SIMPLIFIED TRANSFORMER BASED MULTILEVEL INVERTER TOPOLOGY FOR RENEWABLE ENERGY APPLICATIONS

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ABSTRACT

As renewable energy sources are playing an important role in development of grid and reducing the pollution of environment but it is polluting the electric power. There are number of power quality issues which are introduced in system due use of switching devices. The renewable energy sources are connected with main grid with the help of power electronic devices and power electronics devices impacts as power quality issues. Hence to minimize the power quality issues occurring due to general inverter topology can be reduced using advanced topologies of multilevel inverter. This work focuses on developing a nine level inverter having a single transformer and reduced component numbers. An optimization of the number of transformers and their turns ratio for a given number of voltage levels resulting in the least number of switches is analyzed by designing hardware

Keywords: Multilevel inverter, Renewable energy sources etc,

I. INTRODUCTION

In this era use of renewable energy is increasing and also integration of these micro sources with main grid is also increasing. Due to advancement in power electronics controller, it is easy to integrate micro sources with grid which can provide liable and efficient operation. Hence micro sources are get integrated with main grid with help of inverter. Inverter is a device which converts DC to AC. Mostly VSI are used in RES because these inverters are easy to control than that of CSI. The use of more power electronics devices leads to more power quality issues in power system. Renewable and non-renewable energy sources are the energy sources that human uses day to day life. The difference between these two is renewable resources can naturally replenish themselves while non renewable cannot. It means that non renewable energy sources are limited and cannot be used sustainably. The examples of renewable energy sources are solar energy, wind energy, hydro energy, tidal energy, geothermal energy and biomass energy. Among which solar photo-voltic and wind power generation are more popular and it is seen that there is growth from last few years. Energies from these sources can meet local energy demand, also improve the environmental loss. The power electronic converter plays a very important role as an linkage between renewable energy sources and power grid. The two level Inverter is one of the power processor used as integrator. These conventional two level inverters have some limitations in operating at high frequency pulse width modulation (PWM), filtering efforts and electromagnetic interface (EMI) issues. The problem resolved by means of multilevel inverters (MLIs). Nabae el al proposed the first MLI Three level configuration. Capability to generate output voltage with low harmonic distortion, (dv/dt) stress, smaller common mode voltage and lower EMI are the main advantages of MLI. These advantages play very important role in the application of MLI for HVDC transmission, wind energy, railway traction, pumps, mining and fans. Neutral point clamped (NPC) MLI or diode clamped, capacitor clamped or flying capacitor (FC) MLI and cascaded H-bridge (CHB) MLI are the main topologies of MLI. Each one has its own advantage and disadvantage. To increase the voltage level NPC MLI requires to add higher number of clamping diodes.

LITERATURE SURVEY

Renewable Energy Sources and Overview of Multilevel Inverter and Issues:-

The multilevel voltage source converters give the staircase voltage wave from several levels of dc capacitor voltages. One of the major limitations of the multilevel converters is the voltage unbalance between different levels. The techniques to balance the voltage between different levels normally involve voltage clamping or capacitor charge control [4]. Pulse width modulation (PWM) techniques are developed for inverters to reduce the magnitude of the harmonics and to control the fundamental component of output voltage [5]. Multilevel converters have reached a certain level of maturity, given their industrial presence and successful practical application [6],[7],[9]. Rule based fuzzy logic controller can be used control the output power of a Pulse Width Modulated (PWM) inverter used in a Stand Alone Wind Energy Conversion Scheme (SAWECS) [10],[11]. Emerging Grid Code proposals for wind farm connection will, of necessity, become increasingly demanding of the performance of connected wind farms with respect to voltage control capability, reactive range capability, active frequency ability, and fault ride through capability [12]. Adjustable speed drives (ASDs) are still an emerging technology pushed by the evolution in power electronic components and microprocessors [13]. Grid connection of renewable energy sources is essential it creates problems of voltage fluctuation and harmonic distortion [14],[15]. The design of large induction motor drives with low torque ripple and fast dynamic response for latest applications are limited by the device ratings and problems of series connections [17][18].Use of microprocessors eliminate the need of PWM techniques which are easily implemented with hardware for inverter control [19]. The important topologies are as diode clamped inverter, capacitor clamped [20][21].

II. FINDINGS FROM LITERATURE SURVEY

The electric energy demand is constantly increasing in world, and conventional energy resources are diminishing and are even threatened to be depleted. This is the reason that their prices are rising. So, the need for alternative energy sources has become necessary, and solar energy has proved to be a very useful alternative because of its availability and pollution-free nature. Due to the increase in efficiencies and decreasing cost of photovoltaic cells and the improvement of the switching technology used for power conversion we are trying to design an inverter powered by PV panels and that could supply stand-alone AC loads. Solar panels give direct supply (DC), and to connect these panels to the main grid or to use for other industrial applications, we need an AC output at a certain required voltage level and frequency. The conversion from DC to AC is essentially accomplished by means of a DC to AC inverter, which is the major component in the system. The output of the solar system is not constant continuously and it is dependent on instantaneous sunlight intensity and ambient temperature.

A. PROPOSED INVERTER TOPOLOGY

The circuit consists of two isolated dc sources, one transformer, four unidirectional devices and two bidirectional devices as shown in Fig. 2.1. The transformation ratio N2/N1 of the transformer is defined as n1. The output voltage is the summation of the voltage across the secondary winding of the transformer and the switched voltage at the terminal Va with respect to the dc link midpoint. The output voltage is the summation of the voltage across the secondary winding of the transformer and the switched voltage V_a with respect to the dc link midpoint. The recommended approach to expand the proposed 9L a topology to a higher number of voltage levels is discussed here.

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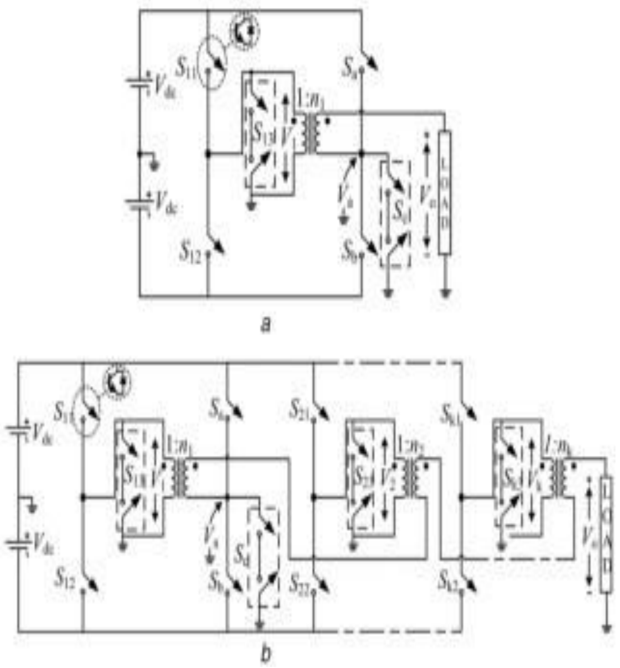

Figure. 2.1 Circuit of Proposed MLI

It is important that two unidirectional switches Sk1 and Sk2 , one bidirectional switch S and one transformer with a transformation ratio of n to has to be added at every stage of addition such that (k = 1, 2, 3, K), where K is the number k of transformers added in the process of extension including the initial one. The secondary windings of all the transformers are connected in series following the convention of additive polarity. With V being the pole voltage of the second leg. The output voltage can be given as,

$$V_0 = n_1V_1 + n_2V_2 + \cdots + n_kV_k + V_a.$$

Operating modes of proposed inverter topology

Various switching combinations generate different output voltage levels. In figure among switches S11, S12 and S, only one at a particular instant should be ON to avoid the shoot through and the same applies for switches Sa, Sb and Sc. The one and only purpose of connecting a bidirectional switch across the transformer winding is to ensure that the transformed voltage is of zero value, which is required in generating specific levels of the output voltage. Depending on the selection of the value of n, the resultant output voltage can have a maximum of nine levels in it. The number of voltage levels

NL for a given number of transformers p is given by, Number of power switches and gate drivers are as,

$$NL = 3p+1$$

$$NSW = 4P + 4$$

$$NGD = 3\ (p + 1)$$

Regarding the voltage stress of the switches, it is the maximum voltage across the switch when it is OFF. Here, all bidirectional switches have to block a voltage of magnitude V, and the remaining switches need to block a voltage of magnitude 2V dc.

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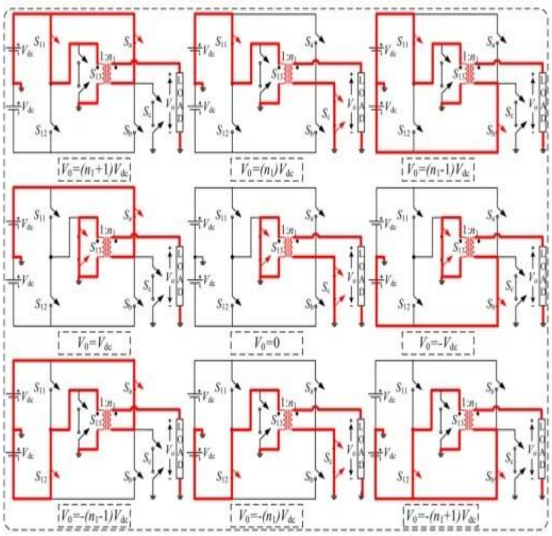

Figure 2.2 Modes of Operation of Proposed Inverter Topology

The total blocking voltage for the proposed topology can be expressed in terms of the number of transformers dc and is expressed as V stress, m = 6(p + 1)V dc where, V is the maximum blocking voltage for given number of transformers p and for p equals to one, the maximum blocking voltage is equal to 12 V dc stress.

Table 2.1 : Switching States of the Proposed Topology

V_0	S_{1} 1	S_{12}	S_{13}	S_a	S_b	S_c
$(n_1+1)V_{dc}$	1	0	0	1	0	0
n_1V_{dc}	1	0	0	0	0	1
$(n_1-1)V_{dc}$	1	0	0	0	1	0
V_{dc}	0	0	1	1	0	0
0	0	0	1	0	0	1
$-V_{dc}$	0	0	1	0	1	0
$-(n_1-1)V_{dc}$	0	1	0	1	0	0
n_1V_{dc}	0	1	0	0	0	1
$-(N_1+1)V_{dc}$	0	1	0	0	1	0

Active switches are shown in Figure. 2.2. There are the modes of operation to generate voltage levels in the positive half cycle of output voltage V. Table 2.1 gives the list of the switching combination for the nine output voltage levels and the various operating modes are given as follows.

Mode 0: Switch S13 is ON resulting in the application of zero voltage across the primary and therefore the voltage across the secondary winding of the transformer is zero. Switch S is ON, i.e Va is 0.

Mode 1: Switch S13 is ON resulting in the application of zero voltage across the primary and therefore the voltage across the secondary winding of the transformer is zero. Switch S is ON connecting terminal marked Va to Vdc so it can be given as Va = Vdc .

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Mode 2: Switch S11 is ON, hence V1 = Vdc resulting in a voltage of n1Vdc across the secondary of the transformer and switch Sb is ON connecting terminal marked Va to Vdc. Now it can be given as, V0 = (n1 − 1)Vdc.

Mode 3: Switch S11 is ON, V1 = Vdc resulting in a voltage of n1Vdc across the secondary of the transformer and switch Sc is ON to produce zero voltage at terminal marked Va . The voltage can be given as, n1Vdc.

Mode 4: Switch S11 is ON, V1 = Vdc resulting in a voltage of n1Vdc across the secondary of the transformer and switch Sa is ON connecting Va to Vdc, Hence it can be given as,

$V_0 = (n_1 + 1)V_{dc}$.

B. SIMULATION SOFTWARE

The simulation has been done in MATLAB. The circuits used for the simulation of 9L and 27L are same with those in Figure 3.1 respectively. PDSPWM strategy is employed for generation of signals for both the proposed inverter structure and its extended structure. For a 27L output voltage, two transformers are necessary.

For an input voltage of 15 V, Figs. 3.1 a and b show the 9L and 27L output voltage as well as load current scaled by a factor of three, respectively. The 9L output voltage has a peak amplitude of 60 V and is composed of nine equal steps. The 27L output voltage has a peak amplitude of 195 V and is composed of 27 equal steps. It is to be noted that owing to the turns ratio of the transformer, the output voltage is boosted by a factor of 4 and 13, respectively. Fig. 4.2 c illustrates the voltage across the secondary winding of the transformer as well as the voltage va.

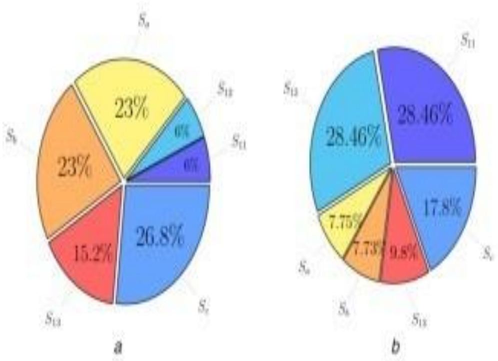

Figure 3.2 Percentage of Power Loss

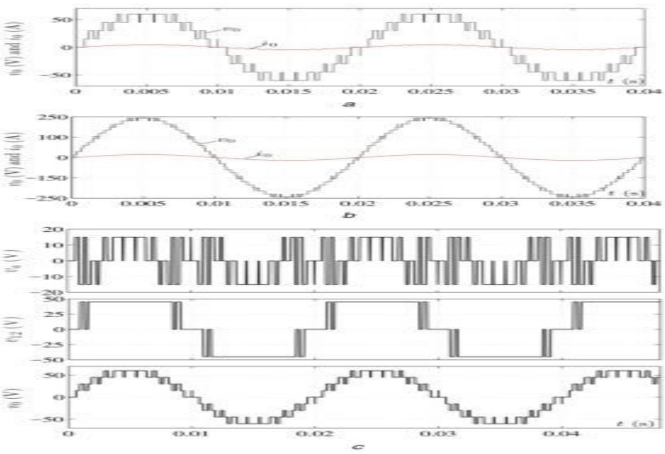

Figure 3.3 Experimental Results

It can be observed that owing to the symmetric nature of the voltage applied to the transformer, it a is not subjected to any saturation due to dc offset. DC offset is mean amplitude displacement from zero. The offset of the waveform is away from the centre zero point. DC offset is source of distortion. Further, Figure 3.2 shows the percentage power loss (conduction, switching, and total losses) among the switches .

Figure 3.5 shows Simulation results, (a) 9L output voltage and load current of the proposed topology, (b) 27L output voltage and load current of the proposed topology, (c) Voltages across various ports of the proposed 9L topology

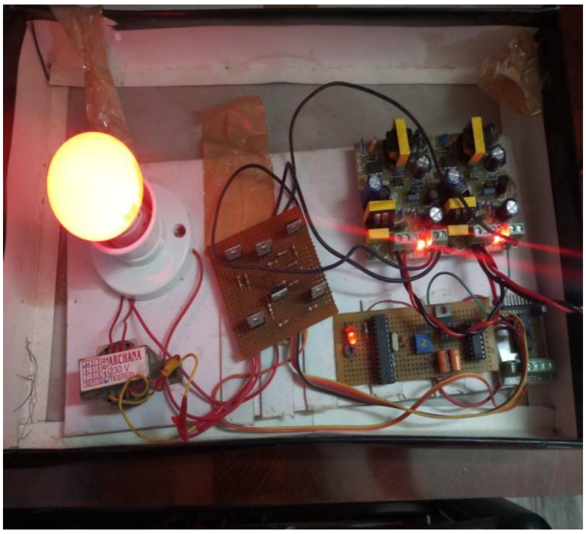

Figure 3.4 Experimental prototype

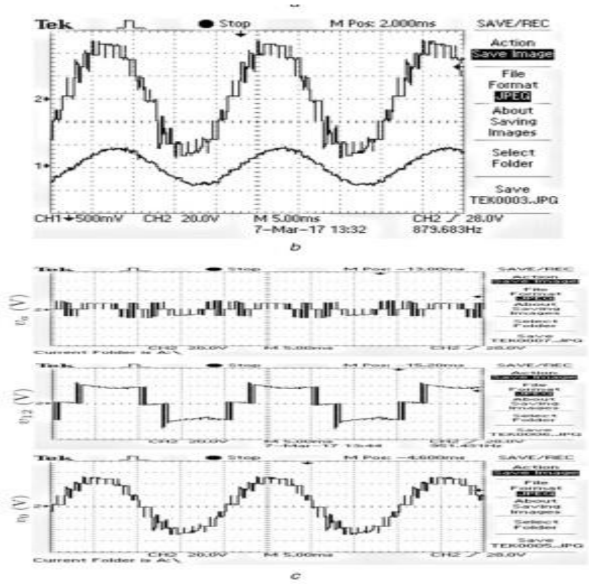

Figure 3.5 Experimental Results:(a) Down scale hardware prototype,(b) 9L output voltage and load current of the proposed topology, (c) Voltages across various ports of the proposed 9L topology

IV. CONCLUSION

For 9L operation, two dc sources and a single transformer is required. For generating gating signals, a simplified logic gate based PDSPWM strategy is developed. The optimal configuration of the proposed topology for a minimum number of switches can be determined by using an algorithm. A comparative analysis of the proposed topology is carried out with other topologies like the number of switches, transformers, on state switches and gate driver circuits required for a given level of output voltage. After comparison the proposed topology is found better among all other topologies. The feasibility of the proposed inverter is validated through simulation and experimental results making proposed configurations a viable alternative with improved voltage waveform quality.

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