DESIGN AND ANALYSIS OF HYBRID POWER INTEGRATION INTO CHB MULTILEVEL INVERTER

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ABSTRACT: Solutions to the longstanding energy problems facing developing countries are potential for renewable sources and technology. Strengthening the Indian energy deficit can be used by renewable sources such as wind, solar, geothermal energy, ocean energy, biomass and fuel cell technology. Power electronic converters are used to turn electricity into energy. The inputs and output voltages are divided into four groups, based on their existence. The inverter is a standard one; it transforms direct electric current at the desired frequency into alternating electric current. Conventional types of inverters may produce voltage only between two levels at the output terminal. When used in high power applications, the range of voltage produced at the output is low. Multi-level inverters (MLIs) are added to increase the voltage profile and reliability of the overall system. The voltage at the output terminal is produced by multi-level inverters from various DC voltage levels fed into the input. Multilevel Cascaded H-bridge (CHB), which increases power quality and redundancy, is flexibly used. As complementary power sources, the HPS uses fuel cell (FC) as its primary and super capacitor (SC). The key characteristics of the proposed HPS system are rapid transient response; high performance and high power density. The present control strategy consists of an HPS unit power management strategy and a CHB multi-level inverter voltage control strategy. The load voltage controls unbalanced and non-linear load conditions using a multi Proportional Resonant (Multi-PR) controller.

1. INTRODUCTION

More than 300 GW of wind power are CURRENTLY installed around the world and over 110 GW of photovoltaic generation. More than 10 MW of Renewable Power Plants are now a reality[1]. However, the daily and seasonal patterns of renewable energy sources differ greatly and the demand for consumer energy is also very variable in nature[2]. A standalone power supply system from one form of renewable energy source is therefore difficult to operate, unless there is a suitable storage power system.If there is not enough energy storage capacity, particularly for medium-sized to large-scale systems, the only feasible solution may be a grid-connected renewable power generation [3].

The use of simple traditional two-level inverter for grid integration generates a square wave that is not suitable for most complex applications. A pure sinusoidal wave is wanted in these situations. The typical rating power of converters is further restricted to the rating power of the semiconductor appliances and the permitted frequencies of switching[4].In renewable power generation systems traditional inverters based on 50- or 60 Hz transformers and AC-filters are used to raise the voltage up to 6-36 kV grid voltage and reduce the THD voltage respectively. Due to its heavy weight and large size[5], high investment and installation costs are expected. New power converter systems have been designed to meet the needs of future medium or high-voltage converters with the advent of new high-power semiconductor devices. In the highly active field of applications in medium- or high-voltage systems, modular multi-level cascaded (MMC) converters and circuitry have attracted high attention[6] [7],[8]. The number of components of MMC converters increases linearly with the number of levels and the modules in design are similar and modular so that a high quality can be achieved[9].

Multi-isolated dc sources [10] and [11] require the MMC converter however. Consequently, its implementation is not simple, particularly in systems for generating renewable energy.

A hybrid power source (HPS) provides excellent scalability and greater versatility with regard to power management. Fuel cells (FC) are considered the key power source in this paper due to the safe and environment-friendly specifications. The slow dynamic response and rapid load changes of the FC stack require the use of super capacitor as a high-power storage system[5]. For each DG unit, parallel FC/SC power source and CHB multi-level inverter are used to increase service redundancy, modularity and power quality in a microgrid, especially with non-linear and unbalanced loads.

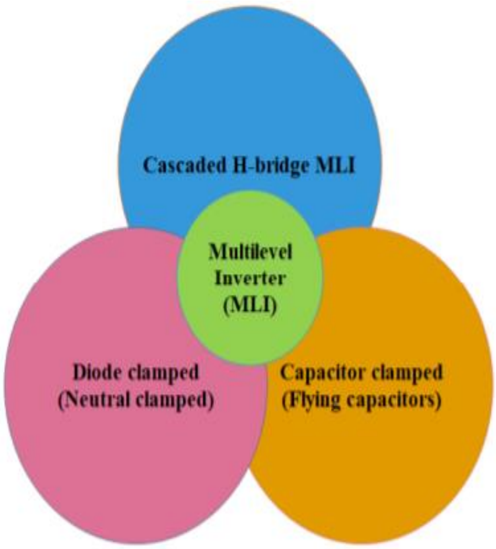

Figure 1. Basic classification of multilevel inverters (MLI)

The aim of this paper is to improve the dynamic response and power quality of the microgrid in the presence of unbalanced and non-linear loads by a voltage control strategy of a Multilevel CHB inverter. Each DG subsystem tracks its own performance and the overall microgrid system separately, based on the decentralised control strategy. For load voltage regulation, a multi-proportional resonant controller (multi-PR) is suggested. Compared to traditional PR controllers[6], the use of a multi-PR controller in nonlinear load conditions is more advantageous.

2. LITERATURE REVIEW

Sid-Ali Amamra, 2018, A modern, multi-level MLI-topology with a new switching technique, linked by a three-phase parallel grid, is suggested. In order to resolve the problem of the polluted sinusoidal power generation of traditional inverters and reduce the number of components, in particular for generating a multispan waveform with several levels, this inverter is designed to power a renewable energy (RES) microgrid. The power converter proposed consists of n two-level (n+1) phase inverters, where n is the RES. The more RES the greater the voltage, the more faithful the wave shape of the output is.The proposed topology is modulated and before the using pulse width and height modulation (PWHM) to minimise the number of switching states and the overall harmonic distortion (i.e. losses of switching) and (THD).

Suvetha Sunddararaj Poyyamani, 2020, The output generated is more appropriate to the sinus wave and the dv/dt rate reduces the number of EMIs. Although the structural complications and triggering methods involved in the creation of multilevel inverters are high in comparison with traditional inverters. Many experiments in the concept of new MLI topologies with reduced switches and the use of various PWM techniques are being performed. A comprehensive analysis of various MLI configurations will be given based on the parameters such as switch numbers, switching techniques, symmetrical, asymmetric, hybrid topology, applications based configurations, THD and power quality.

Lei Wang, Q.H. Wu, 2017, A new topology is proposed in this paper for the integration of the medium voltage renewable energy system with the cascaded multi-level inverter (CSD).Second, with its door drivers, it is aimed at reducing the number of switches. Thus, multilevel inverter space and costs are minimised. The switch for the reverse load current added in the first stage of the inverter offers a fluid path, which eliminates high voltage spikes at the base of the phase output voltage on the basis of standard CSD multi-level inverter topologies. Furthermore, the one-cycle control clock phase-shifting (CPS) (OCC) is built to control two-stage CSD multi-level inverter to solve the issues associated with dc source multilevel inverter fluctuations for integration of renewable energy.

Mamatha Sandshu, 2020, This paper provides the modified Hybrids Renewables Energy Sources multi-level inverter (MLI) topology and the design of a 9-, 13-and 17-level inverse topology model of hybrid solar wind power generation. A HRES is built, connected to Cascaded Multi Level Inverter (CHB-MLI) with Artificial Neural Network (ANN) models to control the switches of that inverter. The hybrid energy system template proposed consists of 10 MOSFETs that are intended to produce 17 output voltage levels. With a reduced number of components and reduced total harmonic distortion, the proposed topology performs well (THD). By designing the MATLAB/SIMULINK environment the performance of the proposed system is evaluated. In order to demonstrate the efficiency of the proposed model the simulation results of the proposed HRES inverter are compared with the results of the already existing topology.

Ho et al., proposer of a single-phase MqZS hybrid three-level inverter with one-phase MqZS-CHI designed to achieve output voltages at nine voltage levels by cascading two three-level PWM switching cells.The proposed MqzS hybrid three-story inverter reduces the inductor number by two compared to both the three-story NPC qZSI and the three-story qZS-CMI. Its boost factor was higher by two compared with the NPC qZSI factor although it was discontinuous with dc source current. The proposed topology provided a nine-level output voltage requiring only nine HF switching devices and four LFS switching devices. The voltage tension over the four low-frequency switches is, however, two to four times the voltage stress over the high-frequency switches.On the opposite, with low frequency high voltage switching devices it is possible to implement the four switches in the SPFB and reducing the switching loss.

3. MULTILEVEL INVERTERS (MLI)

An MLI is a power electronic system that, using many low DC voltages, can make the appropriate voltage level in the output as input sources. MLI topologies are the three basic categories

(i) Cascaded H-Bridge MLI

(ii) Diode clamped

(iii) Flying capacitor MLI

Cascaded H-Bridge MLI

For medium voltage high-power conversion applications, MLI is a very appealing solution. An MLI is a power electronic system designed using many lower-level DC voltages to provide the desired AC voltage level at the output. A two-level inverter is commonly used to produce AC voltage from DC voltage. Mlis topologies are divided into groups, i.e. diode-clamped, flying condenser and H-Bridge MLI cascade. Cascaded MLIs are extensively useful in the grid interface of PV systems. MJSC has now become a breakthrough for the generation of solar energy by traditional silicon PV.MJSC with MPPT is used in this study to extract extreme power and to improve conversion efficiency. In general, CHB MLI is fitted with four H-Bridge switches and eight H-Bridge double switches. However, only 10 MOSFETs in the updated CHB MLI are used in the proposed method to produce 17 output voltage levels. And the architecture proposed is based on the basic concept of CHB MLI with a smaller number of resistor replacement switches. With many H- bridge circuits, the CHB MLI produces a sinusoidal Vo.The Vo assisted by the inverter is a number of each H-bridge circuit's voltages. As compared with the MLI clamped diode and the MLI flying capacitor, the H-bridge cascade inverter demands a reduced number of components. Its total weight is thus decreased and thus the price is lower. The Simulink models of updated MLIs of 9, 13 and 17 levels are shown in the figures below.

Advantages of modified cascaded H-bridge inverter:

1. The current input is drawn at low MLI distortion.

2. Vo may be augmented.

3. There is space for development in total harmonic distortion (THD).

Structural Configuration of Multilevel Inverters

Due to the MLI structure, three forms - symmetric, asymmetric and hybrid MLIs - are defined.

Symmetric Multilevel Inverter

The symmetrical group is used for traditional multileveled inverters such as CHB-MLIs, DC-MLIs and FC-MLIs as DC voltage sources used in the system are equal[2]. A new power system topology has been planned for an 11-level performance and is shown in Figure 2.

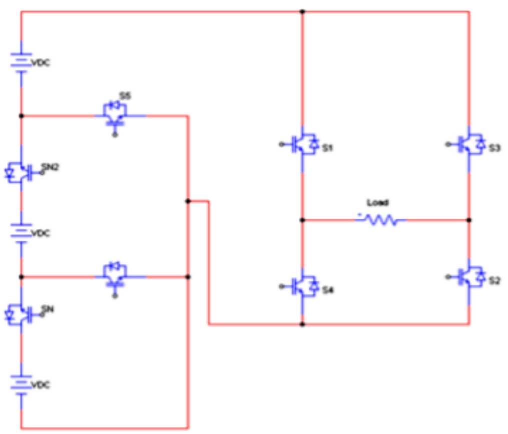

Figure 2. Circuit of 11-level inverter.

To increase the amount, the current configuration as defined in [3] has been completed by two additional switches along with a DC voltage source. However, because of the lack of a bidirectional switch, this setup is different from the current way. The desired voltage was obtained by the following equation of the circuit configuration,

$$N_{step} = 2n + 1$$

where n represents the number of dc voltage sources.
The maximum voltage at this n cascaded multilevel inverter's output terminal (Vomax) is:

$$V_{omax} = n \times Vdc$$

By connecting the 'N' number of basic circuits, voltage at the output end (Vo) can be increased. Although the high voltage performance of the inverter topology mentioned in [4] is high, the number of switches is high. This causes the machine to lose further switching. In order to remove this deficiency, in [5], the authors suggested a seven-level MLI with four DC sources. The symmetrical design works in a way that is based on a pulse pattern that is specific to activate switches at the right time. The decrease in the switch number contributes to low switching losses as the sources are less used. This topology uses two switches to transform the polarity instead of using an H-bridge. Figure 3 shows the seven-level, 5-switch MLI.

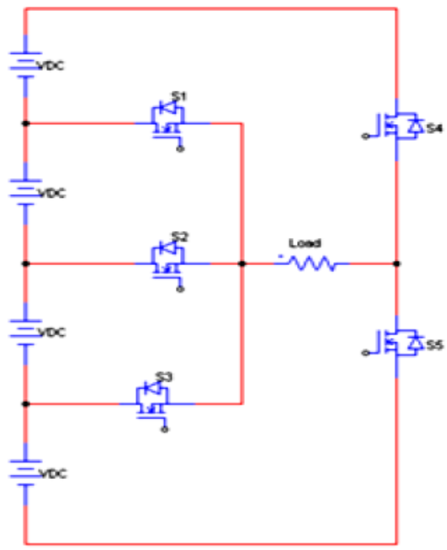

Figure 3. Circuit of seven-level five-switch inverter.

The output voltage levels for the investigated topology can be calculated as follows:

$$p = (2 * (S - 3))$$

where, p = number of output voltage levels,

S = number of switches

The symmetric multilevel inverter provides one of the key benefits of its very high modularity, which in the case of asymmetric MLI is lacking. Various research projects in the field of multi-level inverters are conducted in order to simplify and e ciency compared to traditional inverters, especially in symmetrical asymmetric configurations. Such topology is explained in a number of studies[6–10] where a large number of power electronic semiconductor switches and door circuits have been used for testing. This makes the circuit complicated and expensive.For this reason, a new MLI is suggested to achieve a nine-level output with a reduced number of switching devices. Figure 4 shows the circuit.

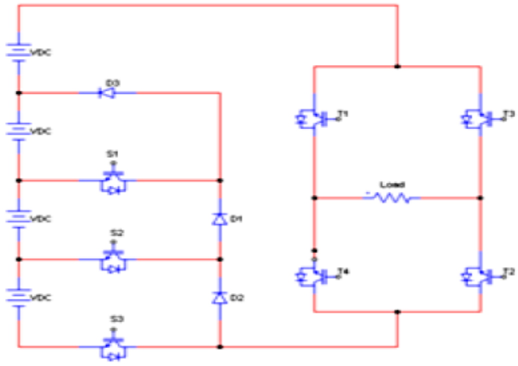

Figure 4. MLI with reduced number of switches.

4. PROPOSED METHOD AND RESULTS ANALYSIS

Hybrid multilevel inverter

The multi-leveled hybrid inverter is a symmetrical and asymmetric combination of topologies. In [17] a new hybrid MLI has been proposed for drive applications. In this article, the authors discussed the three-phase inverter with two outputs for each individual phase inverter and induction engine each leg of the inverter. This can act as three MLIs in a single step. The voltage levels are achieved by the communication of the condenser voltages with Vdc. In Figure 5 the circuit is shown.

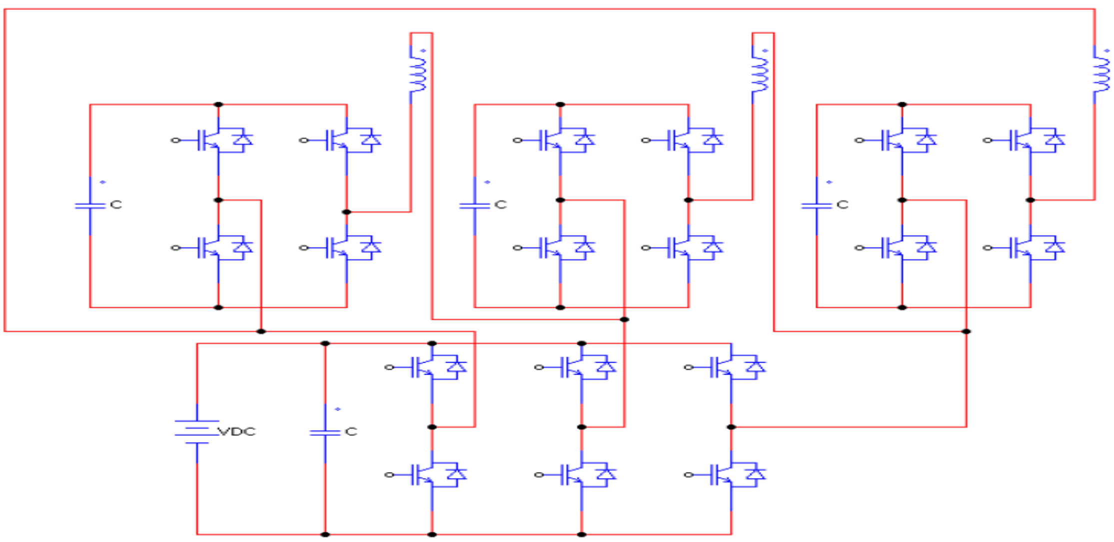

Figure 5. Hybrid three-phase multilevel inverter.

The researchers tested a similar topology for a three-phase application[18,19]. Each beam is designed for a single step in this topology and has a series H-bridge with a DC voltage source. Figures 6 demonstrate the circuit diagram for the topologies.

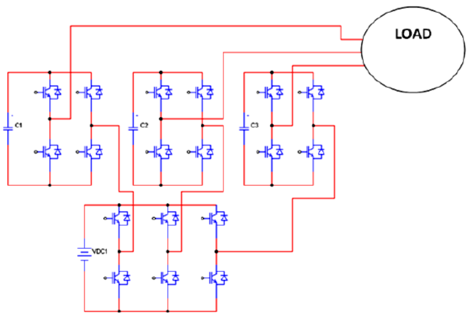

Figure 6. Circuit diagram for three-phase MLI.

Proposed Topology

In contrast to 9 and 13 level inverters, the hybrid energy system using 17-level inverters increases performance. Figure 7 displays the block simulation diagram for the updated 17-level inverter.

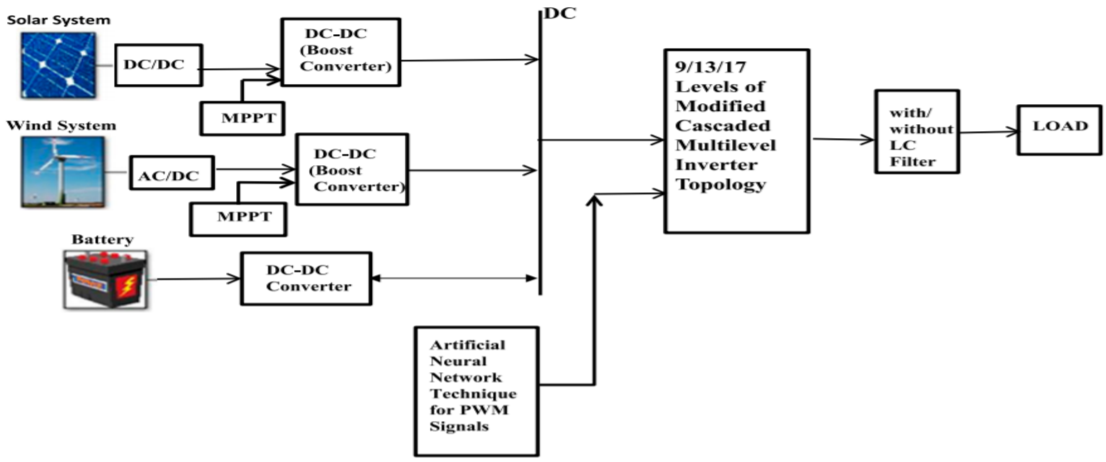

Figure 7: Proposed model of the microgrid

This hybrid model is equipped with ten MOSFET switches that offer seventeen levels to Vo. Table 1 displays the switching voltage of the various switch keys. All other switches are operational at a maximum voltage of 4.5 V with the exception of 4 and 8, while all other switches are operational at a minimum voltage of -4.5 V with the exception of 3 and 7. At 0.5 V and −0.5 V, only one switch is operative at the voltage, i.e. switch 5 and switch 6.

As the voltage increases, the number of switches is increased in operating condition.

Figure 8 displays the 9-level V waveform inverter. The 9-level inverter has a power rating of 1KW. This result was derived from the design of the simulation consisting of the solar, wind, and BESS hybrid RES model, the AnN model, and a modified MLI of 9 stages. The waveform displays a maximum or maximum voltage of 9 inverter voltages of 420v.

Table 1: Switching table of proposed

Output voltage Vdc	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
4.5	1	1	1	0	1	1	1	0	1	1
4	1	1	1	0	1	1	1	0	1	0
3.5	1	1	1	0	1	0	1	0	1	0
3	1	0	1	0	1	0	1	0	1	0
2.5	1	0	1	0	1	0	1	0	0	0
2	1	0	1	0	1	0	0	0	0	0
1.5	1	0	0	0	1	0	0	0	0	0
1	1	0	0	0	1	0	0	0	0	0
0.5	0	0	0	0	1	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0
−0.5	0	0	0	0	0	1	0	0	0	0
−1	0	0	0	0	0	1	0	0	0	1
−1.5	0	0	0	0	0	1	0	1	0	1
−2	0	0	0	0	0	1	0	1	0	1
−2.5	0	0	0	1	0	1	0	1	0	1
−3	0	1	0	1	0	1	0	1	0	1
−3.5	0	1	0	1	0	1	0	1	1	1
−4	0	1	0	1	1	1	0	1	1	1
−4.5	1	1	0	1	1	1	0	1	1	1

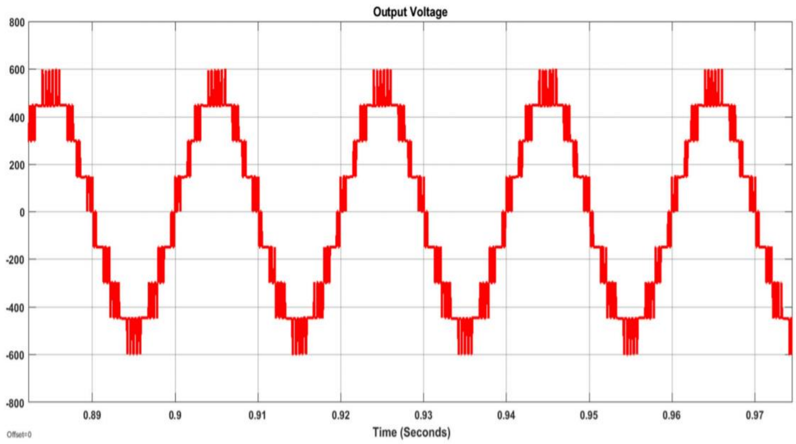

Figure 8: Output voltage waveform for modified 9-level inverter

Figure 9 displays the 13 level inverter Vo waveform. The 13-level inverter has a power rating of 1KW. On the 13-level inverter, the maximum voltage is 321,4 V

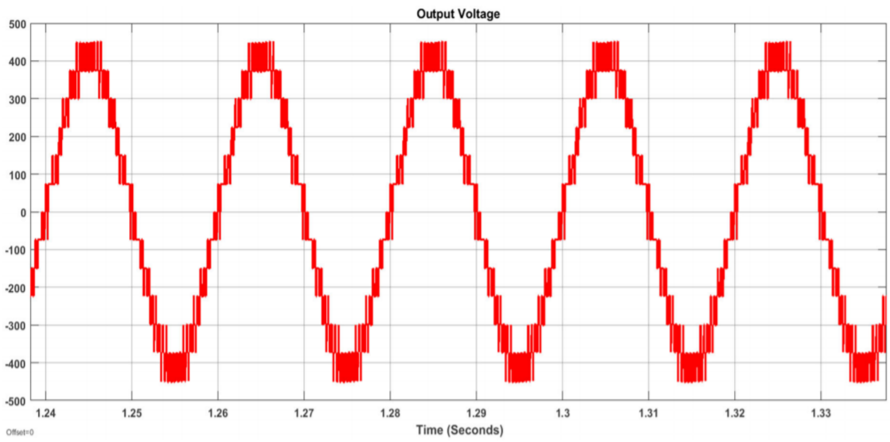

Figure 9: Output voltage for modified 13-level inverter

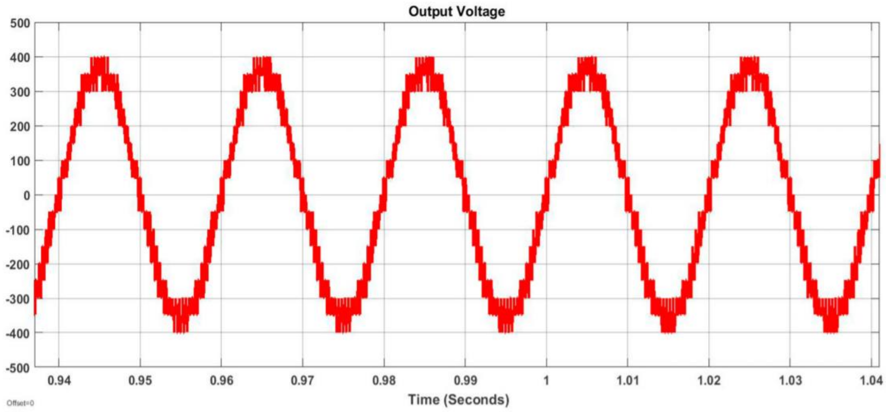

Figure 10: Output voltage for modified 17-level inverter.

Table 2: Modulation index of 17-level 10-switch pulse firing angles

	Switching angles (sec)									
MI	θ1	θ2	θ3	θ4	θ5	θ6	θ7	θ8	θ9	θ10
0.6	0.00115	0	0.0113	0.00980	0.00235	0	0	0.00980	0.00980	0.00041
0.65	0.00116	0	0.0113	0.00980	0.00240	0	0	0.00980	0.00980	0.00043
0.7	0.00117	0	0.0113	0.00980	0.00276	0	0	0.00980	0.00980	0.00076
0.75	0.00119	0	0.0113	0.00980	0.00290	0	0	0.00980	0.00980	0.00077
0.8	0.00120	0	0.0116	0.00978	0.00319	0	0	0.00978	0.00978	0.00078
0.85	0.00121	0	0.0116	0.00978	0.00300	0	0	0.00978	0.00978	0.00080
0.9	0.00080	0	0.0111	0.00981	0.00197	0	0	0.00981	0.00981	0.00033
0.95	0.00079	0	0.0111	0.00981	0.00194	0	0	0.00981	0.00981	0.00038
1.0	0.00078	0	0.0111	0.00981	0.00193	0	0	0.00981	0.00981	0.00040

Table 2 contains details for various modulation indices concerning 17-level 10-switch Pulse Spring Angles. On the base of Vo waveform, the switching angle is produced. Figure 10 shows the Vo single-phase waveform of 17 level inverter.

Table 3: Comparison of hybrid energy system THD values using different inverter topology

Levels/Models	Solar	**Wind**	**Hybrid**
9 level MCHBMLI	4.49	4.59	**4.38**
13 level MCHBMLI	**4.77**	**4.85**	**4.17**
17 level MCHBMLI	**3.71**	**3.81**	**3.58**

CONCLUSION

This paper describes a powerful control strategy for an autonomous microgrid that takes into account the HPS and CHB inverter in unequalled and non-linear terms. The proposed solution involves hybrid FC/SC power source power management and multi-level inverter voltage control of the CHB system. High performance; high power density; fast transitional response are the key characteristics of the proposed HPS. The proposed new MPPT algorithm can rapidly and precisely scan the MPP on the basis of the feedback stress and current at different solar radiation and environmental temperatures.The simulations are carried out in the environment MATLAB/SIMULINK. With a reduced number of power switches, the output voltage waveform displays less distortion and is validated by THD as a performance indicator. The findings of the proposed model are superior to the models previously suggested. With various sources such as fuel cells, diesel generators etc. in standalone microgrid topology, the proposed updated system can be explored in the future. The smaller number of switches and other parts makes this much more cost efficient.In terms of the energy efficiency of the insulated microgrid, this helps to increase the overall harmonic distortion according to IEEE 519 requirements.

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