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Total harmonic distortion reduction using Photovoltaic cell and LC filter in Three Phase 11 Level Inverter

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Abstract- This paper deals with reducing THD in three phase 11 level inverter by using photovoltaic cell and LC filter. Mostly used three topologies for inverter are diode clamped, capacitor clamped and cascaded inverter. Out of these three cascaded inverter has reduced harmonics and reduced switching loss while switches are large in all three inverter topologies this cause much heat loss, high cost and large size also more gate drive circuit. Proposed method uses reduced switches inverter topology to get 11 level output voltage, the PV panel is connected in input and LC filter is connected in the output so that reduced THD can be attained. The simulation using MATLAB /SIMULINK is done and result is verified in Fast Fourier transform analyses.

Index Terms- 11 step multilevel inverter1, Total harmonic distortion2, PV cell3, battery4, LC filter5.

1. INTRODUCTION

Higher demand of power in industries is being fulfilled by power electronics devices from many years. Conversion of AC to DC / DC to AC is easily done by converters, inverter converts DC to AC while rectifier converts AC to DC power we can also achieve variable ac or variable dc by using appropriate converters from invention of semiconductor to IGBT, this replaces the old mechanical type switching devices which has more disadvantages as compare to its advantages. The output obtained by inverter is not sine wave thus giving harmonic distortion with increment in steps at the output this distortion can be reduced. Here 11 level inverter having less switches is taken and harmonic content is reduced by using PV cell and LC filter.

Photovoltaic cell uses solar energy to generate output power as it has advantage of having renewable source of energy also it has disadvantage of unavailability of all the time .To overcome this problem the battery application is used which stores energy, so that the continuous supply does not get interrupted. PV cell rejects the extra voltage requirement in the system and this voltage is stored in dc battery circuit.

An LC filter is designed and connected at the output to produce a sine wave from the staircase inverter output. This LC filter attenuates voltage ripples due to the inverter switching. This paper provides low output harmonic content in its output in three phase configuration of 11-level inverter.

For generating 11 level, Diode clamped MLI requires 20 switches 90 diodes and 10 main DC-bus capacitors per phase, Capacitor clamped MLI needs 20 switches 45 clamping capacitor and 10 main dc bus capacitor, while H bridge inverter requires 24 switches per phase to get same level in output. This paper uses a single phase inverter configuration with eight switches and three DC sources. A model of three phase multilevel inverter is obtained by interconnecting three single phase inverters to a star, with a resistive load and a common earth point. Therefore, this circuit offers lesser gate control circuitry and installation is easy.

2. MULTILEVEL INVERTER

The basic structure of the multilevel inverter is to synthesize a sinusoidal voltage from several levels of voltages typically obtained from capacitor voltage sources. A three-level inverter with center tapped two capacitor voltages is also known as a “neutral-clamped” inverter, each phase leg has two pairs of switching devices in series .The output obtained from a three-level inverter is not a sine wave but in the form quasi-square wave. High power capability, lower output harmonics and lower commutation problems are the reason for multilevel inverter being used in most number of applications. Multilevel inverters are the best option to get AC from DC with least distortion in the output. The three main multilevel topologies are categorized according to their circuit structure:

(1) Diode clamped inverters
(2).Flying capacitor inverters
(3).Cascaded inverters

With respect to many advantages, multilevel inverters also have several disadvantages which have to be addressed. The most and important one is that it uses large number of switches as we go on increasing the level larger switches are required thus overall system become bulky and complex.

3. PHOTOVOLTIC CELL

Non renewable sources such as coal, petroleum are not going to exit in this world all the time as demand of power is increases the rate of using and extracting of these resources are also increased while renewable sources like sun wind are available all the times which is natural source of energy and can fulfill all the demand if these are properly utilized. Photovoltaic power generation is the way of fulfilling the needs of power by utilizing solar

energy which has benefits of being eco friendly, less maintenance and no noise. Photovoltaic cell is an electrical device that converts the energy of light coming from the sun directly into electricity by the photovoltaic effect, which is a physical and chemical phenomenon. Light consists photons which excite electrons into a higher state of energy, hence they behave like charge carriers for generating an electric current. From the solar cells we get direct current in the output, this d.c can be stored in battery or can be used for power equipment device. Efficiency of a PV cell can be defined as the rate of output generated from the given input. The basic expression is given below Eq. (1)

$$\eta = \frac{P_{max}}{E \cdot A_{cell}}, \qquad \text{Eq. (1)}$$

4. PROPOSED TOPLOGY AND ITS OPERATIONS

The proposed model has eight switches and three d.c sources circuit as shown in Figure 1. Source circuit is the combination of d.c battery circuit and PV panel .Due to irradiation factor actual requirement of voltage reduces, which could be of 20% to 30% and this extra voltage is saved in the storage battery thus reducing the harmonic content in the output. The series combination of sources Vdc, 2Vdc and 2Vdc can be used to produce 11 dc levels at the inverter output in a single cycle.

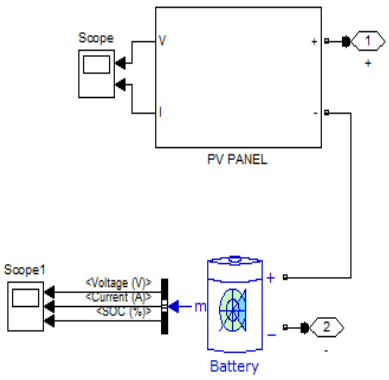

Fig. 1. D.C voltage source system

The proposed simulating model is given in Figure 2. The switches are triggered by applying pulses Table. 1 shows the switching operation of the inverter.

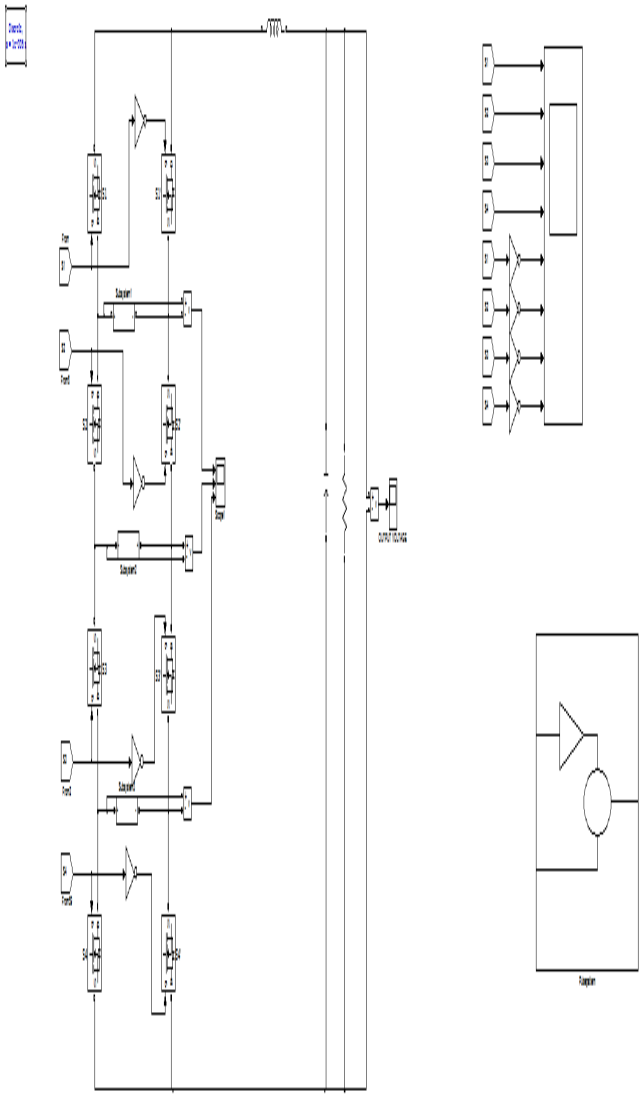

Fig. 2. Simulation circuit of the proposed model

Table 1. Switching states in 11 level inverter

Output Voltage	S1	S2	S3	S4	S1B	S2B	S3B	S4B
$+5V_{dc}$	1	0	1	0	0	1	0	1
$+4\ V_{dc}$	0	0	1	0	1	1	0	1
$+3\ V_{dc}$	1	0	1	1	0	1	0	0
$+2\ V_{dc}$	0	0	1	1	1	1	0	0
$+\ V_{dc}$	1	0	0	0	0	1	1	1
0	0	0	0	0	1	1	1	1
$-\ V_{dc}$	0	1	1	1	1	0	1	1
$-2\ V_{dc}$	1	1	0	0	0	0	1	1
$-3\ V_{dc}$	0	1	0	0	1	0	1	1
$-4\ V_{dc}$	1	1	0	1	0	0	1	0
$-5V_{dc}$	0	1	0	1	1	0	1	0
0	1	1	1	1	0	0	0	0

5. SIMULATION RESUTS

The simulating result gives 11 levels of output voltage as shown in Figure 3 when filter is not used D.C output from PV panel is 89V and 189V when irradiation of 120 and 200 provided to it as shown in figure 4, 5 and 6 while the remaining voltage is bypassed to charge battery which can be used for continues supply when energy coming from sun is not of appropriate level.

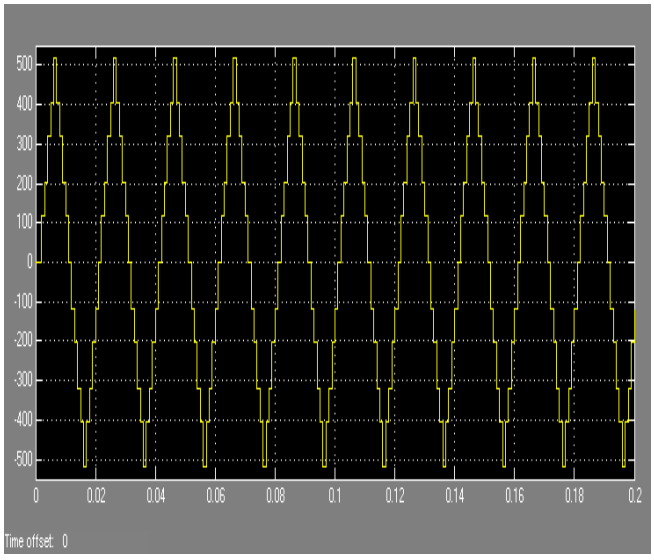

Fig. 3. 11 step output voltage without LC filter

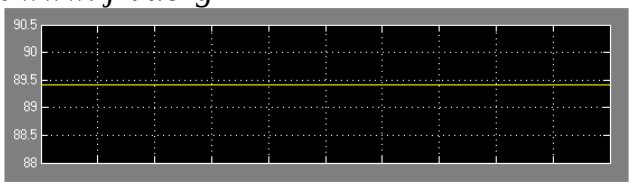

Fig. 4. Output value of PV panel 1

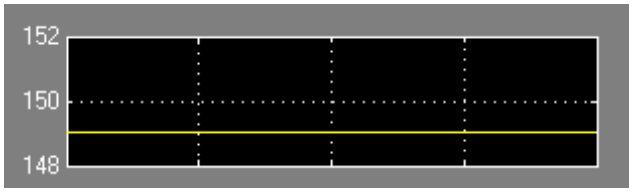

Fig. 5. Output value of PV panel 2

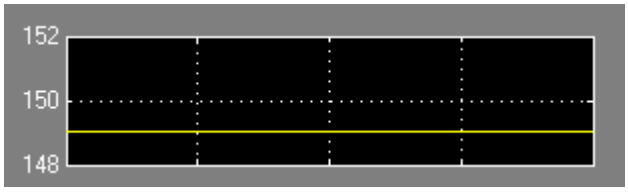

Fig. 6. Output value e of PV panel 3

FFT analysis of two models with PV panel without LC filter and PV panel with LC filter of 11 step inverter is shown in figure 7 and 8 and their harmonic distortion is compared, while figure 9 represents output voltage of the proposed model.

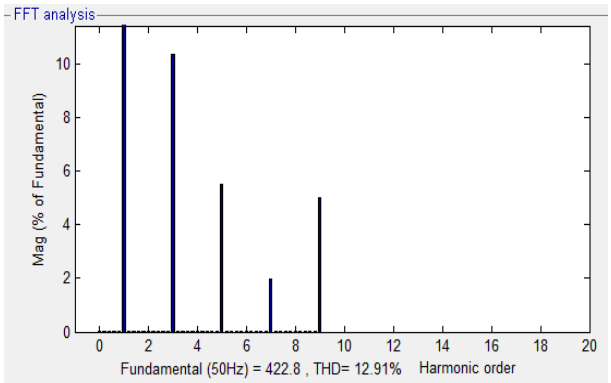

Fig. 7. FFT analysis of THD without filter

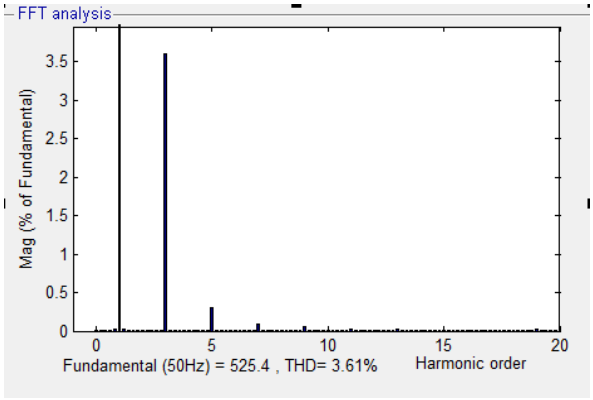

Fig. 8. FFT anaysis of THD with RL filter

The L and C values are designed to maintain the switching ripple current under the target value. The inductance value is thus given by Eq. 2

$$L \geq \frac{R_{L-max}}{3\omega} \text{ for single phase}$$

$$L \geq \frac{2*R_{L-max}}{p(p^2-1)\omega} \text{ for polyphase}$$

Eq. (2)

p=number of phases

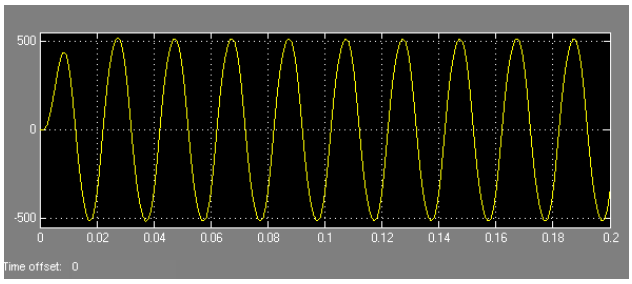

Fig. 9. Output voltage of proposed model

6. CONCLUSION

From the proposed model and simulation results we can finally conclude that the Total Harmonic Distortion of 11 level inverter using photovoltaic cell with LC filter is reduced to 3.61 % while earlier it was 12.91%

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