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Comparative Design Analysis of Modified Solar Based 15 Level Multi Level Inverter for Power Quality Improvement

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ABSTRACT

Enhanced quality of power and reduced distortions have entered the wider research domains for the rating of the power to be obtained using Multilevel Inverters. This also directs towards the lowered EM interference as and when the levels keep on increasing. As compared to the traditional module these configurations with a reduced switched count act as the conversion device of energy so as to offer less THD, with lowered losses due to switching and hence stress level on voltage to be reduced. This paper lays the comparison facts regarding the topological analysis of the solar source fed 15 level MLI with a modified modulation technique and reduced switches against the primitively modulated the traditional counterpart and lowered levels. The main aim here is to project the potential of renewable solar powered and the final THD Comparison of above model for modified PWM techniques thereby being cost effective as well as not compromising on the efficiency. The results demonstrate the Staircase waveforms which correspond to a nearly sinusoidal reference wave with the required switching sequence. The simulated design is developed using Mat lab to authenticate the performance of the found results in prevailing conditions.

Keywords- Multilevel Inverter, Sinusoidal PWM, THD, boost converters, Solar MPPT, reduced switching

I Introduction

Multilevel inverters are being tremendously utilized in the industry due to the extended benefits regarding enhanced power quality, lowered THD, and superior waveform with lowered stress on voltage levels thereby being likely to the sinusoidal reference. The vibrant advances in this field find a demanding space in industrial VSD's, systems involving renewable sources, flexible transmissions, DG's and almost all allied areas of power electronics for energy conversions. The sole goal is to obtain a stair-cased output waveform thereby being likely to the sinusoidal reference. For the same research scholars find interest in the topologies popularly including the forms - CHBMLI, DCMLI and FCMLI. The pulse width modulation strategies employing the SPWM, LSPWM, PSPWM, PDPWM, NLCPWM, SHEPWM, Space vector techniques and many more. But the shortcomings of the mentioned designs include the extended complexities with diversified switching and also the control part. As we go on increasing the levels the required number of switches (2N+1such that N shows the count of levels proposed) and the required sources gets on being complex. Scholars are constantly developing ideas in order to mitigate the issues and come up with better solutions regarding cost, control and complexity of mathematical modeling without compromising on the efficiency part. Based on the same principles the paper focuses to analyze the primitive model with 15 levels and then devising solution with reducing the switch count with solar fed modified modulated extended version of the same for lowering the THD to a remarkable value.

The cascaded design specifications for the modified version demonstrate the inclusion of the isolated dc sources being powered by the PV cells for the boost configuration. Also it reflects the efficacy of the MPPT and perturb and observation algorithms. A reduced switch count directly reflects the lowered switching losses and ease of control algorithm as per the modulation requirements. The same can be even modified for the 3 phase module design as per requirements. The sinusoidal modulations being the extensive area with much research finding proves to be the least complex. The total standing voltage as reflects the involvement of the costing and performance of the state of conduction with respect to the states of blocking. The mathematical equivalent for the same,

$TSV=\sum_{1}^{n} V\ mn$

Here V_{mn} is for the n^{th} switch that blocks the maximum voltage. The lesser the TSV the reduced is design cost.

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Module Topology and Mathematical Modeling

The cascaded design of the MLI has N number of bridge that has been cascaded such that an isolated source (PV cell) feeds each DC link. The four switches S_1, S_2 , S_3 and S_4 hovering the voltage levels to be generated as $-V_{dc}$, zero and $+V_{dc}$.

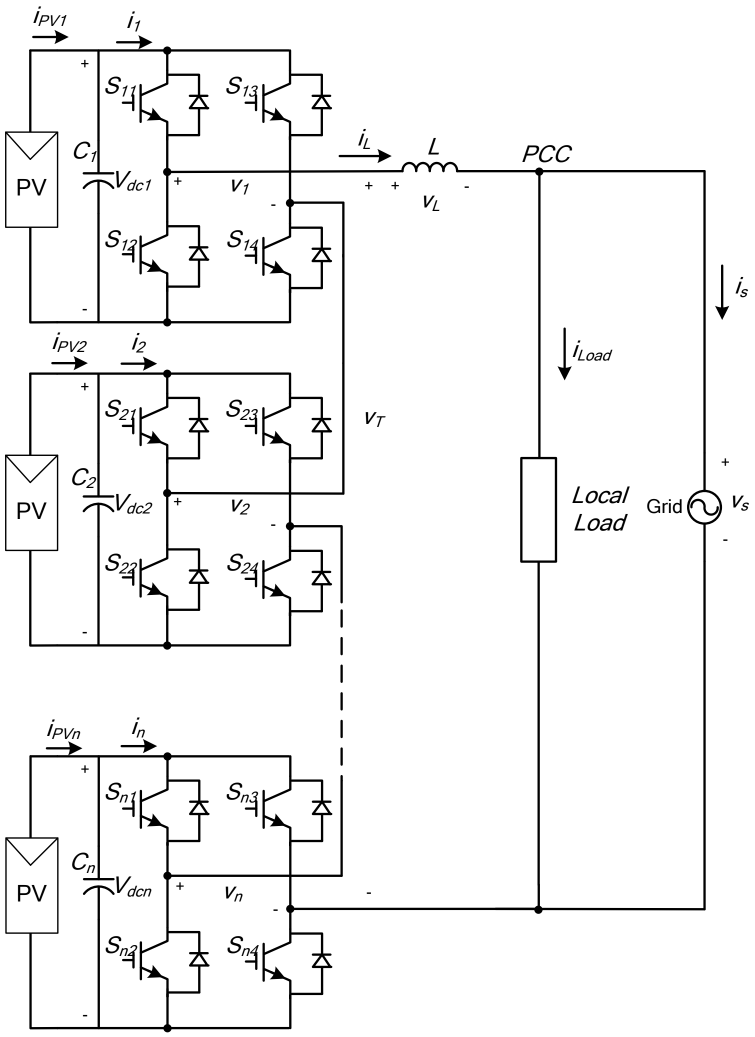

Figure 1- 1ΦPV system configuration

So, the synthesis of the output lowers the harmonics and voltage stress. So, the output of the individual H bridge is

$$v_j = (S_{j1} - S_{j3})v_{dcj} = P_j v_{dcj}$$

Here, the dc link voltage for the value of j=1, 2, 3…n is V_{dcj} and S representing the switch state. So, for linearity

$$\frac{di_L}{dt} = \frac{1}{L}\left(\sum_{j=1}^{n} S_j v_{dcj} - v_s - Ri_L\right)$$

$$\frac{dv_{dcj}}{dt} = \frac{1}{C_j}(i_{PVj} - S_j i_L)$$

Therefore, $i_L = i_{Load} + i_s$

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Where i_s is the grid current.
This is the standard to be followed for L as inductance of decoupling and R for resistor respectively. The design considers $v_{dcj} = v_{dc}$ for SPWM and generality considerations K=0

$$kv_{dc} \le v_s(\omega t) \le (k+1)v_{dc}$$

Also, $$2\Delta i_L = \frac{v_{dc} - v_{ave}}{L} \cdot \frac{d_{on}}{2} \cdot \frac{1}{f_{sw}}$$

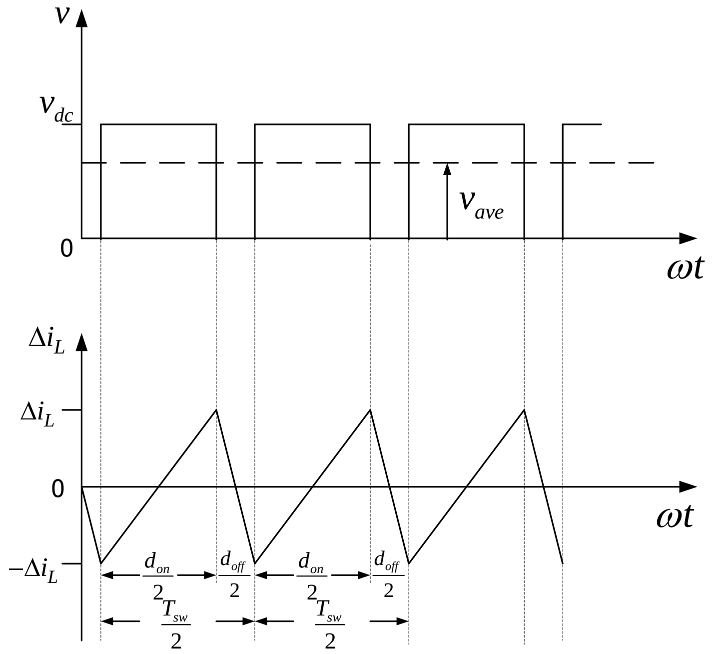

Figure 2 Waveform depicting ripple current and voltage of inverter

II PV module Modeling

The module is a connection of numerous solar cells in parallel and series so as to deliver the required system voltage and current. The fig below demonstrates the PV module with only one diode.

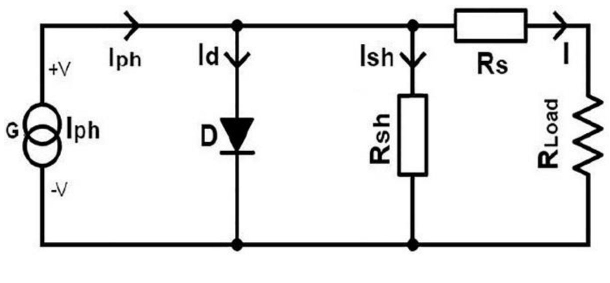

Figure 3 PV module Modeling

There seems a voltage at the output terminal if it's circuited and known as open circuit voltage (V_{OC}). This voltage causes a current through the contact a bit like a diode.

$$I_{PV} = I_{ph} - I_D - I_{shunt}$$

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$$I_{PV} = I_{ph} - I_o \left[\exp\left(\frac{V_{PV} + R_s I_{PV}}{n\left(\frac{\eta k T}{q}\right)} \right) - 1 \right] - [\frac{V_{PV} + R_s I_{PV}}{R_{sh}}]$$

$$I_{ph} = I_{SCO}\left(\frac{G}{G_o}\right)(1 + (\alpha_1(T - T_o))$$

$$I_o = I_{oref}(\frac{T}{T_o})^3 \exp[(\frac{qE_g}{\eta K_B})(\frac{1}{T_o} - \frac{1}{T})]$$

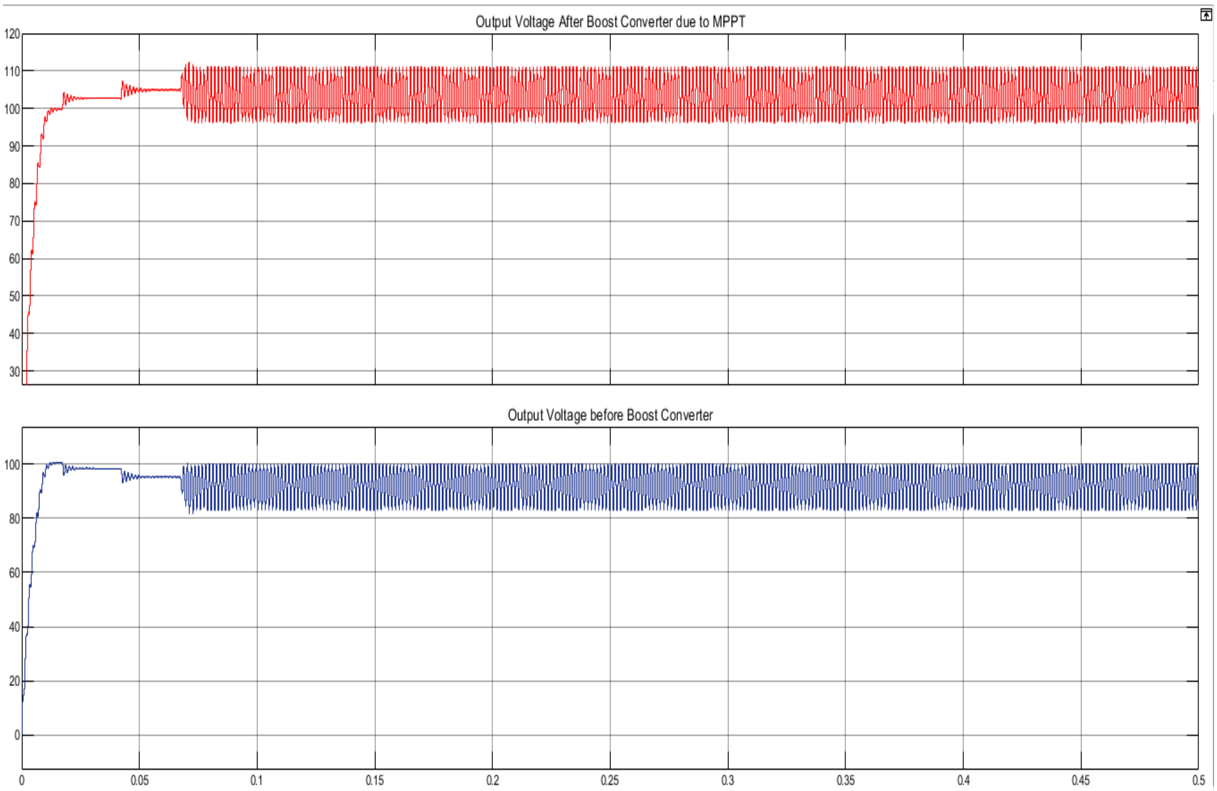

Figure 4Before & after Voltage of the Boost converter

The output of solar cell with bypass diode is connected to the boost converter input the pulses square measure generated by exploitation MPPT formula to the boost device switch and hence at the output voltage is measured. By decreasing the current value by implementing a bit resistance within the path of the current then the MPPT charge controller will maximize the voltage value. This amount of voltage to current quantitative relation modification is called as most outlet tracking (MPPT) usually; it will increase the present to the battery by around 20% to 25%. From figure above its clearly visible that the output of the boost device is stable and therefore the power is obtained is to be most.

III Analysis Of 15 Level Multilevel Inverter Without PWM:

The module is fed by a sinusoidal time based wave with amplitude of 7 and zero bias. The repeating sequence varies from 0 to 13 time values [0 1]. The gain of -1 with a Boolean data type performs the control. The input is DC 100 v with 28 switches as a primitive count (2N+1). A non-linear load is considered at the output side that injects the harmonics. Sampling time is 50 e^{-6}.

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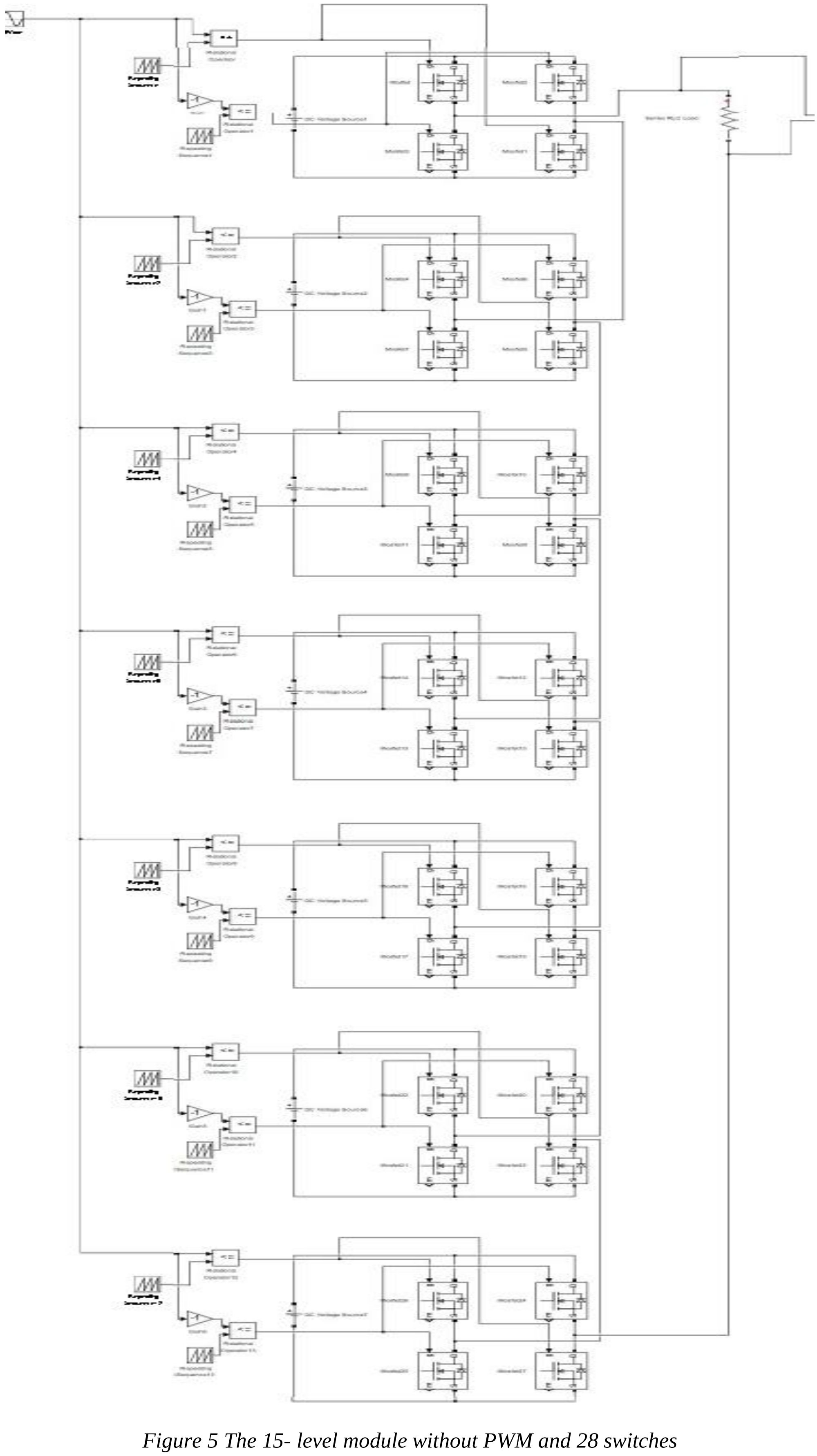

Figure 5 The 15- level module without PWM and 28 switches

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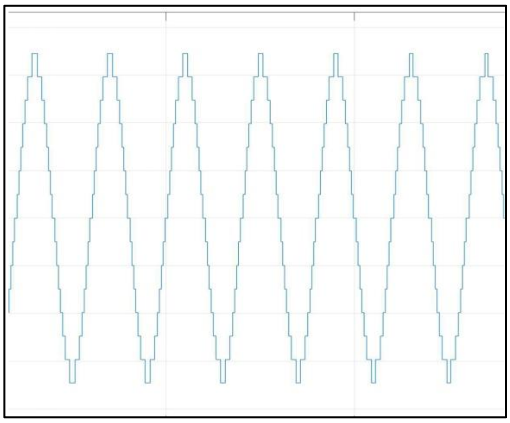
SCOPE PARAMETERS:

Voltage steps	Voltage Levels (v)
$V_{dc}/15$	300
$2\ V_{dc}/15$	500
$3\ V_{dc}/15$	700
$4\ V_{dc}/15$	900
$5\ V_{dc}/15$	1100
$6\ V_{dc}/15$	1200
$7\ V_{dc}/15$	1300
0 level	0
$-\ 7\ V_{dc}/15$	-1300
$-\ 6\ V_{dc}/15$	-1200
$-\ 5\ V_{dc}/15$	-1100
$-\ 4\ V_{dc}/15$	-900
$-\ 3\ V_{dc}/15$	-700
$-\ 2\ V_{dc}/15$	-500
$-\ V_{dc}/15$	-300



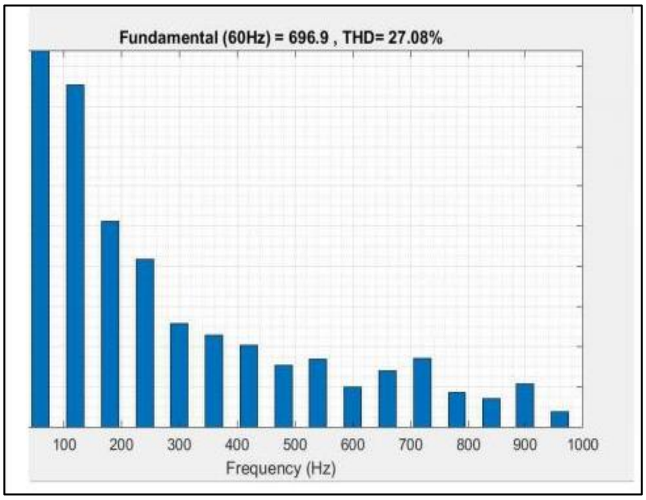


Figure 6 Scope Output & THD

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SWITCHING SEQUENCE:

Switch	**0**	**100**	**200**	**300**	**400**	**500**	**600**	**700**	**600**	**500**	**400**	**300**	**200**	**100**	**0**	**-100**	**-200**	**-300**	**-400**	**-500**	**-600**	**-700**	**-600**	**-500**	**-400**	**-300**	**-200**	**-100**	**0**
S1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
S2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
S3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	0
S4	0	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S5	1	1	1	1	1	0	1	1	1	0	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
S6	1	1	0	0	0	0	0	0	0	0	0	0	0	1	1	0	1	1	1	1	1	1	1	1	1	1	1	0	1
S7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	0
S8	0	0	1	1	1	1	1	1	1	1	1	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0
S9	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
S10	1	1	1	0	0	0	0	0	0	0	0	0	1	1	1	0	0	1	1	1	1	1	1	1	1	1	0	0	1
S11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	0
S12	0	0	0	1	1	1	1	1	1	1	1	1	0	0	0	1	1	0	0	0	0	0	0	0	0	0	1	1	0
S13	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
S14	1	1	1	1	0	0	0	0	0	0	0	1	1	1	1	0	0	0	1	1	1	1	1	1	1	0	0	0	1
S15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	0
S16	0	0	0	0	1	1	1	1	1	1	1	0	0	0	0	1	1	1	0	0	0	0	0	0	0	1	1	1	0
S17	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
S18	1	1	1	1	1	0	0	0	0	0	1	1	1	1	1	0	0	0	0	1	1	1	1	1	0	0	0	0	1
S19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	0
S20	0	0	0	0	0	1	1	1	1	1	0	0	0	0	0	1	1	1	1	0	0	0	0	0	1	1	1	1	0
S21	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
S22	1	1	1	1	1	1	0	0	0	1	1	1	1	1	1	0	0	0	0	0	1	1	1	0	0	0	0	0	1
S23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	0
S24	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	1	1	1	1	1	0	0	0	1	1	1	1	1	0
S25	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
S26	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1
S27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	0
S28	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	1	1	1	1	1	0	1	1	1	1	1	1	0

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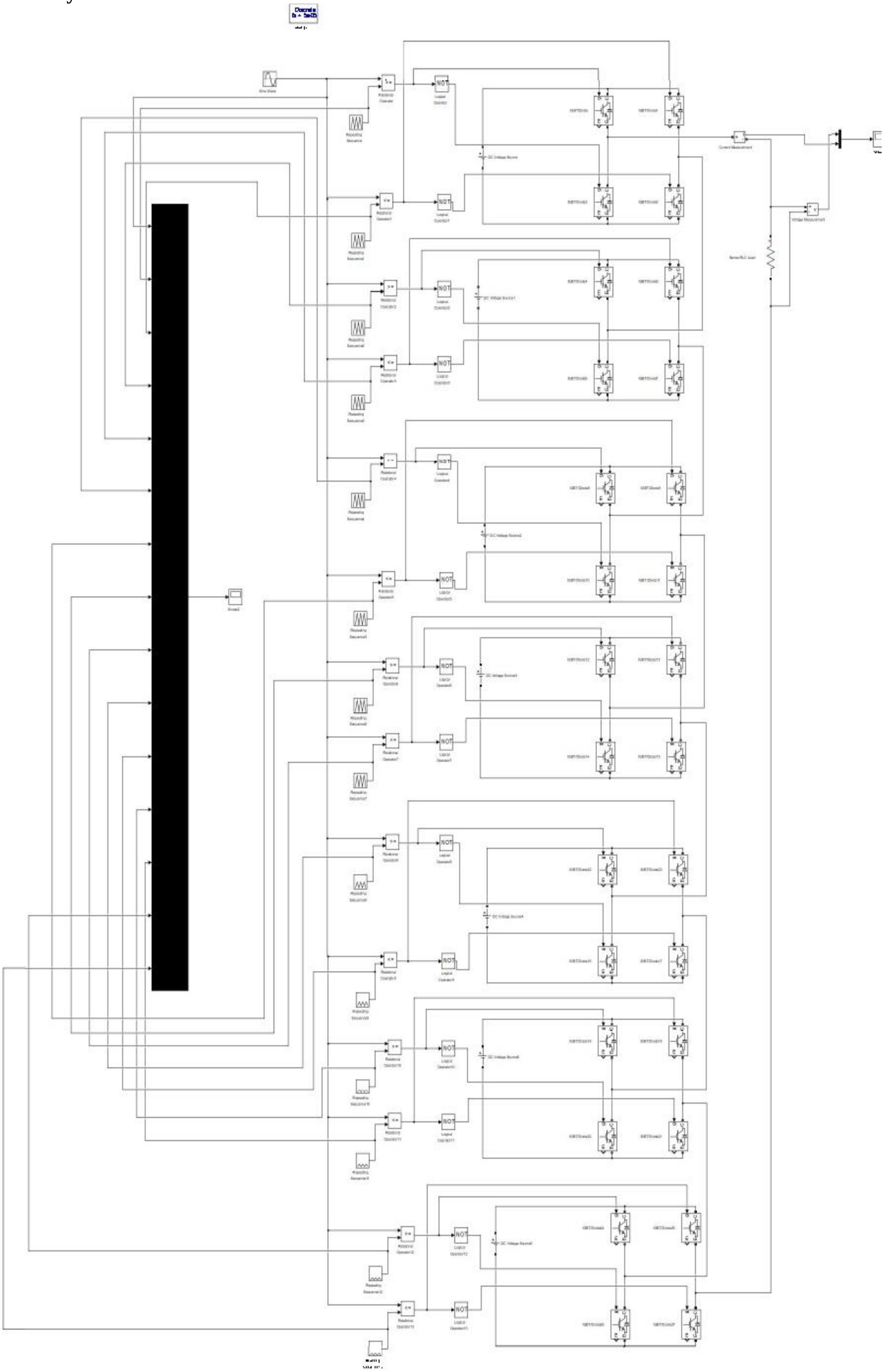
IV Analysis Of 15 Level Multilevel Inverter With PWM:



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V SCOPE ANALYSIS OF 15 LEVEL MLI WITH PWM :

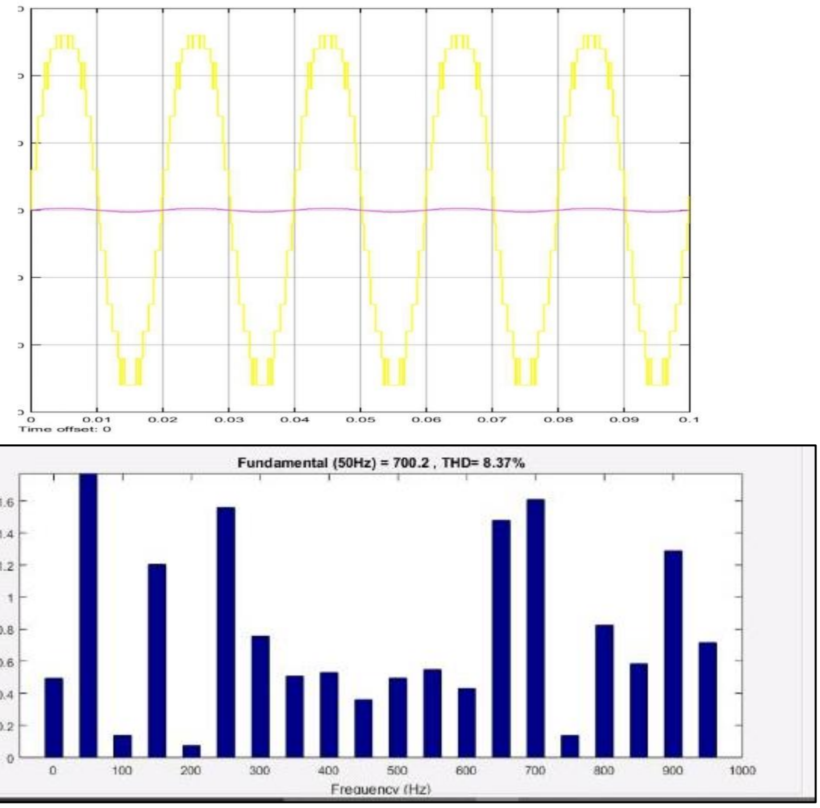
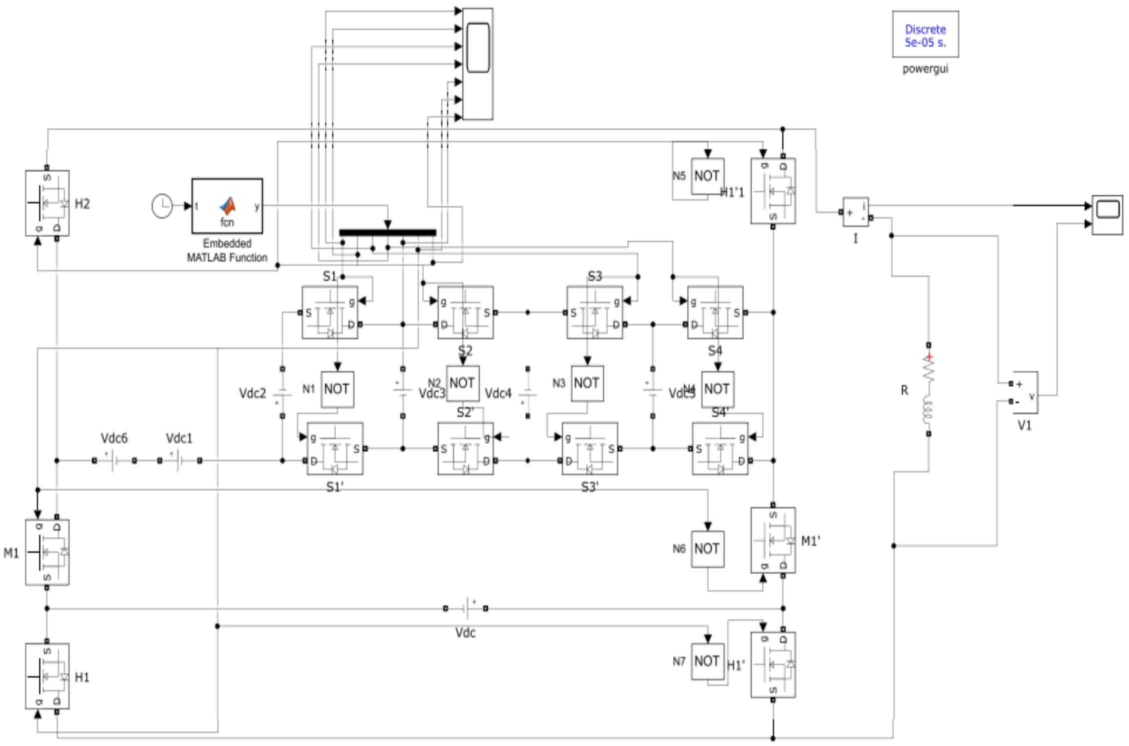


Figure 7Scope & THD

VI Analysis of 15 Level Multilevel Inverter with modified PWM and reduced switching:



Algorithm for switching sequence

```
Function y = fcn (t)

f=50

r=sin (2*pi*f*t)
ar=abs(r)
If ar<0.5/7
S1=0; S2=0; S3=0; S4=0;
elseif ar<1.5/7
S1=0; S2=0; S3=0; S4=0;
elseif ar<2.5/7
S1=0; S2=0; S3=0; S4=1;
elseif ar<3.5/7
S1=0; S2=0; S3=0; S4=0;
elseif ar<4.5/7
S1=0; S2=0; S3=0; S4=1;
elseif ar<5.5/7
```

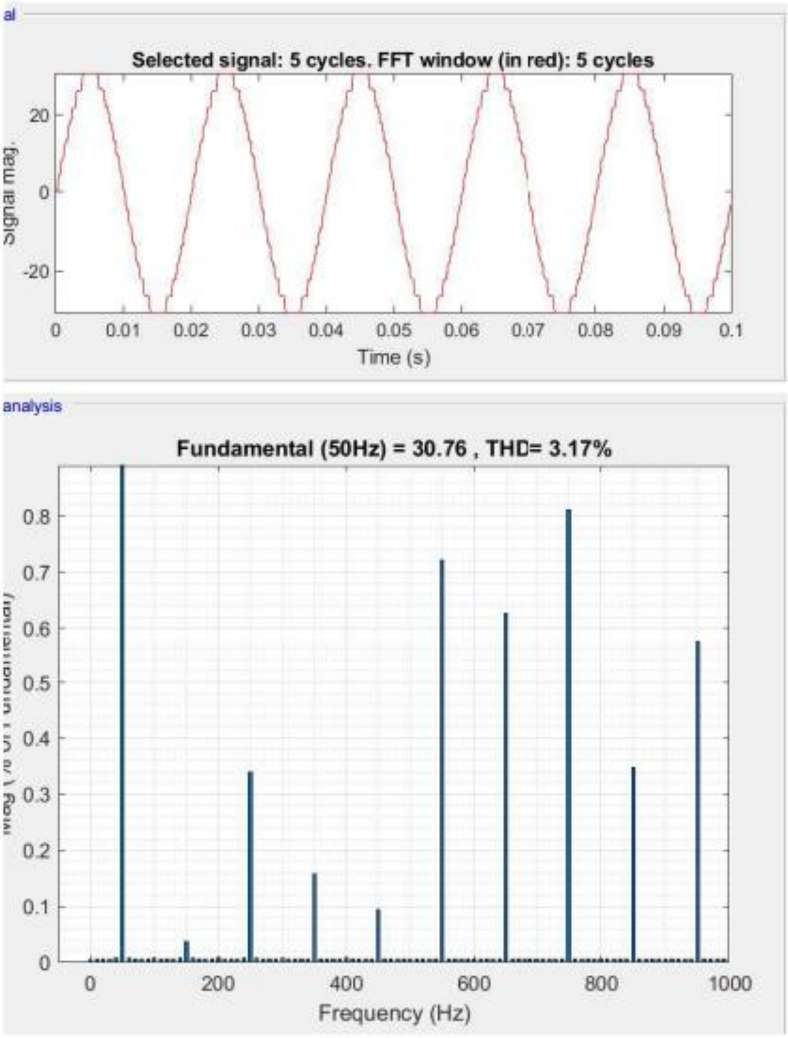


Figure 8Scope & THD

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Comparison with Level Of THD

Level	**THD (%)**
15 level without PWM	27.08
15 level with PWM	8.37
15 level with PWM and reduced switches	3.17

CONCLUSION

The above model depicts clearly the cascaded modified design very suitable considering the solar scenario of India regarding the enhanced power quality characteristics. The suggested PWM technique with the Solar PV panel reduces the THD remarkably considering the solar as the isolated DC source. Based on the results, it is found that the final method with reduced switching and modified PWM for delivering least THD when compared to the conventional modules. The modified simulation clearly reflects that reduced switches are resulting in the lesser poer losses and hence less injection of the reactive component of power. So, the paper reaches the satisfactory benchmark to validate that the algorithms for modulation interfaced with the semiconductor power electronics devices are proving highly beneficial to enhance the power quality and the finally obtained voltage levels and the waveform resembles very closely to the sinusoidal reference. Thus as non-linear loads cannot be totally avoided the best possible solution is to improve the quality of power by lowering the THD as standards mention to be less than 5% using the proposed module with a renewable touch.

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