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ENHANCEMENT OF POWER QUALITY IN SAPS SYSTEM WITH MULTILEVEL INVERTER

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ABSTRACT

This paper presents a standalone hybrid power system by the use of wind/PV/diesel energy system in Matlab/Simulink environment. PV & Wind are the basic power sources of the system. The most frequently used renewable energy sources are those consisting of PV module and/or wind Turbine with/or Diesel generator. Multi-level inverters play a vital role in today's interconnected grid systems with renewable energy sources. Those power electronics devices which converts DC input power to AC at required output level of voltage and frequency are known as inverters. They are used for high voltage and high power applications, with the improved advantages of low switching stress and reduced total harmonic distortion (THD), hence they reduce size of the passive filters. Multilevel inverter can be used with this standalone hybrid system for the electrification of rural areas to provide uninterrupted power supply.

KEYWORDS: Standalone hybrid power system, Multi-Level Inverter, Topologies, THD.

INTRODUCTION

Renewable energy sources are omnipresent, easily available, and environmentally friendly. This is very useful in distant and remote area locations, that's by it is becoming very famous and can be used for rural electrification of remote areas. Rural electrification is the process of bringing electrical power to rural and remote areas. Electricity is used not only for lighting and household purposes, but it also allows for mechanization of many farming operations, such as threshing, milking, and hoisting grain for storage. Due to their geographical location and low demand compared to the area, rural areas are mainly suitable for renewable energy off grid applications Renewable energies based mini grids are less dependent on larger-scale infrastructure and could be placed in service faster.

In these areas, alone wind energy can supply large amount of power but its presence is highly unpredictable. Similarly, solar energy is present throughout the day but the solar irradiation level varies due to sun intensity and unpredictable shadows casting by clouds, trees etc.

The intermittent nature of the wind and photovoltaic systems makes them unreliable, which is its major drawback. The combined utilization of these two renewable energy sources, the power transfer efficiency and reliability of the system can be improved significantly. This system is called hybrid energy system. In this system when any one of the energy source is absent or insufficient to fulfill the load demands, the presence of the other energy source compensates the difference. [1, 2]

As fuel cells reduce the dependence on fossil fuels thus having a significant environmental and national security, they are the centre of interest for excessive research & can also be used in standalone power supply system in addition with wind and PV module. Fuel cell is an emerging technology which could allow a clean, cost effective supply of energy on demand on a large scale. But it has persisting disadvantages of requirement of power electronics devices to be added to the overall system as an interface between the FC and the load for low output voltage thus complicating its design. The slowness of reaction makes it unable to meet fast-variation loads

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Basically inverters are those devices which converts DC power to AC power at desired output voltage. Beside this it has some other advantages such as high power quality, lower order harmonics, lower switching losses, and better electromagnetic interference and frequency. But it has some disadvantages also like high switching losses, high cost and less efficiency.

Hence because of these disadvantages multilevel inverters are used over conventional inverters. The output of the multilevel inverter is a staircase waveform which is similar to the sinusoidal waveform. The no. of harmonics present in the output voltage of multilevel inverter is much lesser than the conventional two-level inverter. The classification of multilevel inverter is as follows; cascaded multilevel inverter, flying capacitor inverter and diode clamped inverter [8, 9, 10].

A stand-alone power system (SAPS or SPS), also known as remote area power supply (RAPS), is an off-the-grid electricity system for locations that are not fitted with an electricity distribution system. Typical SAPS include one or more methods of electricity generation, energy storage, and regulation.
Electricity is typically generated by one or more of the following methods:

- [1] Photovoltaic system using solar panels
- [2] Wind turbine
- [3] Geothermal source
- [4] Micro combined heat and power
- [5] Micro hydro turbine
- [6] Diesel or bio-fuel generator
- [7] Thermoelectric generator (TEGs)

This paper basically focuses on wind energy, solar energy and diesel generator.

Multilevel inverters

In today's world, multilevel inverters are widely used in power industries. It starts from three level inverter. Voltage unbalance problem is one of the major issue in working of multilevel inverter.

Its major types are diode clamped multilevel inverter, flying capacitor based multilevel inverter & cascaded H-bridge multilevel inverter.

Diode clamped multilevel inverter

This inverter mainly use diodes to limit the power devices voltage stress. The voltage over each capacitor and each switch is Vdc. An m level inverter needs (m-1) voltage sources, (m-1) capacitors,2(m-1) switching devices and (m-1) (m-2) diodes per leg [6].

Flying capacitor multilevel inverter

This inverter uses capacitors to limit the voltage of the power devices. The configuration of the flying capacitor multilevel inverter is like a diode clamped multilevel inverter except that capacitors are used to divide the input DC voltage. The voltage over each capacitor and each switch is Vdc. It requires (m-1) capacitors on dc bus form level converter.

Cascaded H- Bridge multilevel inverter

The concept of this inverter is based on connecting H-bridge inverters in series to get a sinusoidal voltage output. The output voltage is the sum of the voltage that is generated by each cell. The number of output voltage levels are ($2n$+1), where n is the number of cells. The switching angles can be chosen in such a way that the total harmonic distortion is minimized.

One of the advantages of this type of multilevel inverter is that it needs less number of components comparative to the Diode clamped or the flying capacitor, so the price and the weight of the inverter is less than that of the two former types [3].

Hence our paper mainly focuses on the modelling of 5 level, 7 level and 9 level multilevel inverter using cascaded H – Bridge multilevel inverter topology.

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SYSTEM DESCRIPTION

In this section the Simulink model of hybrid power system based on PV module, wind turbine, and diesel generator set is described. The proposed system consists of a PV module, a wind turbine module , multilevel inverter, diesel generator set and battery.

Modelling of wind turbine

Wind power is rapidly becoming a mature industry as performance of wind energy conversion system (WECS) and leverage of large-scale industrial production steadily decrease cost. Measures taken by governments and other agencies to subsidize the costs of electricity installation and regulations in several countries concerning the purchase of electricity produced by grid-connected systems are promoting public awareness and the widespread use of environmentally friendly wind electricity.

To convert wind power into electricity, many types of generator concepts have been used and proposed [4,5]. The main wind turbine generators can be grouped into 2 classes: variable and fixed speed [7,11]. The main difference is the electrical system where variable–speed wind turbine is more complicated than fixed-speed wind turbine. The fixed-speed wind turbine has the advantage of being simple, robust and reliable and well proven and the cost of its electrical parts is low.

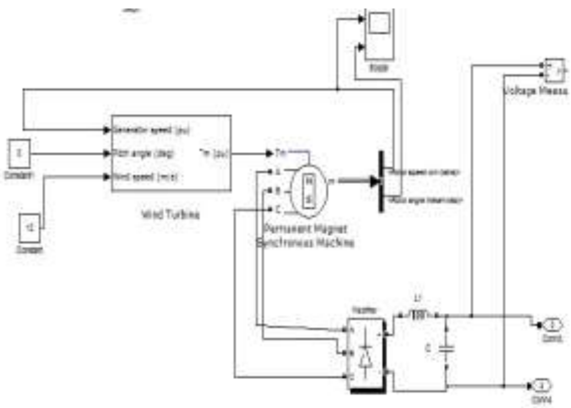

Fig.1: Wind turbine module

The fundamental equation can be given as
PWIND = $0.5A\rho v3$ (i)

The available energy part in wind is described by the power coefficient Cp.

The theoretical maximum value of this coefficient is 0.59 and this is called the Betz limit.

PTURBINE = $0.5CpAv3$ (ii)

The practical value of Cp lies between the value of 0.4 and 0.5 for industrial wind turbines. The power coefficient is a function of the tip-speed ratio λ

$\lambda = r\,\Omega/V$ (iii)

where r is the rotor radius and Ω is known as the angular rotor speed.

3.2 Modelling of PV module

Most renewable energy comes either directly or indirectly from the sun. Sunlight, or solar energy, which can be used directly for generating electricity, and also for hot water heating, and a variety of commercial and non commercial uses.

The solar energy has the great potential as a power generating energy source, because of its many advantages like zero emission of pollutant gases, zero cost of fuel, inexhaustible and easy availability of this energy source. But this system has some disadvantages like dependency on weather conditions.

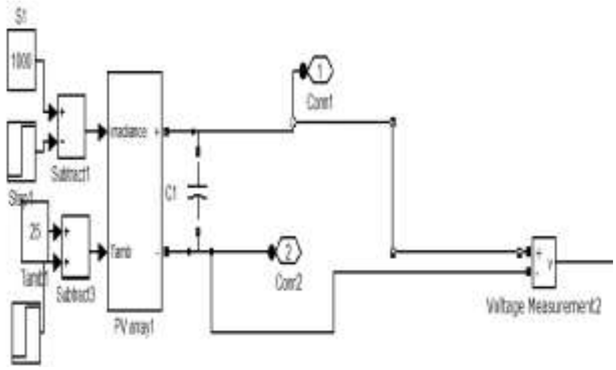

Fig.2: PV array module

PV system naturally exhibits a nonlinear I-V and P-V characteristics which vary with the radiant intensity and cell temperature.

The voltage-current characteristic equation of a solar cell is given as

$$I = IPH - IS\,[\,exp\,(q(V + IRS)\,/\,kTCA\,) - 1\,] - (V + IRS)\,/\,RSH$$

Where Iph is photocurrent, *I*s is the cell saturation of dark current, q = 1.6 ×10−19C is an electron charge, k = 1.38 ×10−23J/K is a Boltzmann's constant, *T*c is the working temperature of the solar cell, *A* is an ideality factor of the diode, *R*sh is a shunt resistance, and *Rs* is a series resistance.

Modelling of Diesel Generator module

Diesel generator set converts fuel energy (diesel or bio-diesel) into mechanical energy by means of an internal combustion engine, and then into electric energy by means of an electric machine working as generator.

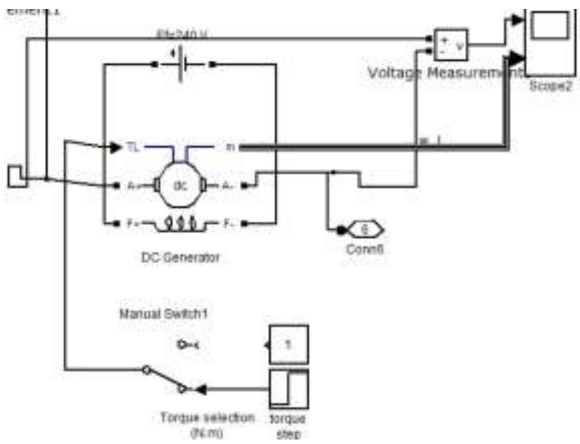

Fig.3: DC generator set module

STANDALONE POWER SYSTEM SIMULINK MODEL & SIMULATION RESULT & DISCUSSION

Using the Simulink environment the stand alone hybrid power system is developed here. This system consists of a PV module, wind turbine module and a DC generator set.

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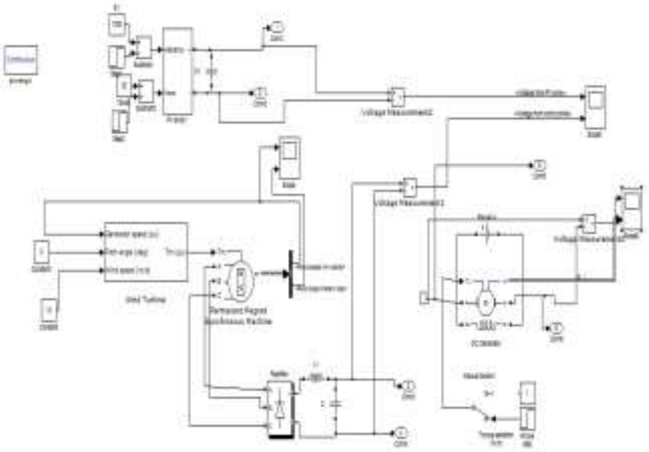

Fig.4: simulink model of standalone power supply system

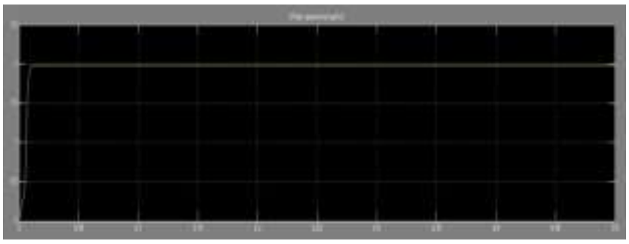

Fig 5: Plot between angular frequency (rad) with respect to time

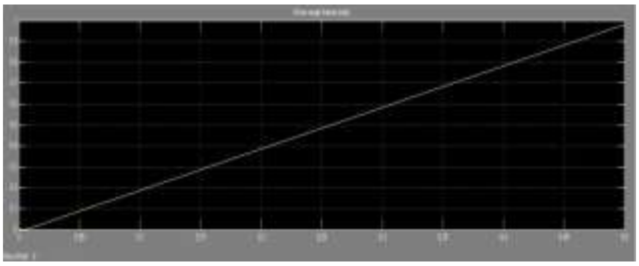

Fig 6: Plot between rotor angle with respect to time

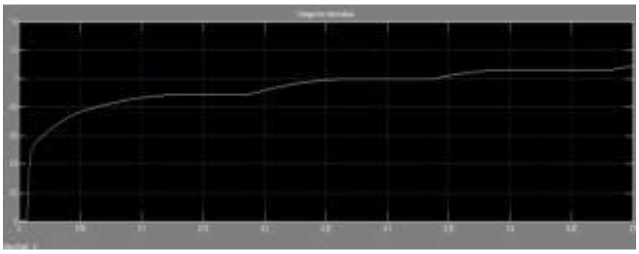

Fig 7: Variation of voltage (volt) with time (sec)

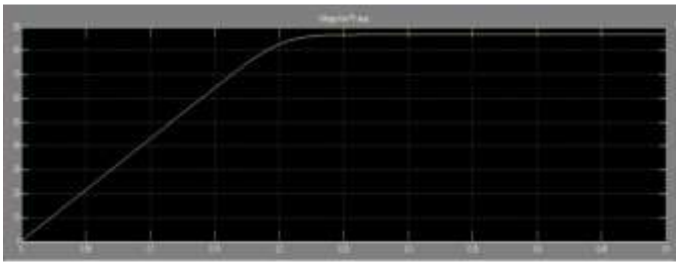

Fig 8: Variation of output voltage (volt) with respect to time (sec)

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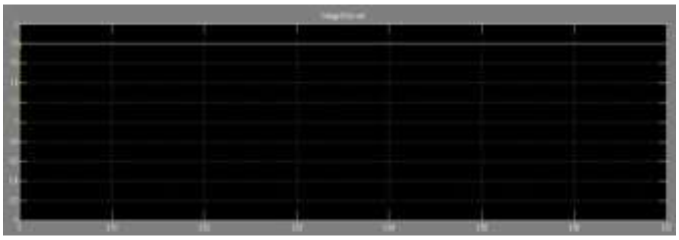

Fig 9: Output terminal voltage of DC generator set module

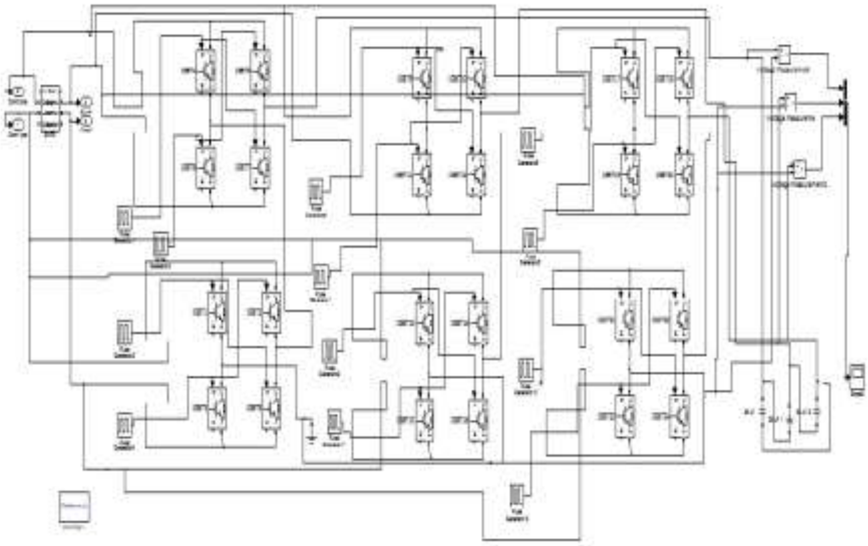

Fig 10: Simulink model of a five level cascaded H-bridge multilevel inverter

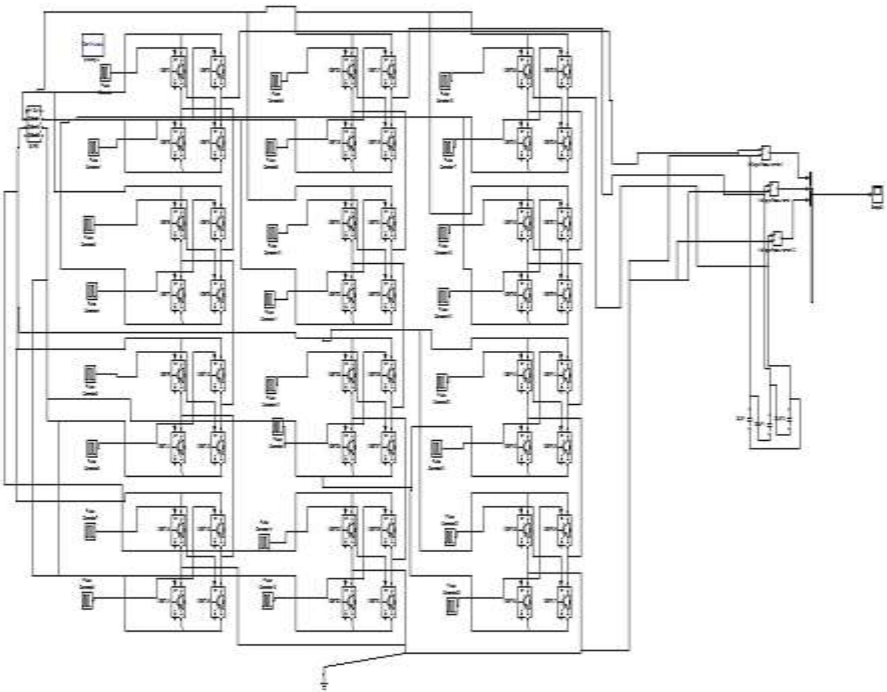

Fig 11: Simulink model of 9 level Cascaded H-Bridge multilevel inverter

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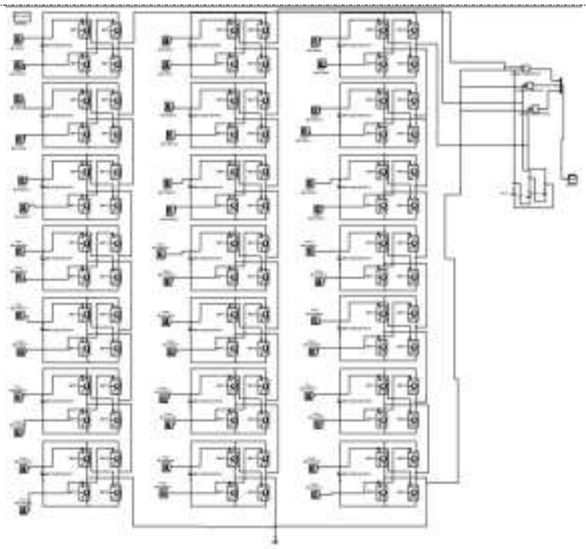
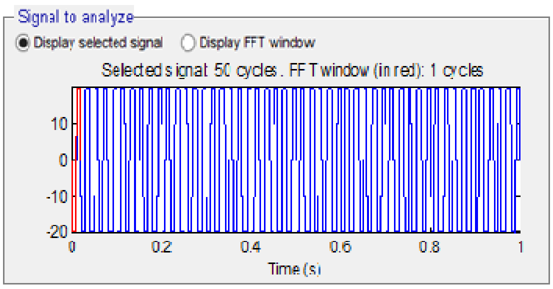
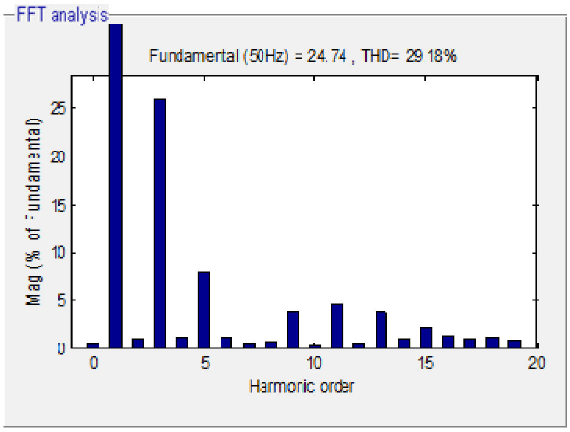


Fig 12: Simulink model of 15 level Cascaded H-Bridge multilevel inverter



Output Voltage of 5 level inverter for SAPS



% THD Analysis of 5 level inverter

Fig 13: THD analysis of 5 level cascaded H-bridge multilevel inverter

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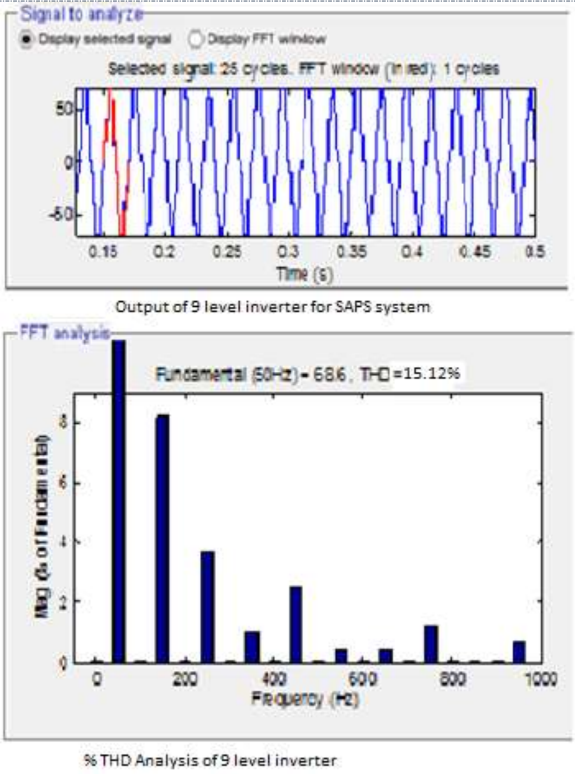

Fig 14: THD analysis of 9 level cascaded H-bridge multilevel inverter

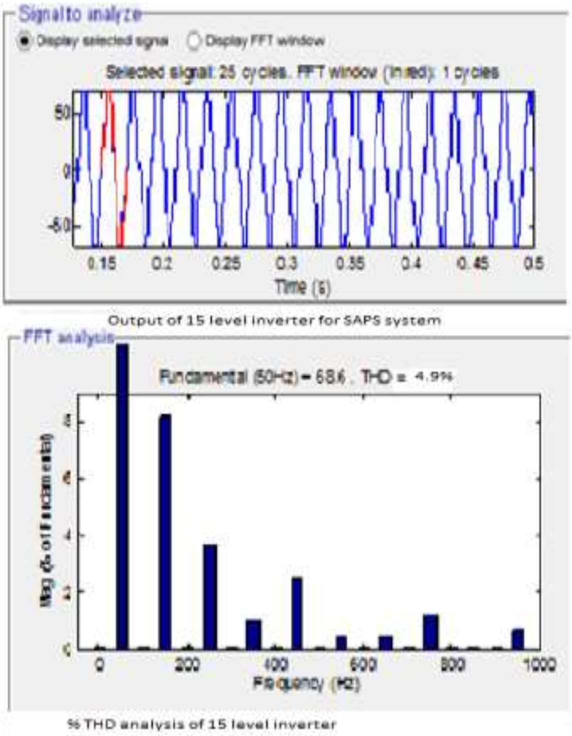

Fig 15: THD analysis of 15 level cascaded H-bridge multilevel inverter

In this paper the THD of 5 level,9 level & 15 level cascaded H-bridge multilevel inverter is calculated for using it in SAPS system for rural electrification. The THD for 5 level cascaded H-bridge is found to be 29.18%, for 9 level it is calculated 15.12% & for 15 level it is calculated 4.9%. This value matches with the IEEE standards of

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THD. In this section the THD values of cascaded H-bridge multilevel inverter with SAPS system is compared with the one which is fed by a DC source. In the comparison we found that the percentage THD values of 5 level, 9 level and 15 level multilevel inverter with SAPS system comes to 29.18%, 15.12% & 4.9% respectively & percentage THD values of 5 level, 9 level and 15 level multilevel inverter without SAPS system comes to 29.18, 16.12% & 5.2% respectively.

CONCLUSION

This paper presents a hybrid wind/PV/diesel energy system for standalone system using Matlab/Simulink environment. That level of cascaded H-bridge multilevel inverter is used in SAPS system which has lower level of THD. It is seen that 15 level has lowest THD & hence it is used in SAPS system for rural electrification. And it is observed that with every increase in the level of multilevel inverter, the THD decreases.

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