e-ISSN: 2582-5208
International Research Journal of Modernization in Engineering Technology and Science
(Peer-Reviewed, Open Access, Fully Refereed International Journal)
Volume:05/Issue:01/January-2023 Impact Factor- 6.752 www.irjmets.com

DESIGN AND IMPLEMENTATION OF A MODIFIED BOOST INVERTER TOPOLOGY WITH REDUCED POWER SWITCHES

Thirumalai Vasan L*1, Ruby Meena A*2

*1PG Scholar, Department Of EEE, Government College Of Engineering, Salem-11, Tamil Nadu, India.

*2Professor, Department Of EEE, Government College Of Engineering, Salem-11, Tamil Nadu, India.

DOI : https://www.doi.org/10.56726/IRJMETS32914

ABSTRACT

This paper proposes, single stage dual DC-AC converter for energy storage and electric vehicle application. Renewable energy/battery can be used as main input source. Based on the source level duty-cycle adjusted automatically to maintain converter operation to maintain performance of dual leg DC-AC converter. System is initially designed by Simulink Model. Simulink model of whole system includes two unidirectional DC-DC boost converters for DC-AC boost operation and simulation results were obtained in MATLAB/SIMULINK software tool. Converter is tested with different operating conditions from different inputs level of voltages. Converter robust performance, characteristics and under different input voltage are tested. The hardware results of the proposed model is obtain from proto-type model and verify with simulation results to check system performance.

Keywords: Inverter, Reduced Power Switches.

I. INTRODUCTION

This research work mainly focused on controllers and two-Leg DC-AC Converter and its control topology because of its inverting and boosting property that is attained by a one stage. The MPPT form P&O algorithm strategy is implemented for controlling the solar output voltage technique was implemented to control and regulate the Dual Leg DC/AC Converter output voltage to meet the single- phase ac loads. There are various controllers were literature for power electronic converters to control the output, such as double loop control method and sliding mode control method involves difficulties like complex theory and variable switching frequency. Therefore the prime motive of this testing work is, to the design an easy controller and in the reduction of power conversion stages in the hybrid electric power generation, since the existing control methods are consisting of more power conversion stages, which leads the high capital cost, and involving more switching losses.

II. LITERATURE SURVEY

Pablo Sanchis et al (2010) implemented the double loop control strategy for dc-ac converter. The prime operation of this topology is to control the inductor current and voltage at capacitor by sensing the inductor current and the capacitor voltage of a converter. However, this topology has a drawback which is incapability to give quick response during sudden load changes period it cannot limit an initial inductor surge current. Siew-Chong Tan et., al (2010) Regulating of the boost inverter can be achieved by applying the control strategy on both dc-dc bidirectional current flow converters and determines converter output voltages with specific dc-biased sinusoidal references. derived the state model of dc-dc converter and implemented sliding mode theory.

The design steps of a sliding mode control controller for a dc-dc converter can be found by a researcher Siew-hong Tan. Nimrod Vazquez et al (2012) was proposed dual stage uninterruptible power supply with high power factor which was consisted by two different double conversion stage schemes. The sliding-mode controller was approached to optimize the inverter dynamics. This controller was control the inverter in a better manner than the classical control schemes for the reason that, its robustness for variations in plant parameter and invariant steady state responses for ideal cases. Sliding mode control identifies a sliding surface of the solid state switch that is a linear arrangement of errors of an inductor current and capacitor voltage with suitable coefficients K_1 and K_2. However, frequency of control pulse for power electronics switches is not constant in this scheme and the more complex theory involved. In addition, the inductor current reference was not predictable due to the high frequency component of the inductor current.

e-ISSN: 2582-5208
International Research Journal of Modernization in Engineering Technology and Science
(Peer-Reviewed, Open Access, Fully Refereed International Journal)
Volume:05/Issue:01/January-2023 Impact Factor- 6.752 www.irjmets.com

Etxeberriaa et. al (2012) was proposed a two capacitor based converter of a output voltage (V_0) of the inverter is not controlled directly. Therefore, the inverter output voltage is affected due to the transient errors and dc offset voltage. In addition, it shows a poor rejection to external disturbances such as transient abrupt loads. So, sliding mode control theory has inconvenient to implement directly to the converters due to the complex theory, the non-constant switching frequency, Inductance averaged current control in lack and the limitations for controller parameter selection.

Etxeberriaa et. al (2012) was proposed a two capacitor based converter of a output voltage (V_0) of the inverter is not controlled directly. Therefore, the inverter output voltage is affected due to the transient errors and dc offset voltage. In addition, it shows a poor rejection to external disturbances such as transient abrupt loads. So, sliding mode control theory has inconvenient to implement directly to the converters due to the complex theory, the non-constant switching frequency, Inductance averaged current control in lack and the limitations for controller parameter selection.

R. Benadli and A. Sellami (2014) implemented the sliding mode control technique for photovoltaic wind hybrid system. The ac to dc and boost dc-dc converters were used to regulate the hybrid power and given dc power to the standalone dc load in this hybrid system. State space averaged model of power converters can be derived and their dynamic model of the converter is be expressed by the representation of state dynamics and it can be exactly characterized by nonlinear state models.

A. Etxeberria et al (2014) implemented sliding mode controller and compared with PI controller for current bidirectional DC-DC converters, which interface with parallel-connected Hybrid Energy Storage System (HESS) & Arunkumar Verma et al (2010) applied the sliding mode control method to control the output of the inverter.

Rong –Jong Wai et al (2011) & Raffia Akhter et al (2017) have used the sliding mode control method to regulate the step up and step down dc to ac inverter output voltage. Anyhow, this control method has some disadvantages which involved in the complicated theory, the unpredictable switching frequency, absence to control an inductance instantaneous current and the limitation of selection the controller parameters.

III. PROBLEM IDENTIFICATION

The existing hybrid power generation and conventional controllers and its power conversion stages has leads to develop the proposed controllers and two-leg dc-ac converter:

- Conventional hybrid power generation has two power conversion stages and this leads high power losses.
- The voltage source inverter gives always-lower output voltage than the input.
- More number of power electronic devices is involved and sizing the power conversion system is large.
- The conventional controllers like double (voltage at capacitor and current in inductor) loop controller and sliding mode controller has a disadvantages due to complex theory and lack of an inductor initial surge current control.
- High Total Harmonic Distortion (THD) by involving more Power electronic switches.

IV. RESEARCH METHODOLOGY

- Weather data collection for solar radiation and wind speed in the particular area.
- Hybrid solar wind energy system is modeled in MATLAB Simulink environment.
- two Leg dc-ac Converter is designed and modeled in the MATLAB Simulink environment.
- Design a various controllers for Dual Leg DC/AC Converter and simulation results were analyzed and the proposed controller output is compared with the experimental prototype results.

V. ANALYSIS OF SINGLE STAGE DUAL LEG CONVERTER

The Single stage dual leg converter circuit as is shown in figure 1. In the converter design, two MOSFETs are used (S1 & S3 and S2 &S4). It also consists of inductance (L), Resistors (R1 and R2); low and high voltage side capacitors (C1 and C2) are used.

e-ISSN: 2582-5208
International Research Journal of Modernization in Engineering Technology and Science
(Peer-Reviewed, Open Access, Fully Refereed International Journal)
Volume:05/Issue:01/January-2023 Impact Factor- 6.752 www.irjmets.com

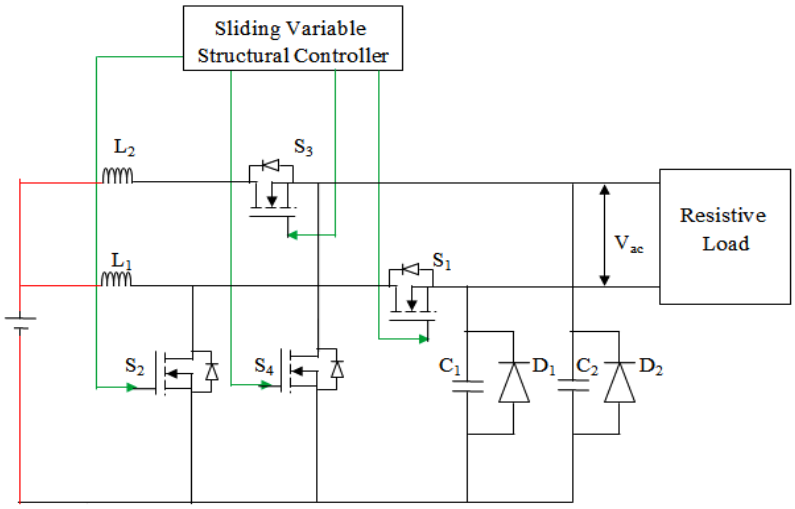

Figure 1. Single stage dual leg converter

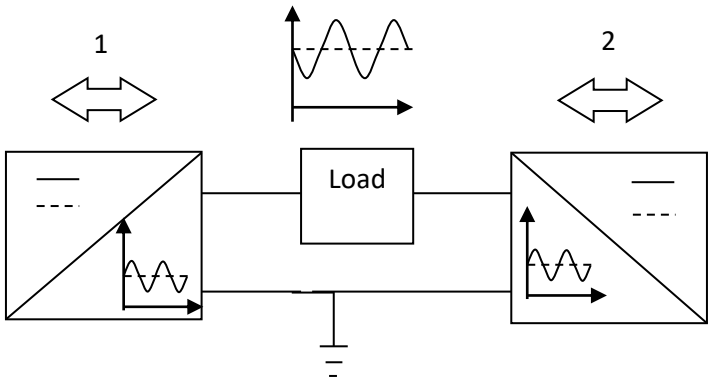

Figure 2. Two bi-directional current flow dc-dc converters

The proposed dual leg dc to ac converter is modelled and constructed by the solid state switches with active and passive components. The solid state switches are controlled at the various switching periods. The proposed dual leg dc to ac converter consists of dual bi-directional current flow dc to dc converters, which produce a dc-biased sine wave result so that each source produces only a uni-polar voltage as shown in Figure 2.

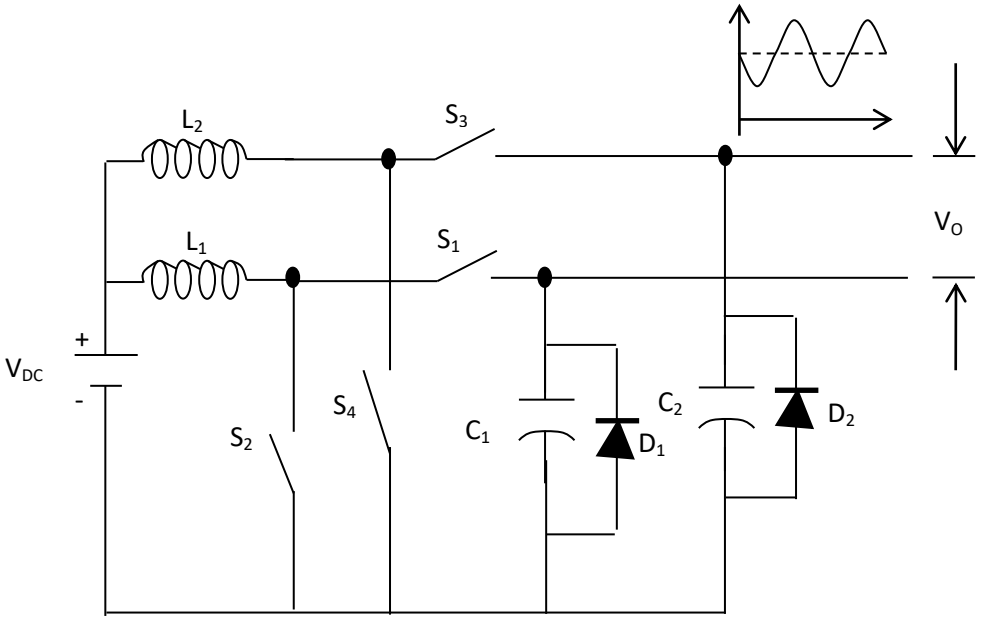

Figure 3. Circuit for Dual Leg DC-AC Converter

e-ISSN: 2582-5208
International Research Journal of Modernization in Engineering Technology and Science
(Peer-Reviewed, Open Access, Fully Refereed International Journal)
Volume:05/Issue:01/January-2023 Impact Factor- 6.752 www.irjmets.com

The phase angle in the response of each converter is 180^0 phase out with each other and maximum voltage will be access across the load. The load is connected positive node of the two converters. The dc biased sinusoidal voltage is appeared at each capacitors on the dual leg dc to ac converter and difference of each dc voltage across the load will be cancel to nil value with respect to ground. The two leg dc to ac inverter has the only one power conversion stages, because it boost-up and convert dc power to ac power in a one stage itself and produce pure sine wave voltage at the output end.

The working module of two leg DC-AC converter can be understood by different working operations and every converter operates with couple of modes.

The output voltage of each converter is

$$V_A = V_{dc} + V_m \sin \omega t \qquad (1)$$

$$V_B = V_{dc} - V_m \sin \omega t \qquad (2)$$

Output voltage at the load end is given by

$$V_O = V_A - V_B = 2V_m \sin \omega t \text{ t.} \qquad (3)$$

The Equation (3) expressed the output voltage of the proposed two leg dc to ac converter which is two times of the input voltage and also the voltage is boosted and inverted in one stage.

A. DC-DC CONVERTER-1 CIRCUIT DESCRIPTION

The working module of dual leg DC-AC converter can be understood by different working operations as shown in Figure 4 and every converter operates with couple of modes such as:

Operation 1: Consider the power switch S_1 is closed and the function is that the current is being circulated in the loop and I_1 is increased, whereas S_2 is open as in the Figure 4, capacitor C_1 gives electric power to the load end and voltage V_{C1} decreases.

Operation 2: If the power switch S_2 is closed, V_{dc} along with inductor current moves to the load and partially energy gets stored by the capacitor and moving on to power switch S_1 is opened as in the state modeling.

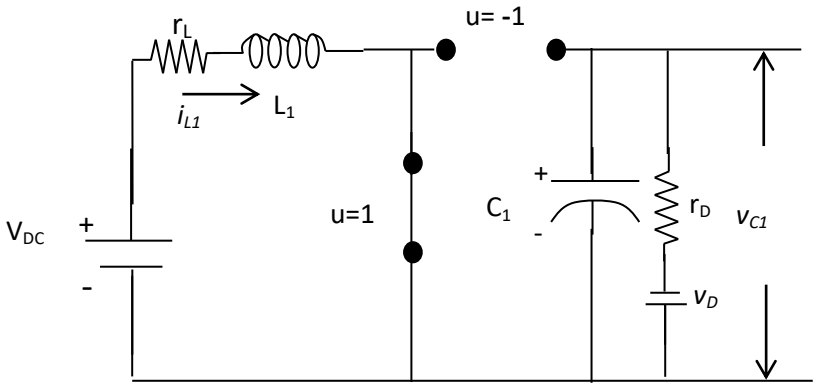

Figure 4. State modeling of the single converter circuit

The conduction mode of the converter A $\Rightarrow$ $\frac{V_A}{V_{DC}} = \frac{1}{1-D}$ (4)

The conduction mode of the converter B $\Rightarrow$ $\frac{V_B}{V_{DC}} = \frac{1}{D}$; (5)

According to the equation, duty cycle = D, voltage across the capacitor of the converter-A = V_A and voltage across the capacitor of the converter-B = V_B, input voltage to the dual leg dc to ac converter = V_{DC}. Since the dual converters are 180 degree phase out, the output voltage is

$$V_O = V_A - V_B \qquad (6)$$

e-ISSN: 2582-5208
International Research Journal of Modernization in Engineering Technology and Science
(Peer-Reviewed, Open Access, Fully Refereed International Journal)
Volume:05/Issue:01/January-2023 Impact Factor- 6.752 www.irjmets.com

$$= \frac{V_{DC}}{1-D} - \frac{V_{DC}}{D} \Rightarrow \frac{V_O}{V_{DC}} = \frac{2D-1}{(1-D)D} \quad (7)$$

The gain characteristics of the dual leg dc to ac converter is shown above output voltage equation and no output voltage when D=0.5.

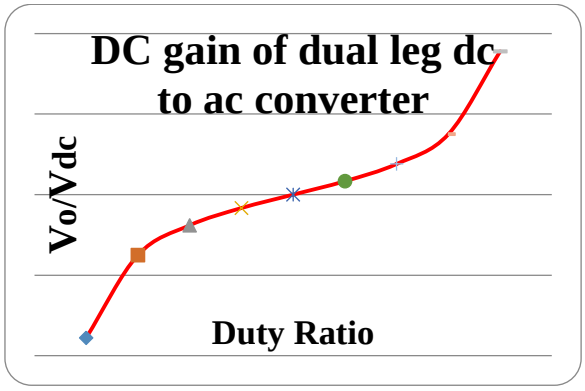

Figure 5. DC gain Characteristics

An ac voltage will be appear across the positive node of the bidirectional current flow dc to dc converters, when the duty cycle varies around this point. The Figure 5 shows that, the output of the two leg dc to ac converter is buck or boost the input voltage depends on the D.

VI. SIMULATION AND RESULT DISCUSSION

The proposed hybrid electric power generation by sliding mode control based dual leg dc to ac converter was developed by MATLAB SIMULINK environment by considering the power IGBT switches, inductors & inductors current and capacitors & capacitors voltage with internal resistance and this output results shown in figure 6.

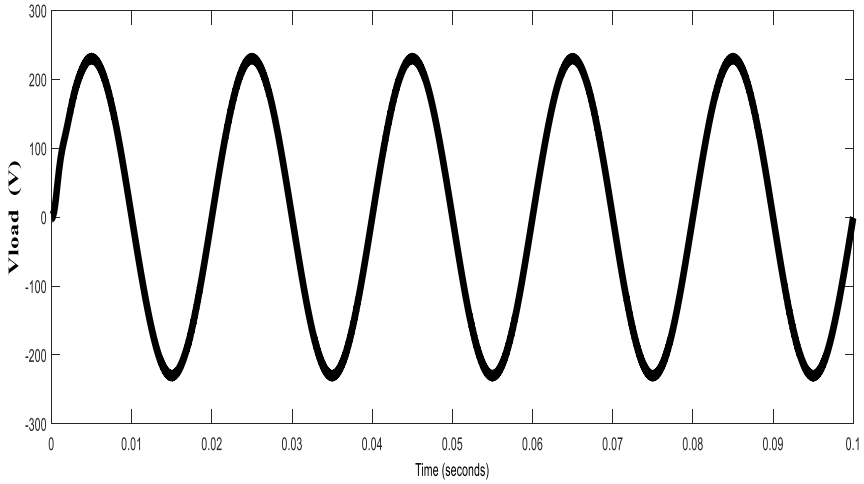

Figure 6. Simulation Result

From the Input supply of 110 V with modulation index, the obtained output voltage is 220 V(rms).solar energy electrical system is analyzed in the Simulink platform with three different controllers, and their results are presented. The simulations of all the three controller operations and the results are obtained from MATLAB/SIMULINK. The boost converter, Solar and single stage dual leg converters are implemented as per design. Simulation output results are as shown in figure 6 respectively.

VII. HARDWARE MODEL AND RESULT DISCUSSION

The proposed hybrid electric power generation by sliding mode control based dual leg dc to ac converter was developed by Hardware environment by considering the power IGBT switches, inductors & inductors current and capacitors & capacitors voltage with internal resistance $r_{L.}$

e-ISSN: 2582-5208
International Research Journal of Modernization in Engineering Technology and Science
(Peer-Reviewed, Open Access, Fully Refereed International Journal)
Volume:05/Issue:01/January-2023 Impact Factor- 6.752 www.irjmets.com

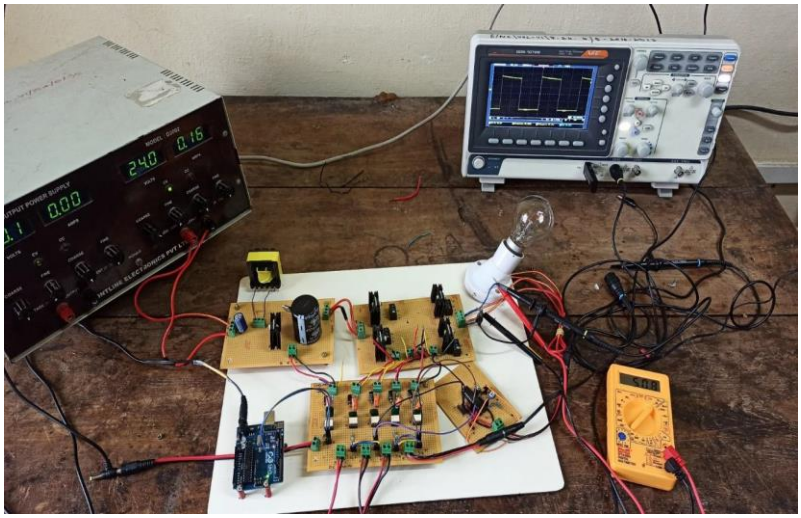

Figure 7. Hardware prototype of proposed modified Boost Inverter

- **Gate pulses for G1,G2 and G3,G4.**

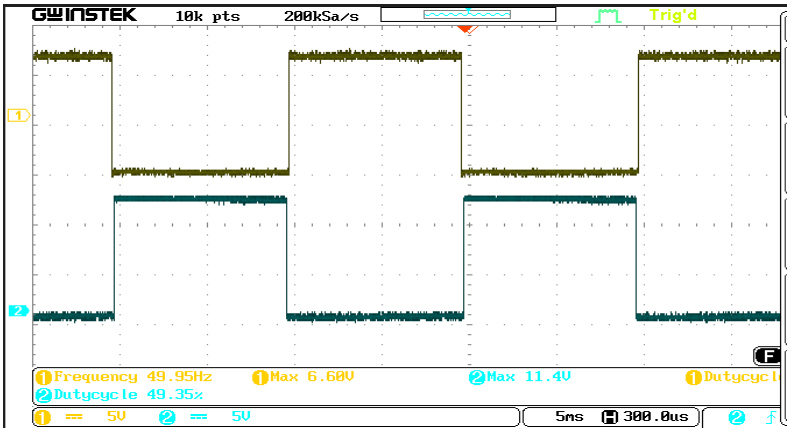

Figure 8. PWM Gate Pulse of Proposed Inverter

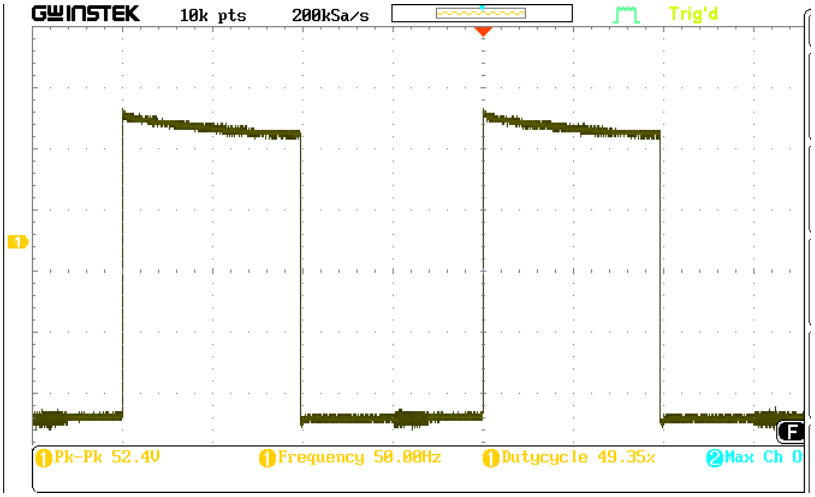

Figure 9. Output voltage of proposed converter

VIII. HARDWARE RESULTS

The boost inverter circuit has been developed as a hardware model with two capacitors, two inductors, and four IGBT switches named S1, S2, S3, and S4. The pulse width modulation pulse is generated by comparing the sine waveform and the triangular waveform. The repeating sequence block with the time values is used to create a triangular wave. These two waveforms are provided as inputs to the relational operator, which compares them and generates PWM pulses.

e-ISSN: 2582-5208
International Research Journal of Modernization in Engineering Technology and Science
(Peer-Reviewed, Open Access, Fully Refereed International Journal)
Volume:05/Issue:01/January-2023 Impact Factor- 6.752 www.irjmets.com

Hardware for the suggested topology is designed to support a lighting load. The prototype device is constructed to generate an approximately 48V AC output from a 12V DC input.

Table 1: Hardware Results For Proposed Inverter

INPUT VOLTAGE Vin	OUTPUT VOLTAGE (RMS) Vout
12V	24V
24V	48V
110V	220V

IX. CONCLUSION

In this project proposed, single stage dual stage DC-AC converter for energy storage/electric vehicle operation. Battery is used as main input source. Based on the source level duty-cycle is adjusted automatically to maintain converter operation to maintain performance of dual leg DC-AC converter. System initially designed in Simulink platform. Simulink model of whole system included two unidirectional DC-DC boost converters for DC-AC boost operation and simulation results were obtained in MATLAB/SIMULINK software tool. Converter is tested with different operating conditions from different inputs level of voltages. Converter robust performance, characteristics and under different input voltage are tested. The hardware results of the proposed model is obtained from proto-type model and verified with simulation results performance also checked.

X. REFERENCES

[1] K. Suresh and E. Parimalasundar, "A Modified Multi Level Inverter with Inverted SPWM Control," in IEEE Canadian Journal of Electrical and Computer Engineering, vol. 45, no. 2, pp. 99-104, Spring 2022.

[2] K. Suresh and E. Parimalasundar, “A novel dual-leg DC-DC converter for wide range DC-AC conversion,” Automatika, vol. 63, no. 3, pp.572-579, 2022.

[3] E. Parimalasundar, S. Jayakumar, R. Ravikumar and K. Suresh, “Investigation analysis of open circuit and short circuit fault on cascaded H-bridged multilevel inverter using artificial neural network approach,” International Journal of Electrical and Electronics Research (IJEER), vol. 10, no. 2, pp.320-326.

[4] V. B. ThuraiRaaj and K. Suresh, "An Intelligent Controller based Power Grid Interconnected System for Reliable Operation," 2019 3rd International Conference on Computing Methodologies and Communication (ICCMC), 2019, pp. 608-613, doi: 10.1109/ICCMC.2019.8819771.

[5] Pandi P, Subbarao M, K Suresh. HBC-Based 3Ø system for wide range of power conversion. IEEE Canadian Journal of Electrical and Computer Eng. 2021;44(3):321–328.

[6] K. Suresh and P. E., "Design and Implementation of Universal Converter Conception et implémentation d’un convertisseur universel," in IEEE Canadian Journal of Electrical and Computer Engineering, vol. 45, no. 3, pp. 272-278, Summer 2022, doi: 10.1109/ICJECE.2022.3166240.

[7] K. Suresh and E. Parimalasundar, "IPWM Based IBMSC DC-AC Converter Using Solar Power for Wide Voltage Conversion System Convertisseur DC-AC IBMSC basésurl’IPWM et utilisantl’énergiesolaire pour un système de conversion à large tension," in IEEE Canadian Journal of Electrical and Computer Engineering, vol. 45, no. 4, pp. 394-400, Fall 2022, doi: 10.1109/ICJECE.2022.3207873.

[8] Suresh K, Parimalasundar E, Jayakumar S &Ravikumar R (2023) Encapsulated 3Ø converter for power loss minimization in a grid-connected system, Automatika, 64:1, 189-197, DOI: 10.1080/00051144.2022.2119501.

[9] Kumar Reddy Cheepati, Suresh K, ‚A Two-Step Horizon Optimum Switching Vector-Model Predictive Control with a Novel Shunt Active Filter Reference Current Extraction’ Journal of Circuits Systems and Computers, Vol. 31, No. 10, 2250174 (2022)

[10] E. Parimalasundar, K. Suresh, R. Sindhuja and K. Manikandan, "A Performance Investigations of Modular Multilevel Inverter with Reduced Switch Count," 2022 International Conference on Intelligent Innovations in Engineering and Technology (ICIIET), 2022, pp. 83-87, doi: 10.1109/ICIIET55458.2022.9967595.