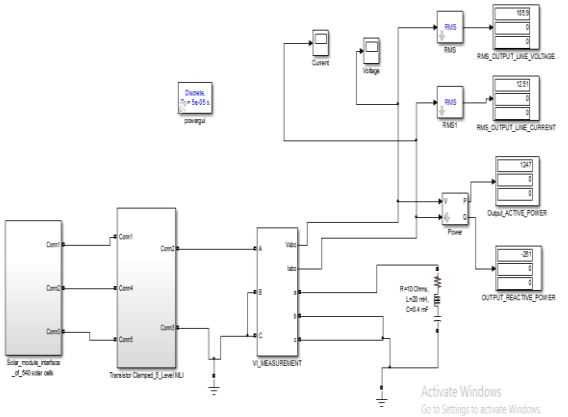


Fig. 6: Complete simulation Circuit diagram of 1-phase, solar based 5-Level Inverter

Table 2: The value of parameters selected for simulation of 1-phase solar based Five-level inverter

S.No.	Name of Parameter	Value of parameter
1	Load Resistance	8 Ohms
2	Per phase Inductive load reactance at 50 Hz	6.28 Ohms
3	Per phase Capacitive load reactance at 50 Hz	7.96 Ohms
4	Power factor of load	0.9861 leading
5	Internal resistance & snubber resistance of switching device i.e. IGBT	1.0 mili-ohm & 1.0 Mega-ohms
6	Internal resistance, snubber resistance of diode	1.0 µOhm & 10 Kohms
7	Solar panel module open circuit voltage	1*10*9 = 90 Volts DC
8	Solar panel module maximum current	7.34*6 = 44.04 Amps

For the values of parameters of load impedance & solar module mentioned in table 2, the output line voltage is shown in fig. 7 which will be same for all types of load & line current for R, RL & RLC is shown in fig. 8 (a) (b) & (c) respectively. The THD of line current of solar based, 1-phase, Five-level inverter feeding the RLC Load having their impedance value in table 2, is observed as 6.63%, the same is shown in fig. 9. The

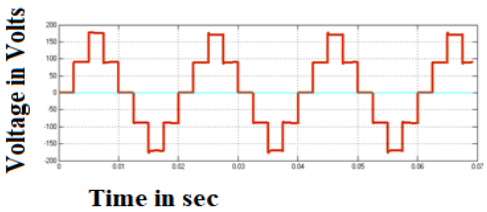


Fig. 7: Output voltage waveform of 1-phase five-level inverter for any type of Load R, RL & RLC.

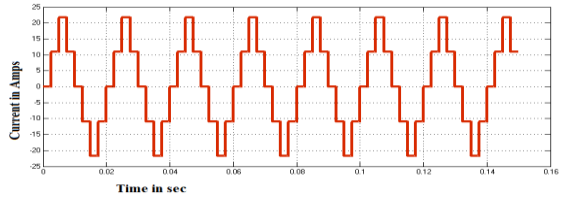


Fig.8(a): Output current waveform of 1-phase five-level inverter for RL load

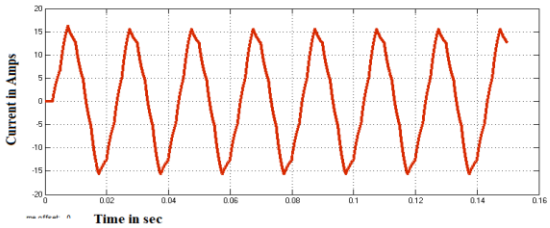


Fig. 8(b): Output current waveform of 1-phase five-level inverter for RL load.

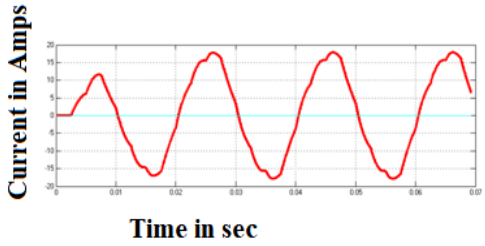


Fig. 8(c): Output current waveform of 1-phase five-level inverter for RLC load.

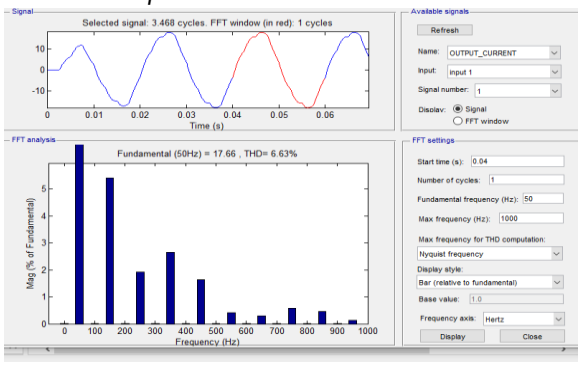


Fig. 9: THD of output line current waveform of 1-phase five-level inverter

As in the simulation of solar panel, there are only 9 solar panels in series each one has 10 solar cells used in series each having open circuit voltage of 1.0 Volts. The maximum and minimum value of pulsating dc output voltage of solar power module (or dc voltage input to Inverter) is 90 volts & 86.5 volts respectively, the waveform of which is shown in fig. 10. As there are six solar cells in parallel in each solar panel, the pulsating dc current of output of solar panel (or dc current input to Inverter) is shown in fig. 11. The maximum and minimum value of which is 30 Amps and 0.0 respectively.

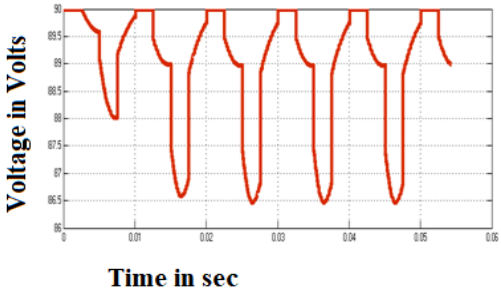


Fig. 6.10: Pulsating output dc voltage of solar power module.

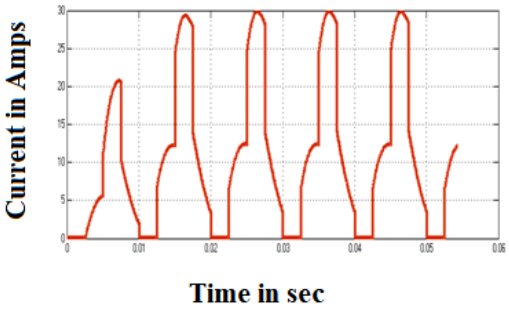


Fig. 6.11: Pulsating output dc current of solar power module.

The output result of concerned simulation circuit in the form of numeric values on the application of input values selected as in table 2 are mentioned in table 3. As it can be seen from table-2, that the load circuit parameter selected such that the equivalent load impedance is capacitive. It was also observed by changing the value of capacitance that the line current stability will depend on the values selected for RLC Load. No stability problem observed for the pure resistive load and R-L type of load for any value of same. But when the value of Capacitance and Inductance in RLC Load will change, then sometimes it is observed that the current magnitude will change for every cycle. Actually the matching of time constant of load and the output voltage wave of five-level inverter is very important for RLC load fed solar based five-level inverter.

Table 3: Output values of concerned simulation circuit on the application of input values mentioned in table 2.

S. No.	Name of parameters	Value of parameter

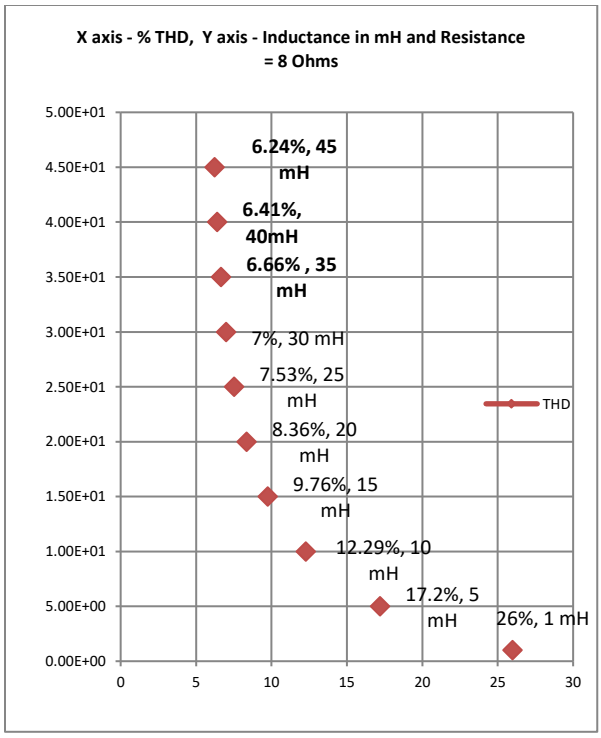
1	Active power output (Pout)	1247 Watts
2	Reactive power output (Qout)	-261 VAr (Leading)
3	Line to Line RMS value of output voltage (VL-L)	105.9 Volts
4	RMS value of Output Line current (IL)	12.51 Amps
5	THD of output line current	**6.63**%
6	DC input Power	1253 Watts
7	Average Input DC Current	14.45
8	Average Input DC Voltage	88.31
9	Efficiency of Five level inverter	(1247*100)/1253 = 99.52 %

An important observation is obtained from the simulation of Solar based Five level inverter by changing the value of R-L Load, as mentioned in the table 4. By fixing the value of load resistance, load Inductance values are increased from 5 miliHenery to 45 miliHenery. The line current THD, Active power, Reactive power consumed by the load is also mentioned in table 4.

A graph is also plotted for changing value of inductance, fix value of load resistance of 8 ohms and Line current THD in %, as shown in graph 1. It is observed that the line current THD Decreases as the value of inductance increases. But it is also observed that the line current THD decreases will decreases sharply by changing the inductance up to a certain extent as shown in the graph 1.

Table.4: Variation of line current THD with change in the value of load Resistance & inductance

S. no.	Resistance In Ohms	Inductance in mH	%THD	Active Power in Watts	Reactive Power In VAr
1	8	0	28.47	1309	0
2	8	1	26.0	1307	51
3	8	5	17.20	1260	247
4	8	10	12.29	1134	445
5	8	15	9.76	972	572
6	8	20	8.36	809	635
7	8	25	7.53	665	654
8	8	30	7	548	645
9	8	35	6.66	452	623
10	8	40	6.41	377	593
11	8	45	6.24	317	561
12	8	50	6.12	269	530



Graph 1: Graph showing the variation in the value of % THD with the change in the value of load inductance

V. CONCLUSION

In proposed work, complete methodology of solar power fed Five-level inverter using MATLAB simulation is presented. The behavior of solar panel module is presented first on the application of different types of load. The thesis work is quite informative about the limitation of current drawn from the solar panel module; unlikely the current drawn from the infinite bus, in which ideally any amount of current can be drawn from the infinite bus. Accordingly on the basis of current limitation drawn from the solar panel module, the rating of circuit breaker and relays can be decided.

An important feature of MATLAB simulation of solar based Multi-level inverter is that the input dc voltage and current is pulsating DC, unlike in the case of dc source fed multilevel inverter. Hence it is seen that the simulation work is more practically realized.

VI. REFERENCES

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