A New High Efficiency AC – DC Conversion System for Hybrid Renewable Energy Sources

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Abstract

The power conversion efficiency of an isolated ac–dc converter is a dominant factor in the overall efficiency of dc distribution systems. To improve the power continuity and power conversion efficiency of the dc distribution system, a three-phase interleaved full-bridge LLC resonant converter employing a voltage source converter which is fed by Photo Voltaic System and Wind Energy System is proposed as the isolated ac–dc high-frequency-link power-conversion system.

The proposed voltage source converter has the capability of boosting the output voltage without increasing the transformer's turn ratio. Especially, the frequency of the rectifier's output ripple is six times higher than the switching frequency, thereby reducing the output capacitor and the secondary transformer's RMS current. However, the tolerance of the converter's resonant components in each primary stage causes the unbalance problem of output ripple current. It cannot be solved using conventional control techniques since the structure of the three-phase interleaving has the limitations of individual control capability for each converter. To solve the current unbalance problem, a current balancing method is proposed for the output rectifying current. The performance of the proposed converter and the current balancing method has been verified through experiments using a 10 kW (300V/33.3A) prototype converter.

Keywords:* *LLC resonant converter

1. Introduction

Due to the day by day increasing energy demand, shortage and environmental impacts of conventional energy sources, more attention has been given to utilize the renewable energy. In a tropical Asian country like India, the most promising alternative of renewable green energy resource of the future is the sun. Since this energy source is free, abundant, feasible and environmental friendly, it become more popular. Although there are several benefits in solar energy, there are some challenges that obstruct its growth. The two main challenges are low conversion efficiency and its erratic nature of power output

The Conventional sources of energy are rapidly depleting. Moreover the cost of energy is rising and therefore photovoltaic system is a promising alternative. They are abundant, pollution free, distributed throughout the earth and recyclable. The hindrance factor is its high installation cost and low conversion efficiency. Therefore our aim is to increase the efficiency and power output of the system. It is also required that constant voltage is supplied to the load irrespective of the variation in solar irradiance and temperature. PV arrays consist of parallel and series combination of PV cells that are used to generate electrical power depending upon the atmospheric conditions (e.g. solar irradiation and temperature). So it is necessary to couple the PV array with a boost converter. Moreover our system is designed in such a way that with variation in load, the change in input voltage and power fed into the converter follows the open circuit characteristics of the PV array. Our system can be used to supply constant stepped up voltage to dc loads.

Different Sources of Renewable Energy:

Wind Power: Worldwide there are now many thousands of wind turbines functioning, with a total nameplate capability of 194,400MW.The wind turbines range from around 600 kW to 5 MW of rated power. The power output increases rapidly with an increase in available wind velocity as the former.

Solar Power: This can be employed in two major ways. The captured heat can be used as solar thermal energy with important applications in space heating. On the other hand it can also be converted into the most useful form of energy, the electrical energy. The latter can be achieved with the use of solar photovoltaic cell.

Biomass: Biomass works as a natural battery to store the sun's energy and yield it on requirement. Biomass energy is derived from five distinct energy sources; garbage, wood, landfill gases, waste, and alcohol fuels. This way, biomass works as a natural battery to store the sun's energy and yield it on requirement

Geothermal: Geothermal energy is the thermal energy which is generated and stored within the layers of the Earth. The gradient thus developed brings about an uninterrupted conduction of heat from the core to the surface of the earth. This gradient can be applied to heat water to produce superheated steam and use it to run steam turbines to generate electricity. The primary failing of geothermal energy is that it is usually limited to regions near tectonic plate boundaries, though recent progresses have led to the multiplication of this technology.

In tropic countries like India and other places where solar energy is available in plenty, photovoltaic has emerged as a major candidate for meeting the energy demand. It extends an alternative for clean (pollution free) energy source, with about no running and sustainment cost.

2. Modeling of wind turbine

A wind energy conversion system is basically comprised of two main components, the aerodynamic component and the electrical component. The turbine forms a major constituent of the aerodynamic system. The energy that could be captured from wind by a specific turbine depends on its design particulars and operating conditions. In this section all aspects related to the power conversion, from kinetic wind energy to rotational energy, that are of relevance for the stability model are explained.

The kinetic energy E_k of a mass of air m having the speed V_w is given by:

$$E_K = \frac{m}{2} V_w^2 \qquad (2.1)$$

The power associated to this moving air mass is the derivative of the kinetic energy with respect to time can be expressed as follows:

$$P_o = \frac{\partial E_K}{\partial t} = \frac{1}{2}\frac{\partial m}{\partial t}.V_w^2 = \frac{1}{2}.qV_w^2 \qquad (2.2)$$

Where q represents the mass flow given by the expression:

$$q = \rho V_W .A \qquad (2.3)$$

Where ρ: Air density;

A: Cross section of the air mass flow.

E_k: kinetic energy of the air

Only a fraction of the total kinetic power can be extracted by a wind turbine and converted into rotational power at the shaft. This fraction of power (P_{wind}) depends on the wind speed, rotor speed and blade position (for pitch and active stall control turbines) and on the turbine design. The aerodynamic efficiency C_p is defined as follows:

$$C_P = \frac{P_{wind}}{P_o} \tag{2.4}$$

For a specific turbine design, the values of C_p (α, β) are usually presented as a function of the pitch angle (β) and the tip speed ratio (α). The tip speed ratio is given by:

$$\alpha = \frac{\omega_{tur} R}{V_w} \tag{2.5}$$

Where R: the radius of the turbine blades.
ω_{tur}: the turbine angular speed.

The aerodynamic efficiency C_p (α, β) is usually defined as a form of a two-dimensional lookup characteristic (for different values of α and β) by actual measurement. The variation of the power coefficient C_p with variation of the tip speed ratio is shown in

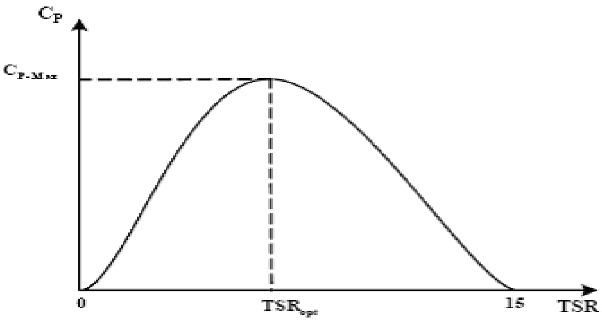

Fig. 2.2. Power Coefficient versus Tip Speed Ratio

Finally, the mechanical power extracted from the wind is calculated using:

$$P_{mech} = \frac{\ell}{2} \Pi R^2 . C_P(\alpha, \beta) . V_w^2 \tag{2.6}$$

The power coefficient of wind turbine can be expressed by:

$$C_p(\alpha, \beta) = c_1 \left(\frac{c_2}{\alpha_i} - c_3\beta - c_4\right) e^{-\frac{c_5}{\alpha_i}} + c_6\alpha \tag{2.7}$$

3. Results and Analysis:

The ZVS interleaved boost converter is an AC to DC converter which is shown below in fig. 3.1

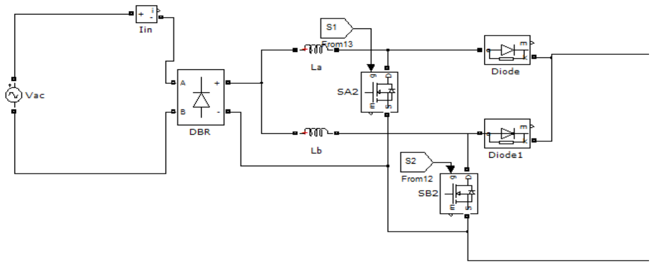

Fig. 3.1: ZVS Interleaved Boost Converter

The input is a single phase AC with a voltage of 220Vrms and 50Hz. The AC supply is converted to variable DC and further fed to the boost converter with two inductors La and Lb with 270uH and two MOSFETs with anti parallel diodes. At the output of the dual boost a diode is connected in series so as to restrict the flow of current from input to output. The control unit controlling the MOSFETs is given below with a reference value of 380V.

The schematic diagram of the proposed three-phase interleaved LLC resonant converter is shown below with a Voltage Source Converter

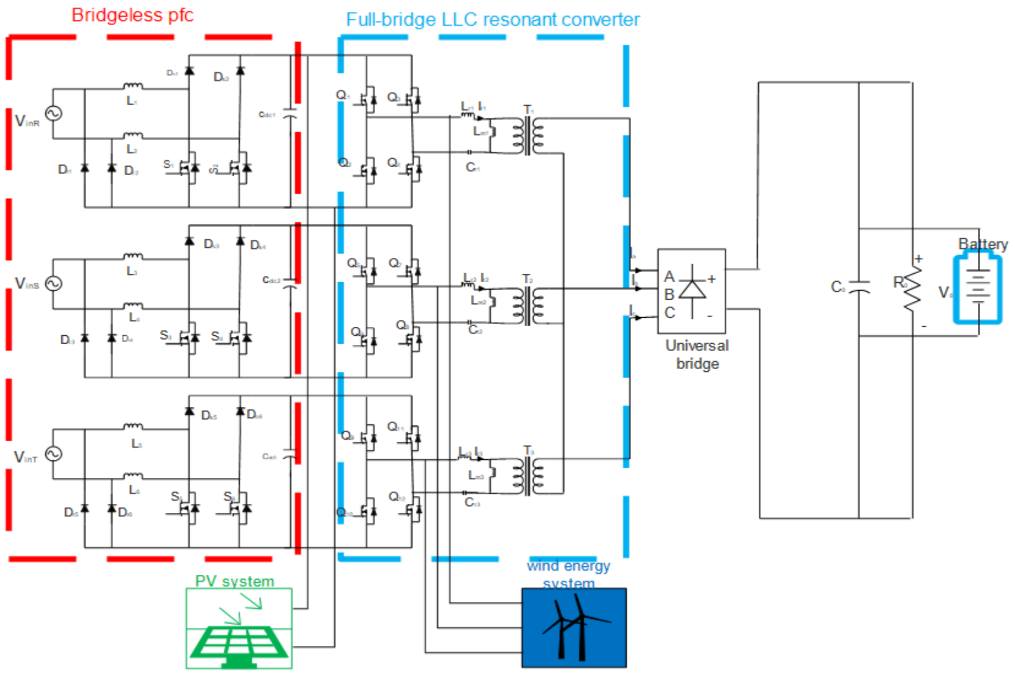

Fig. 3.2: Three-Phase Interleaved LLC Resonant Converter with Voltage Source Converter

The schematic diagram of the ZVS Three-phase interleaved LLC resonant converter is shown below.

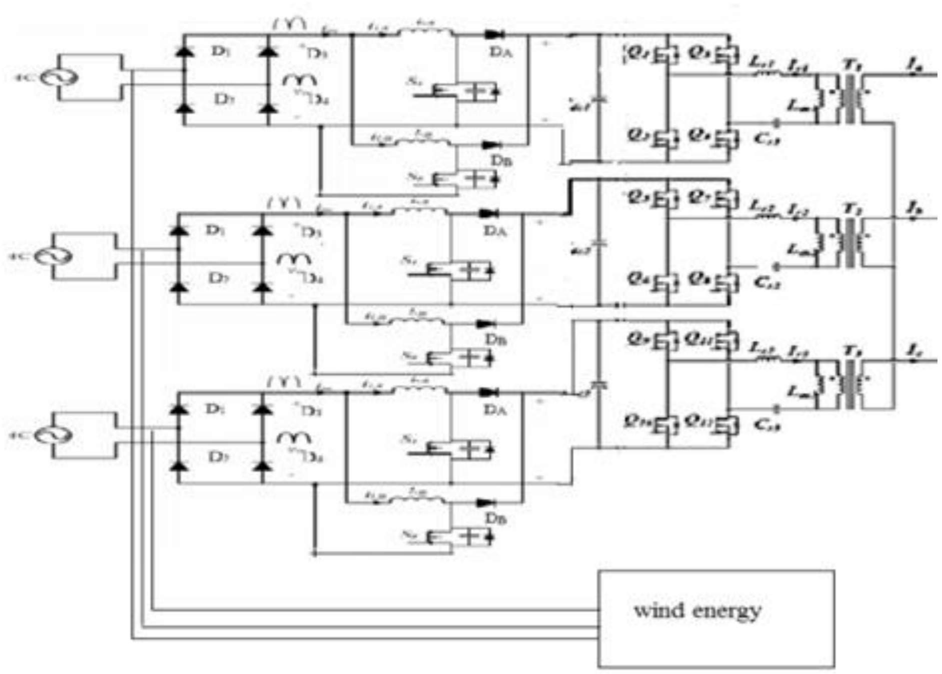

Fig. 3.3: Interleaved Boost Converter Fed LLC Resonant Converter

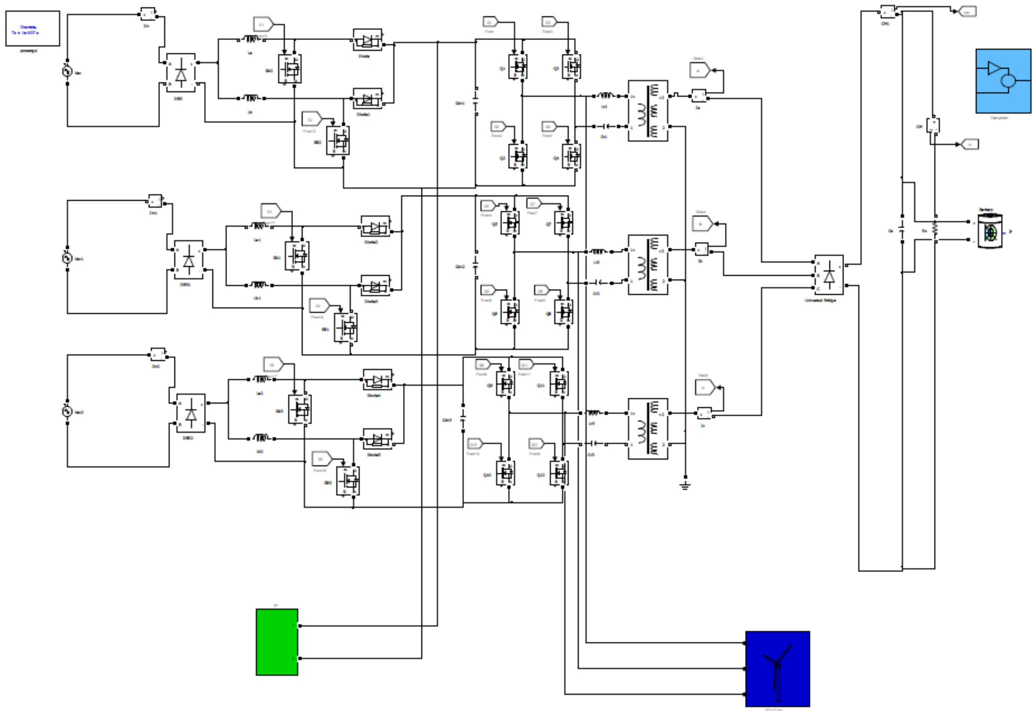

Fig. 3.4: Simulink Design of ZVS Three-Phase Interleaved LLC Resonant Converter with Voltage Source Converter

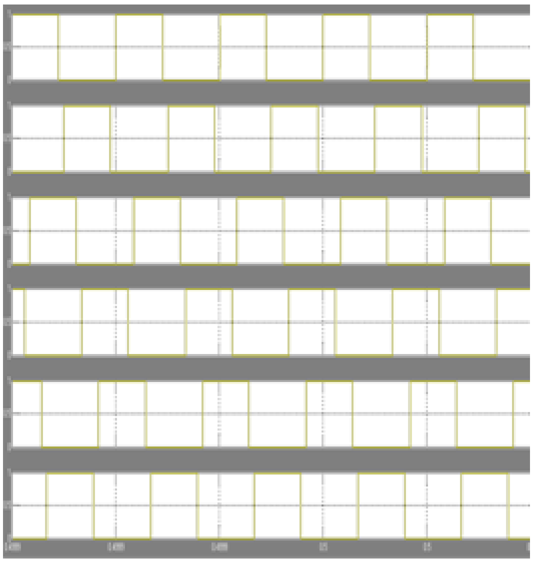

Fig. 3.5: Pulses of switches Q1-Q12

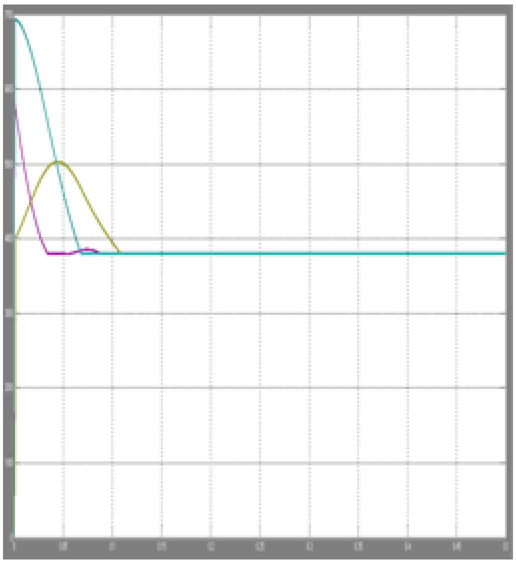

Fig. 3.6: DC Voltage output of ZVS Interleaved Boost Converters

Under the light load condition of 8-kW output power, the peak to peak ripple current of the rectifier under the balanced condition is 0.66 A as shown in Fig. 3.6. In the case of Fig. 7.10, Lr2 is 10% larger than the original resonant inductance of 120μH. The second converter's resonant gain is smaller than other converters' resonant gain because of the large resonant inductance.

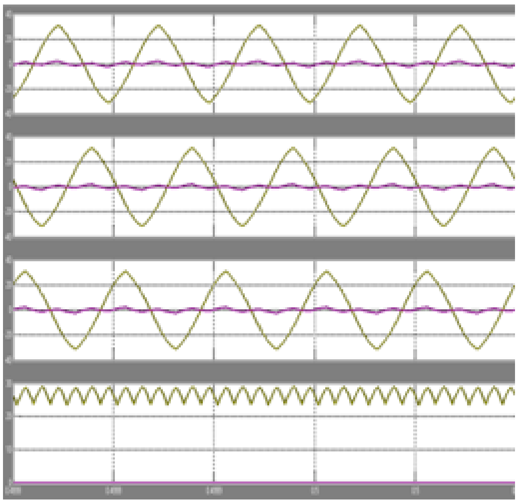

Fig. 3.7: Current waveforms of Resonance inductors and Magnetizing currents of HFT

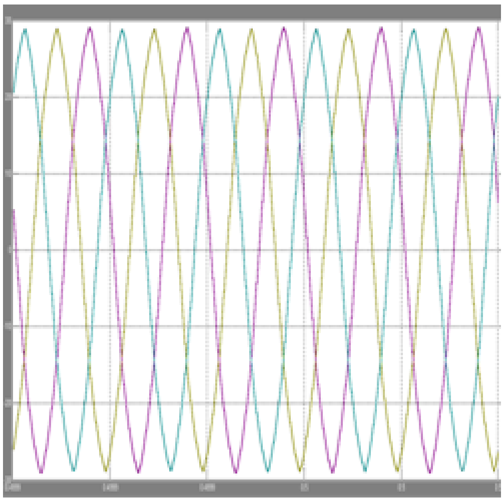

Fig.3.8: Currents of secondary winding of the Transformer

4. Conclusion

In power sector the power demand is increasing day to day. It is better to depend on renewable energy sources, because, by using non renewable energy sources we cannot reach the total power demand. We can get unlimited power from renewable energy sources and also those renewable energy sources are eco friendly. We can say that solar and wind are best renewable sources because they can available any place on the earth.

With the given reference and modeling of the Three phase ZVS interleaved boost LLC resonant converter with Voltage Source Converter fed by photo voltaic system and wind energy system has been analyzed with all graphical representation. The variation of the output rectifier current is been observed with change in the resonance inductor value with 10% change. The output voltage at the load is observed to be 300V with very less ripple at 0.45% and the conduction losses are been eliminated with the use of high switching of the inverter. Consequently, the power conversion efficiency and power continuity is improved.

5. References

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