HIGHLY EFFICIENT ASYMMETRICAL PWM FULL-BRIDGE CONVERTER FOR RENEWABLE ENERGY SOURCES

[1]Mrs.M.Suguna, [2]Ms.S.Nivetha

[1,2]Assistant professor

[1]Department of EEE

[1]Narasus's sarathy institute of technology, Salem, India.

Abstract: This paper presents a highly efficient Asymmetrical Pulse-Width Modulated (APWM) full-bridge converter for renewable energy sources. The proposed converter adopts full-bridge topology and asymmetric control scheme to achieve the zero-voltage switching (ZVS) turn-on of the power switches of the primary side and to reduce the circulating current loss. Moreover, the resonant circuit composed of the leakage inductance of the transformer and the blocking capacitor provides the zero-current switching (ZCS) turn-off for the output diode without the help of any auxiliary circuits. Thus, the reverse recovery problem of the output diode is eliminated. In addition, voltage stresses of the power switches are clamped to the input voltage. Due to these characteristics, the proposed converter has the structure to minimize power losses. It is especially beneficial to the renewable energy conversion systems. To confirm the theoretical analysis and validity of the proposed converter, a 400W prototype is implemented with the input voltage range from 40V to 80V.

Index Terms **- Asymmetrical Pulse-Width Modulated (APWM) full bridge inverter, ZVS, ZCS.**

I.INTRODUCTION

1.1 DC - DC CONVERTERS

DC-DC converters are electronic devices used whenever we want to change DC electrical power efficiently from one voltage level to another. They are needed because unlike AC, DC cannot simply be stepped up or down using a transformer. In many ways, a DC-DC converter is the DC equivalent of a transformer.

Typical applications of DC-DC converters are where 24V DC from a truck battery must be stepped down to 12V DC to operate a car radio, CB transceiver or mobile phone; where 12V DC from a car battery must be stepped down to 3V DC, to run a personal CD player; where 5V DC on a personal computer motherboard must be stepped down to 3V, 2V or less for one of the latest CPU chips; where the 340V DC obtained by rectifying 240V AC must be stepped down to 5V, 12V and other DC voltages as part of a PC power supply.

1.2. CONVERSION METHOD

1.2.1. LINEAR

Linear regulators can only output at lower voltages from the input. They are very inefficient when the voltage drop is large and the current is high as they dissipate heat equal to the product of the output current and the voltage drop; consequently they are not normally used for large-drop high-current applications.

The inefficiency wastes energy and requires higher-rated and consequently more expensive and larger components. The heat dissipated by high-power supplies is a problem in itself and it must be removed from the circuitry to prevent unacceptable temperature rises.

Linear regulators are practical if the current is low, the power dissipated being small, although it may still be a large fraction of the total power consumed. They are often used as part of a simple regulated power supply for higher currents: a transformer generates a voltage which, when rectified, is a little higher than that needed to bias the linear regulator.

The linear regulator drops the excess voltage, reducing hum-generating ripple current and providing a constant output voltage independent of normal fluctuations of the unregulated input voltage from the transformer/bridge rectifier circuit and of the load current.

Linear regulators are inexpensive, reliable if good heat sinks are used and much simpler than switching regulators. Linear regulators do not generate switching noise. As part of a power supply they may require a transformer, which is larger for a given power level than that required by a switch-mode power supply. Linear regulators can provide a very low-noise output voltage, and are very suitable for powering noise-sensitive low-power analog and radio frequency circuits. A popular design approach is to use an LDO, Low Drop-out Regulator that provides a local "point of load" DC supply to a low power circuit.

1.2.2. SWITCHED-MODE CONVERSION

Electronic switch-mode DC to DC converters convert one DC voltage level to another, by storing the input energy temporarily and then releasing that energy to the output at a different voltage. The storage may be in either magnetic field storage components (inductors, transformers) or electric field storage components (capacitors). This conversion method is more power efficient (often 75% to 98%) than linear voltage regulation (which dissipates unwanted power as heat). This efficiency is beneficial to increasing the running time of battery operated devices.

The efficiency has increased since the late 1980s due to the use of power FETs, which are able to switch at high frequency more efficiently than power bipolar transistors, which incur more switching losses and require a more complicated drive circuit. Another important innovation in DC-DC converters is the use ofsynchronous rectification replacing the flywheel diode[2] with a power FET with low "on resistance", thereby reducing switching losses. Before the wide availability of power semiconductors. most DC-to-DC converters are designed to move power in only one direction, from the input to the output.

However, all switching regulator topologies can be made bi-directional by replacing all diodes with independently controlled active rectification. A bi-directional converter can move power in either direction, which is useful in applications requiring regenerative braking.

Drawbacks of switching converters include complexity, electronic noise (EMI / RFI) and to some extent cost, although this has come down with advances in chip design.

DC-to-DC converters are now available as integrated circuits needing minimal additional components. They are also available as a complete hybrid circuit component, ready for use within an electronic assembly.

II.EXISTING SYSTEM

2.1. EXISTING SYSTEM ANALYSIS

A novel high step-up dc/dc converter is presented for renewable energy applications. The suggested structure consists of a coupled inductor and two voltage multiplier cells, in order to obtain high step-up voltage gain. In addition, two capacitors are charged during the switch-off period, using the energy stored in the coupled inductor which increases the voltage transfer gain.

The energy stored in the leakage inductance is recycled with the use of a passive clamp circuit. The voltage stress on the main power switch is also reduced in the proposed topology.

Therefore, a main power switch with low resistance RDS (ON) can be used to reduce the conduction losses. The operation principle and the steady-state analyses are discussed thoroughly. To verify the performance of the presented converter, a 300-W laboratory prototype circuit is implemented.

2.2. EXISTING SYSTEM CIRCUIT DIAGRAM

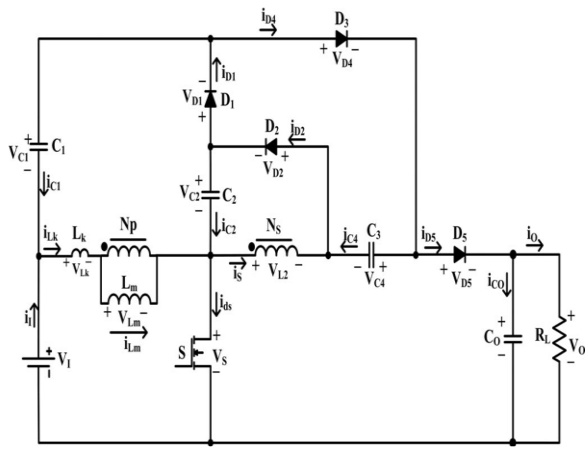


Fig. 2.1:Step-Up Converter

The coupled inductor is modeled as an ideal transformer with a turn ratio N (NP/NS),a magnetizing inductor Lm and leakage inductor Lk. In order to simplify the circuit analysis of the converter, some assumptions are considered as follows:

1) All Capacitors are sufficiently large; therefore VC1, VC2, VC3, and VO are considered to be constant during one switching period.

2) All components are ideal but the leakage inductance of the coupled inductor is considered. According tothe aforementioned assumptions, the continuous conduction mode (CCM) operation of the proposed converter includes five intervals in one switching period. The operating stages are explained as follows.

2.3. INPUT AND OUTPUT VOLTAGE

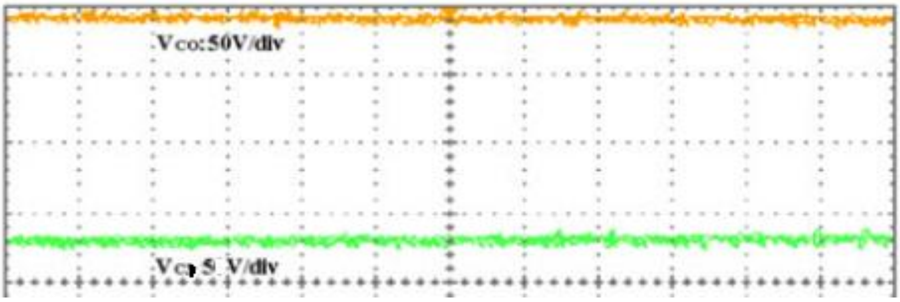


Fig. 2.2: Input and Output Voltage

2.4. INPUT AND OUTPUT CURRENT

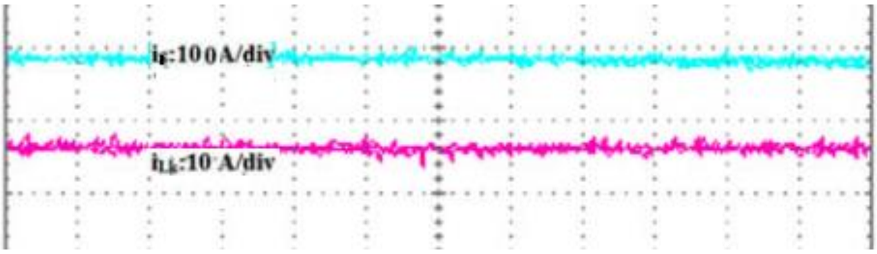


Fig. 2.3: Input and Output Current

2.5. DRAWBACKS

In this system, more conduction and switching losses were there at operating time. During voltage spike in input of the converter in this system may be creating some other problems. And also Switching voltage and current stresses are still high.

III. PROPOSED SYSTEM

3.1. PROPOSED SYSTEM ANALYSIS

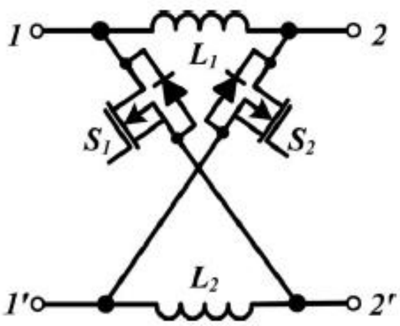


Fig.3.1: Active Network

Fig.3.1 shows the basic structure of active-network derived from the concept of switched inductor, to perform both the series and parallel connection of two inductors. The switches S1 and S2 share the same switching signal, when the switches are turned ON simultaneously, the inductors L1 and L2 are parallel connected; when S1 and S2 are turned OFF, L1 and L2 are connected in series seen from the input port (1–1') of the two-port network.

Multiple capacitors and diodes on the output-stacking form a switched-capacitor unit, with the series or parallel connections between the capacitors, high voltage gain can be achieved, shown in Fig. 3.2. The two active switches (S1 and S2) share the same switching signal. Diodes D1, D2, D3and capacitors C1, C2, C3 are adopted in the switched-capacitor unit.

Systematic risk is the only independent variable for the CAPM and inflation, interest rate, oil prices and exchange rate are the independent variables for APT model.

Consumer Price Index (CPI) is used as a proxy in this study for inflation rate. CPI is a wide basic measure to computeusualvariation in prices of goods and services throughout a particular time period. It is assumed that arise in inflation is inversely associated to security prices because Inflation is at lastturned into nominal interest rate andchange in nominal interest rates caused change in discount rate so discount rate increase due to increase in inflation rate and increase in discount rateleads todecreasethe cash flow's present value (Jecheche, 2010). The purchasing power of money decreased due to inflation, and due to which the investors demand high rate of return, and the prices decreased with increase in required rate of return (Iqbal et al, 2010).

Exchange rate is a rate at which one currency exchanged with another currency. Nominal effective exchange rate (Pak Rupee/U.S.D) is taken in this study.This is assumed that decrease in the home currency is inverselyassociated to share prices (Jecheche,2010). Pan et al. (2007) studied exchange rate and its dynamic relationship with share prices in seven East Asian Countries and concludethat relationshipof exchange rate and share prices varies across economies of different countries. So there may be both possibility of either exchange rate directly or inverselyrelated with stock prices.Oil prices are positively related with share prices if oil prices increase stock prices also increase (Iqbal et al, 1012).Ataullah (2001) suggested that oil prices cause positive change in the movement of stock prices. The oil price has no significant effect on stock prices (Dash & Rishika, 2011).Six month T-bills rate is used as proxy of interest rate. As investors arevery sensitive about profit and where the signals turn into red they definitely sell the shares. And this sensitivity of the investors towards profit effects the relationship of the stock prices and interest rate, so the more volatility will be there in the market if the behaviors of the investors are more sensitive. Plethora (2002)has tested interest rate sensitivity to stock market returns, and concluded an inverse relationship between interest rate and stock returns. Nguyen (2010) studies Thailand market and found thatInterest rate has aninverse relationship with stock prices.

KSE-100 index is used as proxy of market risk. KSE-100 index contains top 100 firms which are selected on the bases of their market capitalization. Beta is the measure of systematic risk and has alinear relationship with return (Horn, 1993). High risk is associated with high return (Basu, 1977, Reiganum, 1981 and Gibbons, 1982). Fama and MacBeth (1973) suggested the existence of a significant linear positive relation between realized return and systematic risk as measured by β. But on the other side some empirical results showed that high risk is not associated with high return (Michailidis et al. 2006, Hanif, 2009). Mollah and Jamil (2003) suggested thatrisk-return relationship is notlinear perhaps due to high volatility.

3.4Statistical tools and econometric models

This section elaborates the proper statistical/econometric/financial models which are being used to forward the study from data towards inferences. The detail of methodology is given as follows.

3.4.1 Descriptive Statistics

Descriptive Statics has been used to find the maximum, minimum, standard deviation, mean and normally distribution of the data of all the variables of the study. Normal distribution of data shows the sensitivity of the variables towards the periodic changes and speculation. When the data is not normally distributed it means that the data is sensitive towards periodic changes and speculations which create the chances of arbitrage and the investors have the chance to earn above the normal profit. But the assumption of the APT is that there should not be arbitrage in the market and the investors can earn only normal profit. Jarque bera test is used to test the normality of data.

3.4.2 Fama-Mcbeth two pass regression

After the test statistics the methodology is following the next step in order to test the asset pricing models. When testing asset pricing models related to risk premium on asset to their betas, the primary question of interest is whether the beta risk of particular factor is priced. Fama and McBeth(1973)develop a two pass methodology in which the beta of each asset with respect to a factor is estimated in a first pass time series regression and estimated betas are then used in second pass cross sectional regression to estimate the risk premium of the factor. According to Blum (1968) testing two-parameter models immediately presents an unavoidable errors-in-the variables problem.It is important to note that portfolios (rather than individual assets) are used for the reason of making the analysis statistically feasible.Fama McBeth regression is used to attenuate the problem of errors-in-variables (EIV) for two parameter models (Campbell, Lo and MacKinlay, 1997).If the errors are in the β (beta)of individual security are not perfectly positively correlated, the β of portfolios can be much more precise estimates of the true β (Blum, 1968).

The study follow Fama and McBeth two pass regressionto test these asset pricing models.The Durbin Watson is used to check serial correlation and measures the linear association between adjacent residuals from a regression model. If there is no serial correlation, the DW statistic will be around 2. The DW statistic will fall if there is positive serial correlation (in worst case, it will be near zero). If there is a negative correlation, thestatistic will lie somewhere between 2 and 4. Usually the limit for non-serial correlation is considered to be DW is from 1.8 to 2.2. A very strong positive serial correlation is considered at DW lower than 1.5 (Richardson and smith, 1993).

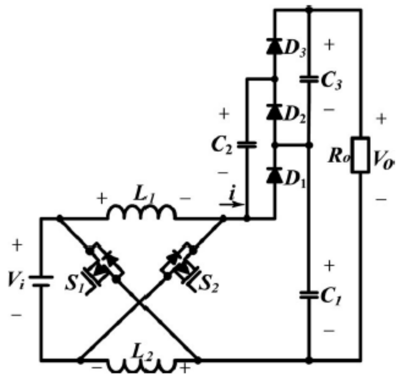


Fig. 3.2: Proposed Switched-Capacitor-Based Active-Network Converter

3.2. OPERATING PRINCIPLE OF THE PROPOSED SYSTEM

3.2.1 CCM OPERATION

The operating modes in CCM condition are the Mode 1 and Mode 2.

Mode 1 [t0, t1]:

During this time interval, switches S1 and S2 are turned ON. The equivalent circuit is shown in Fig.3.3. Inductors L1 and L2 are charged in parallel from the dc source, the capacitor C2 is charged, and the energy stored in the capacitors C1, C3 is released to the load. Thus, the voltages across L1 and L2 are given as follows:

VL1 = VL2 = Vi.

During this time, the dc source, the switches S1, S2, the diode D2 , and the capacitor C1, C2 forms a circuit loop, according to the KVL rule, the relationship between the VC1 and VC2 is given as follows:

Vi + VC1 = VC.

Mode 2 [t1, t2]:

During this time interval, S1 and S2 are turned OFF. The equivalent circuit is shown in Fig. 3.4. C2 is discharged and C1 is charged.

According to the KVL rule, the relationship between the capacitor voltage VC1, VC2, and VC3 can be written as follows:

VC2 = VC3 (3)

VC1 + VC3 = Vo.

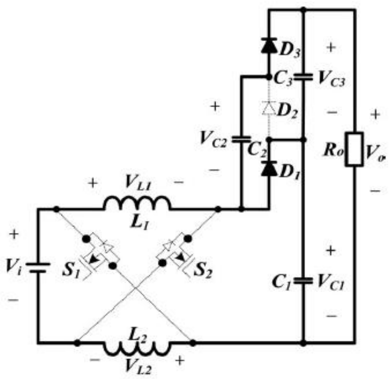


Fig.3.3: Equivalent Circuits in CCM

According to Richardson and smith(1993) to make the model more effective and efficient the selection criteria for the shares in the period are: Shares with no missing values in the period, Shares with adjusted $R^2 < 0$ or F significant (p-value) >0.05of the first pass regression of the excess returns on the market risk premium are excluded. And Shares are grouped by alphabetic order into group of 30 individual securities (Roll and Ross, 1980).

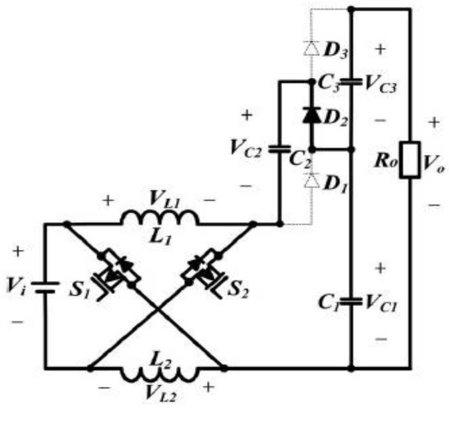


Fig.3.4: Equivalent Circuits in DCM-1

3.2.2 DCM OPERATION

Three modes exist in DCM condition.

Mode 1 [t0, t1]:

During this time interval, the operational principle is the same as the mode 1 of CCM. The peak currents of L1, L2 are derived as follows:

IL1p = IL2p = (Vi/L) DTs

Where L is the inductance of L1 and L2.

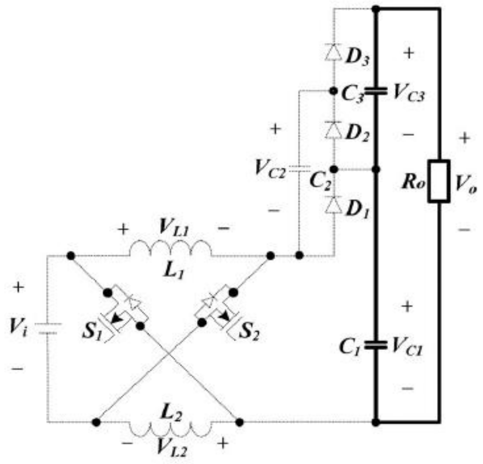


Fig.3.5: Equivalent Circuits in DCM-2

Mode 2 [t1, t2]:

S1 and S2 are turned OFF. The equivalent circuit is shown in Fig. 3.5. C2 is discharged and C1 is charged. At the time of t2, the current through inductors decreases to zero.

Mode 3 [t2, t3]:

S1 and S2 are still turned OFF, the inductor current is 0, and the energy stored in the capacitor C1 and C3 is released to the load.

3.3 BLOCK DIAGRAM

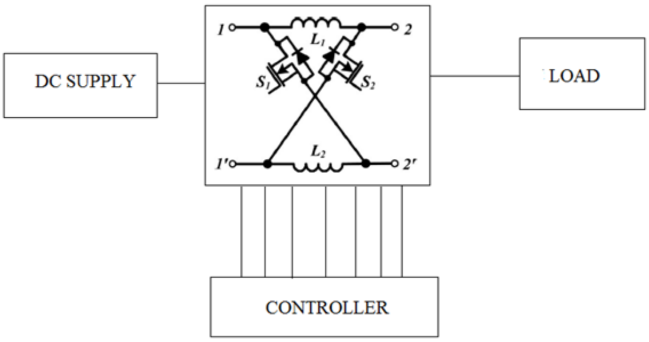


Fig.3.6: Proposed System Block Diagram

3.4 BLOCK DIAGRAM DISCRIPTION

In a closed-loop system, a controller is used to compare the output of a system with the required condition and convert the error into a control action designed to reduce the error and bring the output of the system back to the desired response.

Then closed-loop control systems use feedback to determine the actual input to the system and can have more than one feedback loop.

Closed-loop control systems have many advantages over open-loop systems.

One advantage is the fact that the use of feedback makes the systemresponse relatively insensitive to external disturbances and internal variations in system parameters such as temperature. It is thus possible to use relatively inaccurate and inexpensive components to obtain the accurate control of a given process or plant.

However, system stability can be a major problem especially in badly designed closed-loop systems as they may try to over-correct any errors which could cause the system to loss control and oscillate.

A proportional-integral-derivative controller (PID controller) is a control loop feedback mechanism (controller) widely used in industrial control systems. A PID controller calculates an error value as the difference between a measured process variable and a desired set point. The controller attempts to minimize the error by adjusting the process through use of a manipulated variable.

The PID controller algorithm involves three separate constant parameters, and is accordingly sometimes called three-term control: the proportional, the integral and derivative values, denoted P, I, and D. Simply put, these values can be interpreted in terms of time: P depends on the present error, I on the accumulation of past errors, and D is a prediction of future errors, based on current rate of change.[1] The weighted sum of these three actions is used to adjust the process via a control element such as the position of a control valve, a damper, or the power supplied to a heating element.

In the absence of knowledge of the underlying process, a PID controller has historically been considered to be the most useful controller.[2] By tuning the three parameters in the PID controller algorithm, the controller can provide control action designed for specific process requirements. The response of the controller can be described in terms of the responsiveness of the controller to an error, the degree to which the controller overshoots the setpoint.

The degree of system oscillation. Note that the use of the PID algorithm for control does not guarantee optimal control of the system or system stability.

3.5 SIMULATION DIAGRAM

The circuit diagram of the proposed converter. HT is a hybrid transformer with primary to secondary turns ratio 1:n and with secondary reflected equivalent leakage inductance L lk; S1 is the main switch and S is the auxiliary active-clamp switch; Cc2 is the clamping capacitor; D is a resonant diode, which provides a unidirectional current flow path to charge the resonant capacitor Cr when S1 is on Dr is the output diode Cj represents the equivalent parasitic junction capacitors of MOSFETs, Cs is the equivalent capacitor of the diodes Do and Dr, Co is the output capacitor; R is the equivalent resistive load, and Vin represents PV-side equivalent voltage.

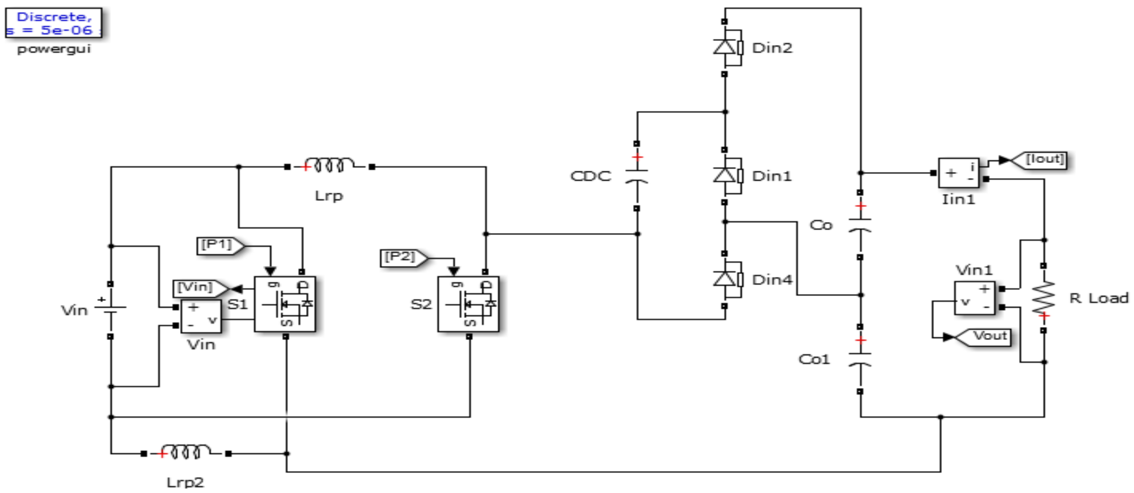
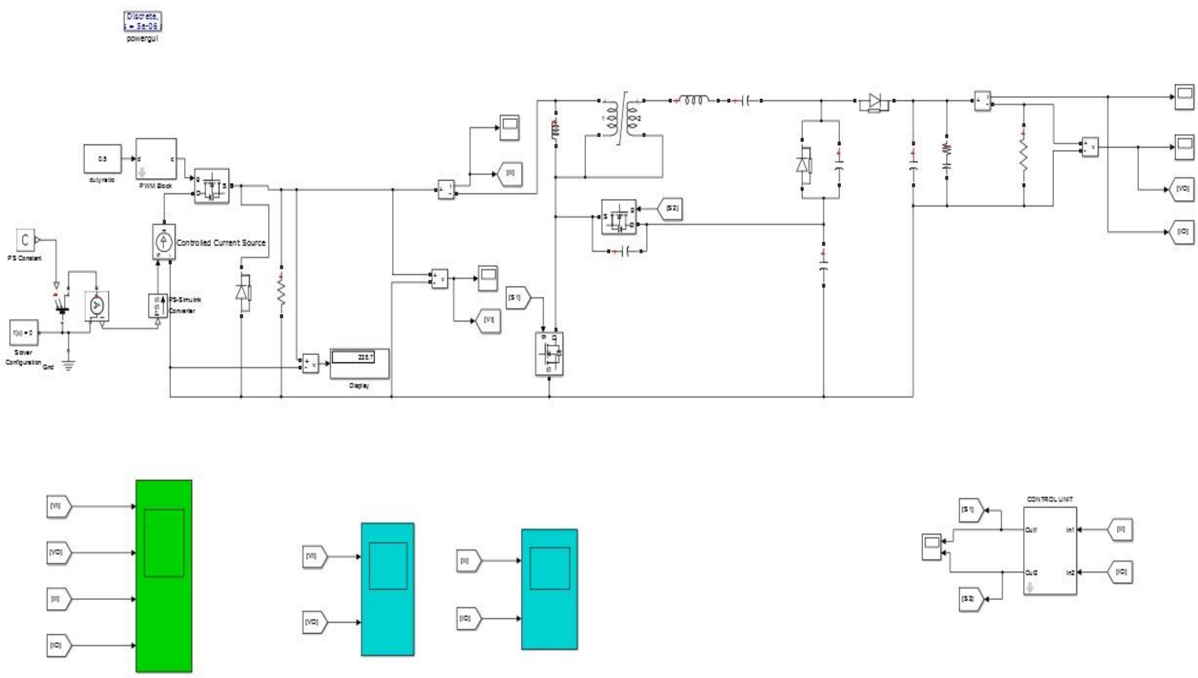


Fig.3.7: Proposed System Simulation Diagram

3.6 SIMULATION CIRCUIT DIAGRAM



3.7. SIMULATION RESULT

3.7.1. INPUT PULSE

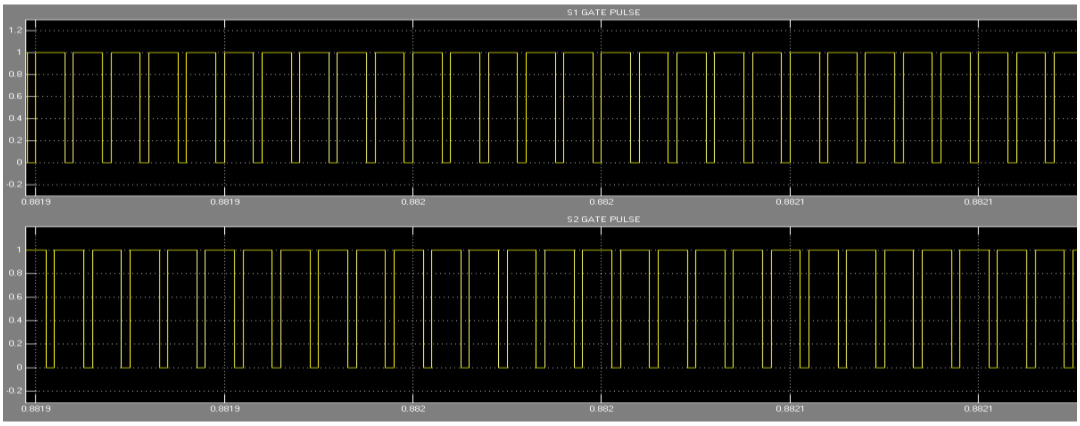


Fig.3.8: Input Pulse

3.7.2. INPUT VOLTAGE AND CURRENT

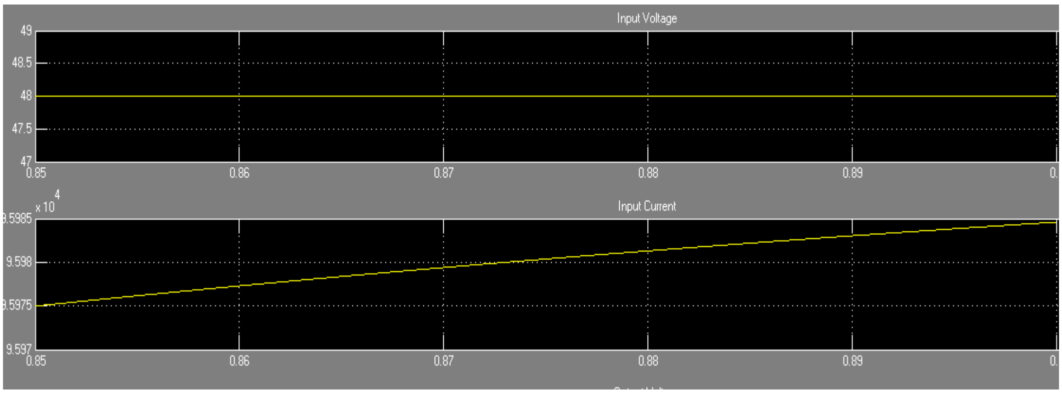


Fig.3.9: Input Voltage and Current

3.7.3. OUTPUT VOLTAGE AND CURRENT

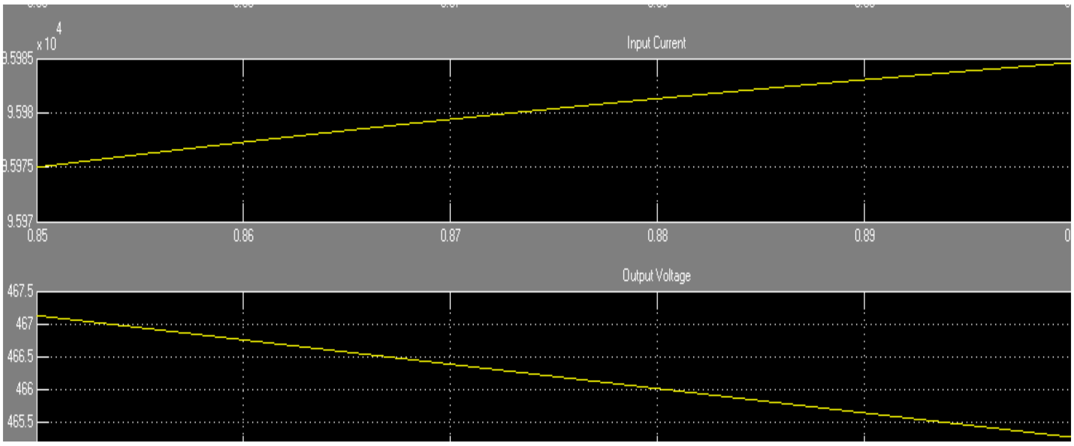


Fig.3.10: Output Voltage and Current

3.7. ADVANTAGES

- Simple circuit.
- Usage of Components reduced.
- Low cost compare with existing system.
- High efficiency.
- High voltage gain.

3.8. APPLICATIONS

- Uninterruptible power supplies.
- Battery chargers.

- Battery operated vehicles.

IV.CONCLUSION

This project has proposed a switched capacitor-based active network converter with high step-up voltage gain. The operating principles of the proposed converter in CCM and DCM have been discussed in detail. The voltage stress on active switches and diodes is low, which is beneficial to the system efficiency and cost. Comparisons of the proposed topology with the boost converter, switched inductor boost converter, and switched capacitor boost converter are shown. Compared with these converters, the voltage gain of the proposed converter is higher; the voltage across the power devices is lower; the inductor current is smaller.

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