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Performance Evaluation for Different Levels Multilevel Inverters Application for Renewable Energy Resources

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Abstract:
Cascade Multilevel Inverters are extremely attractive and promising lot of advantages over traditional inverter. Multilevel inverters are required for high power applications. Multilevel inverters are not only achieving high power ratings, but also use the renewable energy sources. Renewable energy sources like photovoltaic, wind and fuel cells can easily been used to supply energy to inverter system. This paper deals with the comparative study between 7, 9 and 11 levels multilevel inverters to evaluate the performance by simulating circuit in MATLAB/Simulink.

Keywords: Different Levels**,** Cascade Multilevel Inverters, Renewable Energy, THD

I. Introduction

World energy consumption knows an exponential progression. The population growth, the development of electric transportation, industrialization of the emerging countries, equipment redundancy in households and the commoditization of digital are some of the reasons for this huge progression.
For example the energy supply of Morocco depends on importation of 91% (crude oil, oil products, coal, natural gas and electricity), which presents 27% of all the country's imports. In the last years, Morocco plans to increase the production of electricity from renewable energy to assure its own needs, and also to be able to export the exceeding production to Europe. The share of the multiple sources of the total primary energy supply in 2012 can be seen in Figure 1.
In this context, Morocco is making an ambitious energy transition program, which aimed to provide the country with a durable, competitive and cost effective energy. The country possesses an extensive wind and solar resource, able to cover a
significant energy demand. Morocco has an ambitious solar plan (MSP), by installing the capacity of 2000 MW of solar energy by the year 2020.

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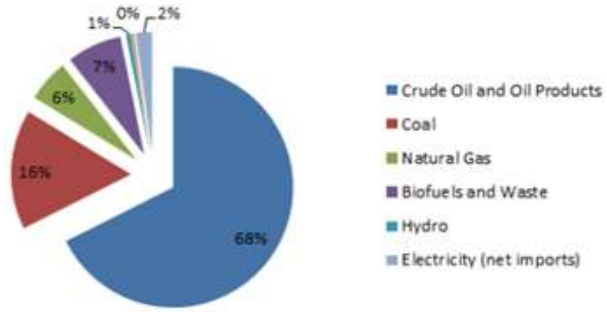

Figure. 1.a: Total primary energy supply in 2012

The project is performed by the Moroccan Agency for Solar Energy (MASEN).
From the end of the previous decade till now, multilevel inverters have represented growing attention due to their promising employment in renewable energy systems and industrial drives [1]. They can be efficiently applied in the diffused energy systems in which, output AC voltage is obtained by joining DC sources such as solar cells, rectified wind turbines at the input side of the inverters [2].
For DC-to-AC converter, the multilevel inverter is a great alternative for renewable energy application. This is because it gives pretty a lot of services [3]. Consequently, in this paper, 5-level multilevel inverter's simulation output will be compared with the 7-level multilevel inverter, 9-level and 11-level multilevel inverter, focusing on power factor, total harmonic distortion (THD) [4], and its efficiency. Hence, the better level of the multilevel inverter will be concluded [5].

II. Types of Multilevel Inverters

The cascaded H-Bridge multilevel inverters are the most advanced and important method of power electronic converters that analyses output voltage with number of dc sources as inputs. Compared to neutral point clamped multilevel inverter and flying capacitor multilevel inverter, the cascaded H-Bridge multilevel inverters requires less number of components and it reaches high quality output voltage which is close to sinewave. By increasing the number of output levels the total harmonic distortion in output voltage can be reduced. In cascaded H-Bridge multilevel inverter required AC output voltage is obtain by synthesizing number of DC sources. The number of H-Bridge units with different DC sources is connected in series or cascade to produce cascaded H-Bridge multilevel inverter [4].
Figure 3 shows the classification of multilevel inverter topologies which is existing in the area of power conversions

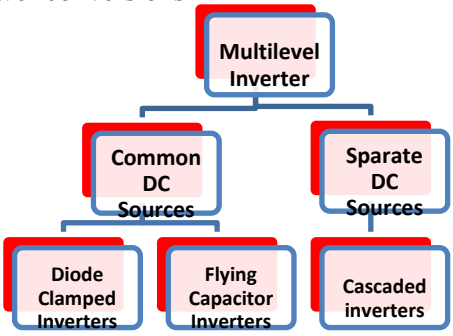

Figure 2: Classification of multilevel inverters

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In this context Comparison of multilevel inverters is based on the following criteria [6]:

- Total Harmonic Distortion of output voltage
- Control complexity based on voltage unbalances and power switches
- Number of DC bus capacitors used
- Number of semiconductor devices used per phase leg
- Amplitude of fundamental and dominant harmonic components

According to these criteria we can conclude that cascaded multilevel inverter is more efficient than other topologies of multilevel inverters [7].

	Topology	Diode Clamped	Flying Capacitor	Cascaded
1	Power semi conductor switches	2(m-1)	2(m-1)	2(m-1)
2	Clamping diodes per phase	(m-1)(m-2)	0	0
3	DC bus capacitors	(m-1)	(m-1)	(m-1) /2
4	Balancing capacitors per phase	0	(m-1)(m-2)/2	0
5	Voltage unbalancing	Average	High	very small
6	Applications	Motor drive system,	Motor drive system,	PV,Wind Turbine battery system

Table 1 : Comparison of different multilevel inverter topologies

III. Different Levels Multilevel Inverters

Three levels multilevel inverters have been analysed in this article to assess their performance based on the three following elements [8]:

- Total Harmonic Distortion (THD)
- Power Factor
- Efficiency

1) Total Harmonic Distortion (THD)

THD is a measurement of the harmonic distortion. It is defined as the ratio of the sum of the powers of all harmonic components to the power of the fundamental frequency. The THD is defined as the

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root mean square (RMS) value of the total harmonics of the signal, divided by the RMS value of its fundamental signal [9]. For example, for currents, the THD is defined as

$$THD = \frac{I_H}{I_F}$$

$$I_H = \sqrt{I_1^2 + \cdots + I_n^2}$$

I_n: RMS value of the harmonic n

I_F: RMS value of the fundamental current

2) Power Factor

Power Factor is defined as the ratio of the real power (P) to the apparent power (S).

$$\cos\theta = \frac{P}{S}$$

Where θ is the angle difference (in degrees) between output voltage and output current. Unity power factor is the best. The load with higher power factor will draw less currents, hence decrease the lost in distribution system and therefore wasted energy will be less.

3) **Efficiency**

In general, efficiency is a measurable concept, quantitatively determined by the ratio of output to input. In this system, input power is the power delivered from PV arrays or wind turbine, while the output power is the power at the grid.

We choose for our simulation among 3 different levels of multilevel inverters:

- 7 level multilevel inverters
- 9 level multilevel inverters
- 11 level multilevel inverters

IV. Numerical simulation

Here we show the programs use in our simulation with Simulink for the three systems to make the comparison in part results:

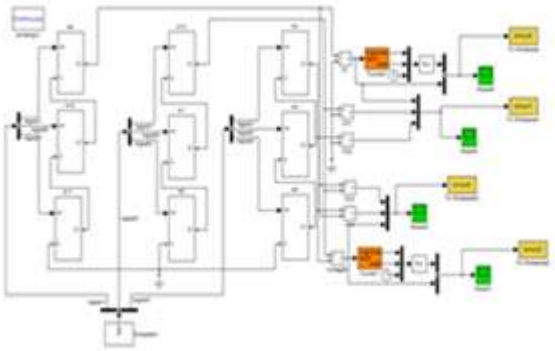

Figure: 3. a 7 Level multilevel inverters diagram

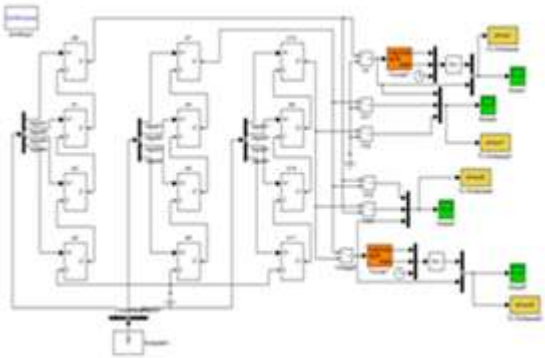

Figure. 3. b 9 Level multilevel inverters diagram

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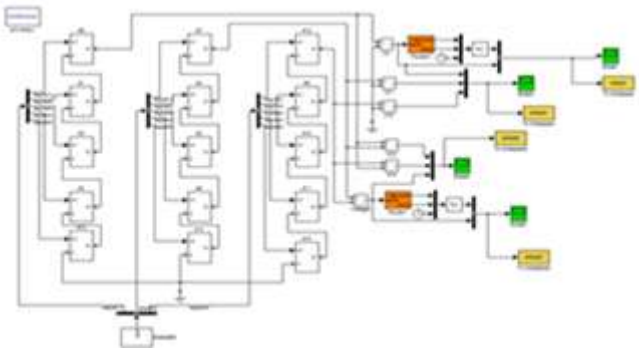
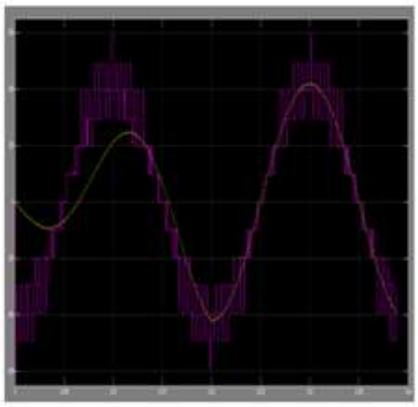


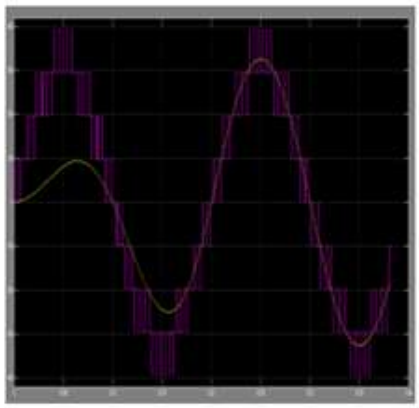
Figure. 3.c 11 Level multilevel inverters diagram

V. Results and Discussion

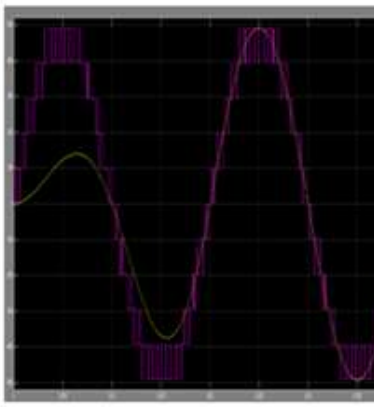
The simulation is done for different levels in order to obtain the optimum solution on the quality of the output waveforms. A comparison between the cascaded topology and suggested topology is displayed in T period clearly presents the percentage reduction in the number of switching devices as the number of output level increases. The obtained output phase voltages are as shown in Figure 4. The output waveform for individual phases confirms the constant magnitude over the wide range of operation.



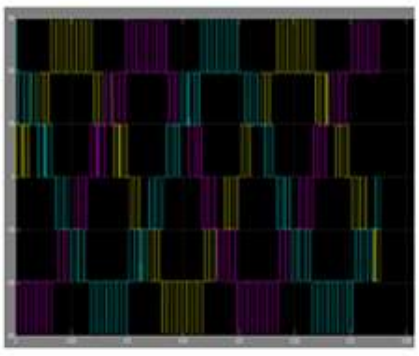
7 Level multilevel inverters



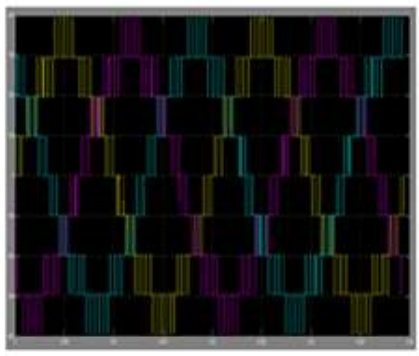
9 Level multilevel inverters



11 Level multilevel inverters



7 Level multilevel inverters



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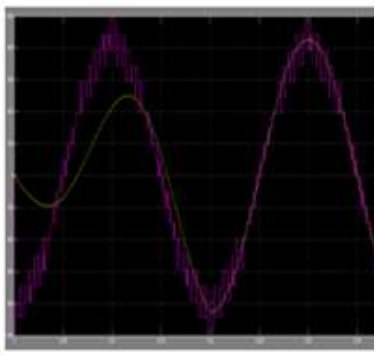

11 Level multilevel inverters

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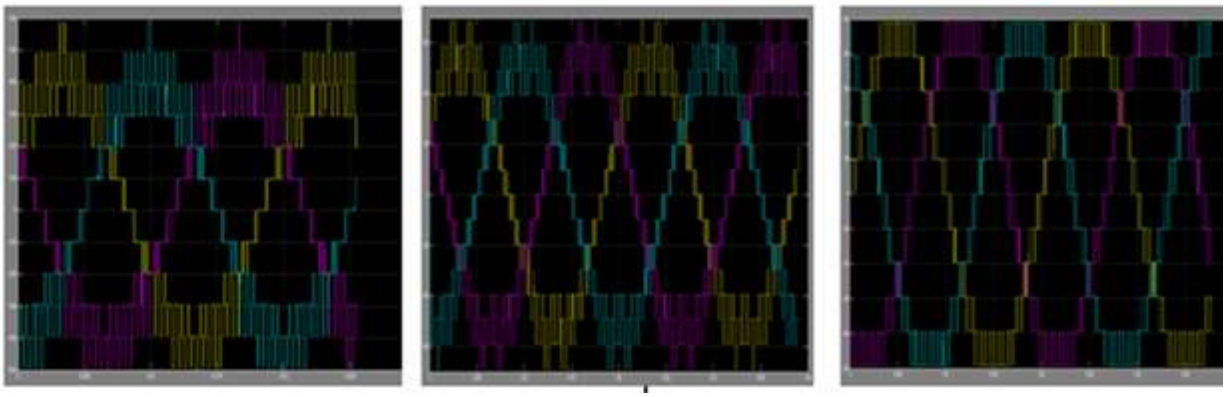

7 Level multilevel inverters **9 Level multilevel inverters** **11 Level multilevel inverters**

Figure 4: Output phase voltage waveforms for various level numbers

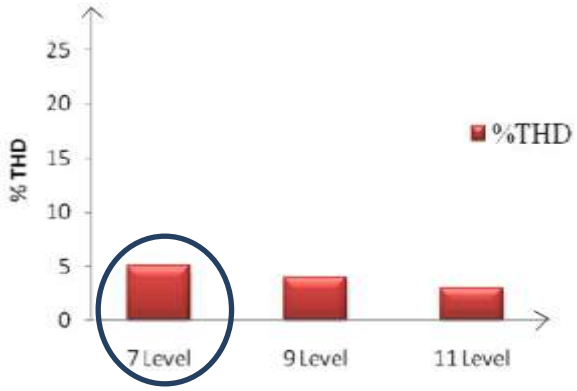

Figure 5: Percentage THD Vs various levels

Similarly the output wave forms are obtained for three phase seven level, nine level and eleven level cascaded configurations, based on the outputs the chart is plotted between the levels and the output percentage THD as shown in Figure 5. From Figure 5 it is inferred that as the level increases the output THD level approaches zero with the implemented, as level increases the number of power switches required to construct the power circuit will also get increased. The control of individual switches will become a complex issue and it is not an economical solution for the power quality issues.

To determine the performance of the advanced multilevel converter topology in the creation of the desired output voltage, different levels multilevel inverters are simulated. The principal objective of this proposed topology is to synthesize the output voltage with minimal error with respected to the reference voltage. It is important to note that the calculation with Riemann approximately of optimal switching angles so as to obtain selective harmonic elimination and minimize the total harmonic distortion is not the objective of this work.

The selective harmonic elimination has a theoretical potential to achieve the highest
output power quality at low switching frequencies in comparison with other methods in the future work. Due to mathematical complexity, this method is less preferred.

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VI. Conclusion

The use of multilevel inverter in renewable energy system was accepted in power system since it gave a lot of advantages. More number of levels of multilevel inverter will give better performance in the system. In this paper, from the simulations and the results, 11 level multilevel inverter (figure 5) had given more efficient performance in terms of the power factor, THD and its efficiency than 7-9 level multilevel inverters.

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