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Analysis of single-phase cascaded H-bridge multilevel inverters under variable power conditions

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ABSTRACT

Easy modular I action is one of the benefits of a cascaded H-bridge (CHB) inverter. This study proposes an only one multilevel inverter comes with a unique H-bridge unit. The structure of the proposed topology is then enhanced in order to make use of switching devices and DC-link voltage inputs while creating a massive number of voltage steps. A cooperative active and reactive power control strategy is offered to earn a better real and reactive power management for every DC voltage source of a photovoltaic (PV) module, as well as boost systems power quality and reliability. A unique control approach and proportional pulse width modulation (PWM) modulation are described for the cascaded H-bridge multilevel inverters for grid-connected systems. Each H-bridge module can give different power levels thanks to this control. To supply the DC source, use the system's proportional, integral and derivative (PID) controller. The functionality and achievements of the proposed scheme with its associated algorithms in production of all operating voltage have been proven using experimental data from a nine-level single-phase inverter. Finally, to construct a cascaded H-bridge nine-level inverter, the proposed control strategy is developed and implemented in MATLAB software.

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1. INTRODUCTION

As the world's attention has turned to worries about energy scarcity, pollution and shifting away from the previous pattern of energy-intensive economic growth are becoming common place options for every countries. Due to its simplicity of availability and conversion, solar energy became the popular renewable energy source. Multilevel inverters have attracted international interest because to their low filter inductance, and enormous system efficiency, low switching stress. There are a variety of topologies for multilevel inverters, including cascaded H-bridge, flying capacitor, diode clamped. The smallest number of devices having same output levels is found in cascaded H-bridge [1], [2]. Furthermore, each power unit's DC side is powered individually by the photovoltaic (PV) module in cascaded H-bridge (CHB), allowing for independent maximum power point tracking (MPPT).

The power imbalance among HBs is one of the major concerns with CHB inverters. The output powers of certain HBs reduce dramatically as a result of damage, ageing of photovoltaic panels, allowing the H-bridge's with more capacity to over-modulate ensuing in a distorted grid current. To overcome the above issue, many control systems have been proposed. In order to balance the output powers, a modified PPT (MPPT) algorithm is created, which provides PV modules a great output power to discontinue MPPT operation, although this diminishes the total system's energy harvesting. It is provided a hybrid modulation scheme (HMS) [3]. To widen the inverter's linear modulation range, this method combines a low frequency square waveform with a greater frequency pulse width modulation (PWM) waveform.

Based on the present status of the system, HMS will have a voltage fluctuation on DC side, lowering MPPT efficiency, in contrast to sinusoidal pulse width modulation (SPWM), which employs PI controllers to correctly manage DC-link voltage. A reactive power compensation method (RPCS) is proposed in that may reduce grid current total harmonic distortion (THD) without increasing DC-link voltage fluctuation, but it reduces the system power factor (PF), restricting its usage. The authors offer a three-phase CHB inverter with a third harmonic correction mechanism (THCS). Then, for single phase CHB inverters, a THCS methodology is developed that effectively overcomes the shortcomings of the previous techniques [4], [5]. That is, it ensures that the system can function with a unit power factor and a reasonably small change in DC-link voltage while without reducing power output. However, because the highest linear modulation range of THCS has only been increased to 1.155, its ability to deal with power imbalance is somewhat restricted. This research proposes a unique harmonic compensatory approach (HCS) based on this notion [6].

This approach may change the over modulation waveform into the quasi-square by injecting many harmonics to the over modulation HBs. Evaluation of converter topology technology is proposed in [7], [8]. In this very dynamic field, various methods and switching circuits are being familiar in the electronic devices. This article depicts high power voltage source inverters and very commonly used multistage inverter techniques, including neutral point inverters. This article proposes the working condition of each method and evaluates the most suitable modulation methods, mainly focusing on the modulation methods proposed in this field [9], [10]. The cascaded multistage inverter synthesizes the average voltage result based on the series association of the power cells using a very less voltage element configuration [11]. This feature makes it possible to get good range of input voltages and currents and exceptional attainability thanks to the intrinsic redundancy of their components. Because of these characteristics, the multilevel inverter has been meant for an alternative in the medium voltage inverter. Renewable and enhanced topologies are also covered. Applications where the mentioned features play an important role will be presented [12], [13]. A dominant neutral point PWM inverter, consisting of main switches depicts for PWM and peripheral switches to moor the output terminal voltage to the output terminal voltage [14]. This inverter output has low harmonic changes than the output of the conventional type. Neutral point locking, the new PWM technology applied PWM inverter has better drive system performance including motor productiveness [15]. The medium voltage multilevel inverters where its main focus is to achieve minimum harmonic distortion and also at low switching it should have high efficiency [16]. By maintaining reasonable power quality at minimizing switch frequency also increases power rating is an important requirement. As an option for future research, a 3-level block is used to generate a five-level voltage graph is mainly suggested [17], [18]. Mostly in multilevel inverters with high power applications have a common topology known as neutral-point-clamped (NPC). In this paper it is shown in a simple way how it is developed in a way that the operation and frequently used modulation techniques are made up to date. It mainly depicts the problems faced in capacitor balances and some technological problems [19]. Using the MATLAB Software simulation portion, we may develop and create a nine-level inverter cascaded H-bridge based on the system's DC supply in this paper. Then we'll move on to the hardware, where we'll design the system's five-level inverter [20].

2. PROPOSED DESIGN AND MODELING

It is made up of n HBs, each with its own DC side generated by a photo voltaic module. An inductor connects to the alternating current side to the power grid. Each HB depicts output three levels of 1, 0, and -1, allowing the output voltage to extend 2n+1 levels. grid are grid voltage and current discretely; are the HB's DC-link voltage and current, respectively; the HB module's output voltage. The output powers of certain Photo Voltaic panels may fall considerably due to damage or occlusion, while the remainder retains their previous output powers, resulting in a reduction in the total output power (PT) of the cascaded H-bridge inverter.

The term "DC sources" refers to electrical energy sources that have constant voltages and currents [21]. A DC power supply may be built as an electronic circuit that operates off ac mains power and is purpose-built. It may also be received from a battery, which is utilized in portable equipment and machinery when a connection to a mains ac supply is inconvenient or impractical. B DC circuits consist mostly of DC power sources and resistive parts, they are an excellent starting point for learning basic concepts of electrical circuit analysis. The H-bridge is kind of electrical circuit that switches to the opposition of a voltage supplied to a load. The H-bridge is a kind of electrical circuit that resembles the letter H. An H-bridge is used to drive a load in both directions, such as a brushed DC motor. It also regulates the flow of electricity to a load [22]. An H-bridge is made up of four switches that control the flow of electricity to a load. In the diagram above, the load is the M that links the two sets of switches. By closing two switches, you may use a single current source to drive current in two directions [23]. The nine-level inverter is created in MATLAB using the Simulink model software, which is then imported into Simulink. A single-phase construction of a single-phase hybrid cascaded multilevel inverter (HCMLI) with nine levels of output is shown in the Figure 1.

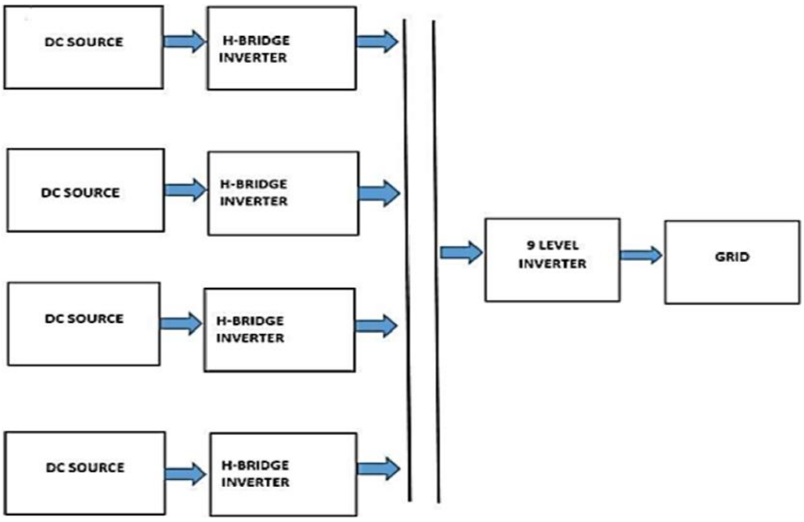

Figure 1. Single-phase HCMLI with nine levels

MATLAB is a technical computer language that is matrix-oriented. It is utilized not just for computing, but also for visualization and programming in a user- friendly environment. It is an interpreted (not compiled) language designed to allow simple access to FORTRAN-based matrix and linear algebra tools [23]. One of the most distinguishing characteristics of MATLAB is that it is aimed on numerical computing rather than symbolic computing (as e.g., Maple software, Mathematical). The software consists of a core application and extra libraries or toolboxes. A toolbox is a set of MATLAB functions (sometimes known as M-functions or M-files) that enhance the core environment's capabilities to tackle certain subject issues. Because MATLAB is built to be reasonably quick when doing array operations, it is critical to keep this in mind when writing appropriate instructions, such as avoiding redundant 'for' loops that process individual array members. The Simulink model is shown in Figure 2.

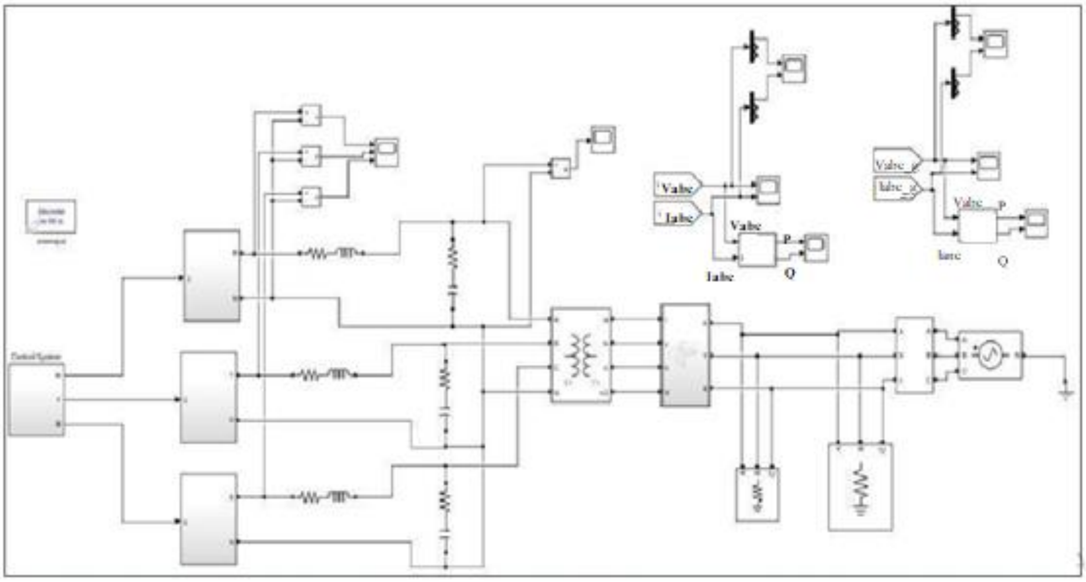

Figure 2. Simulink model

A successfully developed portion is executed to present the results in the scope of the system. The major blocks employed here are distributed energy resources, a nine-level H-bridge inverter, a filter portion, a transformer part, an inverter part, and a grid connection component of the system [24]. To evaluate the efficacy of the suggested method, a cascaded multilevel structure with 9 Threshold HBs was developed in MATLAB/Simulink. The major goal was to create a system that utilized the efficiently and consistently full charged inverter idea for H-bridge [25]. The system's power grid design employs a nine-level inverter to create power in the DC voltage sources in between.

3. SIMULATION RESULTS AND DISCUSSION

The extraction module of the output current and real and reactive power constituency is used to transmit the results of internal looping and even in the dq reference frame. The angle of the grid current is critical for completing the transformation. The power system's current is monitored, and the -axis signal may be used. A transport delay block that may create the imaginary quadrature signal of the grid current. As a consequence, the grid voltage phase angle may be calculated using the dq sections of grid current and the transformation. In this part, the suitable functioning of the anticipated cascaded inverter in producing all values of voltage (even or odd) at the output is verified using the results of the nine-level cascaded inverter. Figure 3 depicts the suggested system for a sub cascaded multilevel inverter, which contains the basic unit and a complete converter. The basic unit is made up of a number of DC voltage sources. Figure 4 depicts the whole Asymmetrical 9 multi-level inverter modeling circuit.

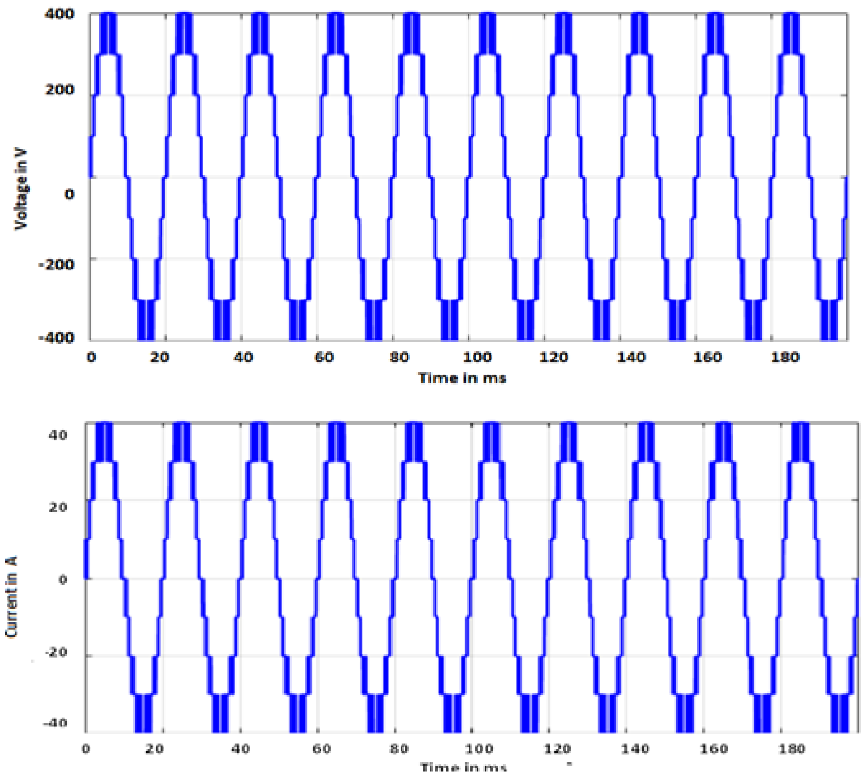

Figure 3. Nine level inverter output

Two switches link a different DC voltage source to the output, which may supply a voltage with either negative or positive polarity. As illustrated in Figure 3, each switch is made up of an integrated circuit bipolar transistor (IGBT) and an antiparallel diode. Both switches are operated in a complementary way throughout the working cycle. The basic gadget generates a desirable staircase voltage waveform. The basic unit's output voltage may be a single DC power source or a bidirectional mix of DC voltages. As a consequence, for v, the maximum number of terminating output voltages is 2n+1. The basic unit's output is linked to an additional converter that alters the polarization of the voltage source and generates a favorable or unfavorable staircase waveform. The cascaded H-bridge output and the link between both time and voltage is displayed in graph shown in Figure 4. This figure depicts the inverter voltage and inverter current (both voltage and current) dependent on the input voltage. Based on the system's voltage and current, Figure 5 depicts the real and reactive power of the inverter component

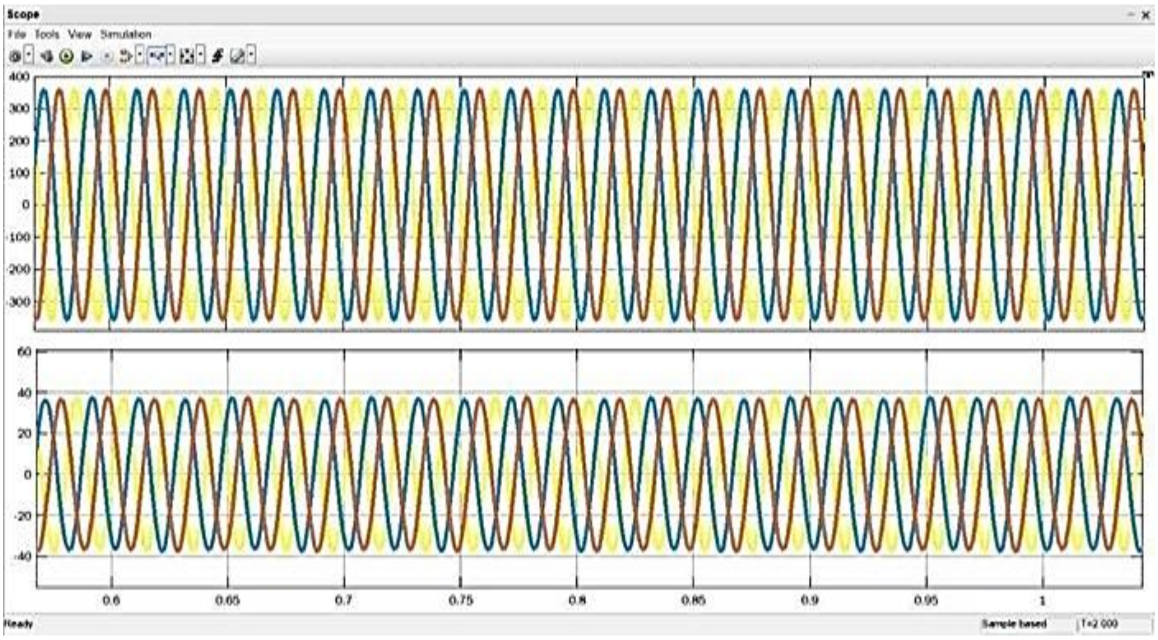

Figure 4. Inverter voltage and inverter current

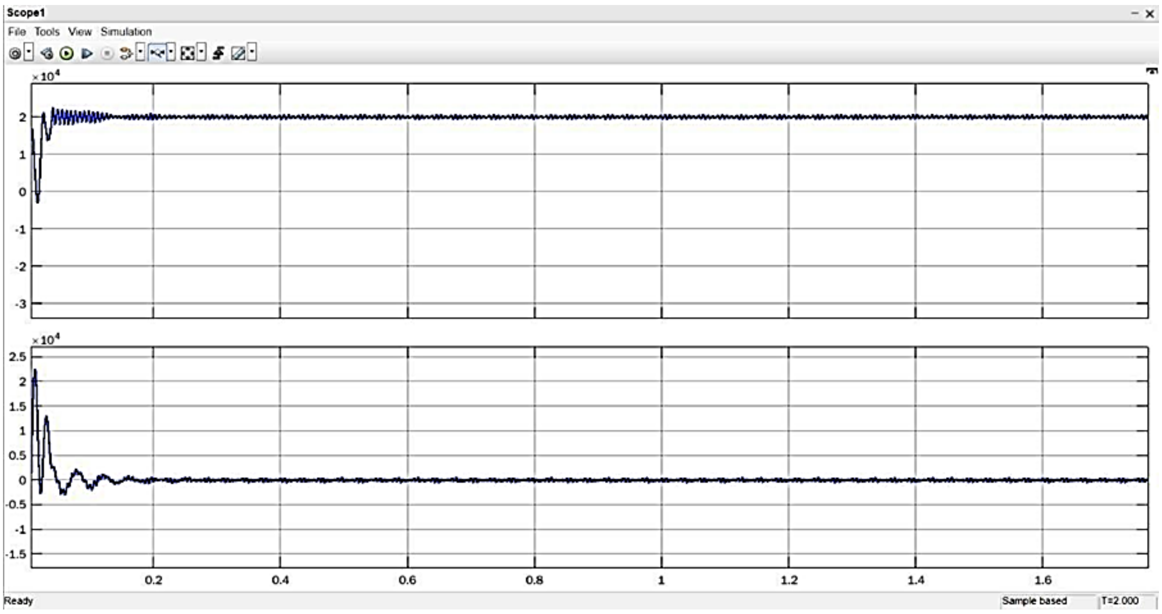

Figure 5. Real and reactive power of an inverter

4. HARDWARE IMPLEMENTATION

The inverters with various levels have been simulated for a wide variety of switching frequencies using MATLAB. The five-level cascaded H-bridge inverter is proposed in hardware experimental part. Switching sequences as well as sophisticated Pulse width modulation methodologies are used. The hardware block diagram with necessary components used for this proposed model is shown in Figure 6 and complete circuit model is shown in Figure 7. The hardware of an experimental evaluation has been carried for the proposed 5-level inverter. The experimental hardware configuration includes two H-bridges series connection, 8 MOS transistors switches, processor controllers, drivers' circuits, two DC Sources, R Load, and a digital oscilloscope. A 5-level inverter is required. A total of 2 H-bridges and 8 switching are used. These topologies have their own benefits, such as lower switching device costs and lower conduction loss across switches. The most common type of loss in electronic power systems is switching loss, and it gets worse as the switching frequency gets higher. Here we have achieved the five-level output in our digital oscilloscope using the hardware components which illustrated in Figure 8.

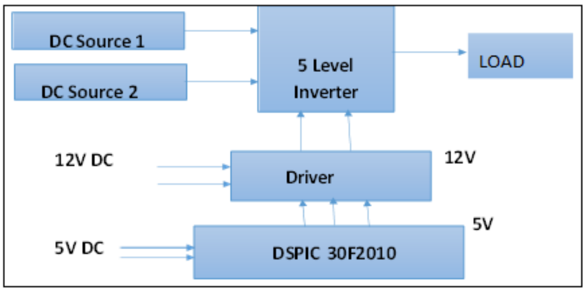

Figure 6. Block diagram of hardware implementation

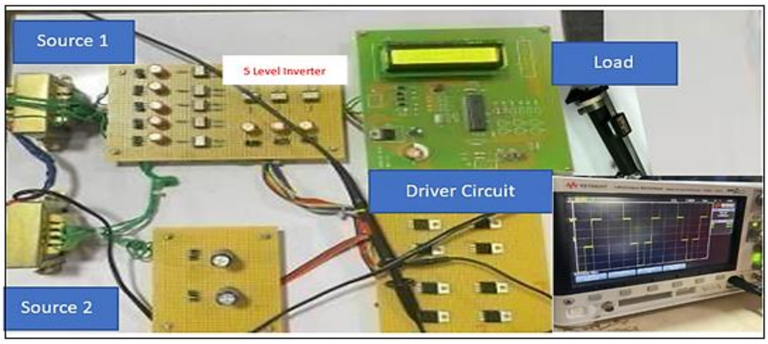

Figure 7. Hardware circuit model

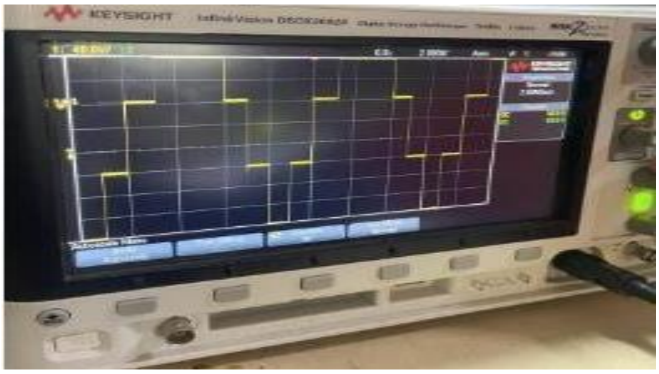

Figure 8. Hardware output results of five level

5. CONCLUSION

In the case of a power imbalance, a harmonic compensation strategy should be used to allow single-phase CHB PV inverters to perform more extensively than previously possible. This approach ensures that CHB inverter can operate at unity power factor and that its linear modulation range may be raised to around 1.27 times the device's nominal value, which is a major improvement. Despite these constraints, the technique is effective in guaranteeing that enough grid current is available to meet demand in some circumstances when there is a significant power imbalance. Through the use of simulations and experiments, it is possible to show to others the significance of the proposed strategy's effectiveness. It is presented in this study for usage when there is a power supply imbalance, and it enables the 9-level H-bridge inverters to function more extensively when there is a power supply imbalance, which is advantageous in a range of applications. It is a research facility devoted to the investigation of matrices. This software-controlled approach ensures that the cascaded multilevel inverters function at a power factor of one throughout the operation. In the event of a significant power imbalance, the system is capable of sustaining grid current to meet the demands of customers. Finally, the simulation results reveal that the proposed technique is effective, as shown by the final analysis.

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