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AUTOMOTIVE AND INDUSTRIAL INVERTER SMART GRID DC ULTRA-FAST CHARGING STATIONS

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ABSTRACT

This project presents a DC-to-DC bidirectional resonant converter to be used for bidirectional power transfer applications especially battery charging/discharging applications in electrical vehicles. It is similar to an LLC resonant converter but for bidirectional functionality, an additional inductor and capacitor have been added in the secondary side of the circuit to make the resonant network symmetric for operation in both forward and backward directions. Zero Voltage Switching (ZVS) of the switches in the inverting stage is ensured. Also, the rectifier diodes in the secondary side turn off under ZCS. ZVS and ZCS result in reduction of losses and allow high frequency operation which leads to a reduction in the size of magnetic elements and filter capacitors thus reducing size, weight, volume and increasing power density. In this project, first an equivalent model of the converter is developed for a detailed Analysis of the converter voltages and currents. Then simulations of the converter are carried out to verify the validity of the conceptual design.

OBJECTIVE

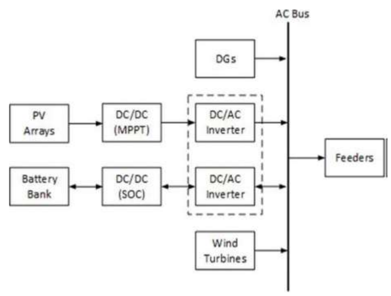
To design a isolated bidirectional DC-DC converter with series connection of bidirectional DC converters is proposed in this project. These soft switching converters offers high voltage gain with reduced voltage stress across the switches, offer wide duty ratio, ZCS for turn-on and zero current transition (ZCT) for turn-off of all switching devices and also offer inherent voltage balance at two poles of DC bus .Since this converter offers soft-switching. However, the LLC resonant converter can transfer power in a unidirectional manner. When operated in the reverse mode, its gain is restricted to below unity. As a novel topology, the CLLC bidirectional resonant converter has been studied and implemented in some energy storage applications. A symmetric LLC-type resonant topology has been put forth for a low-voltage DC power distribution system and high efficiency has been achieved.

Hybrid Power EV/PHEV

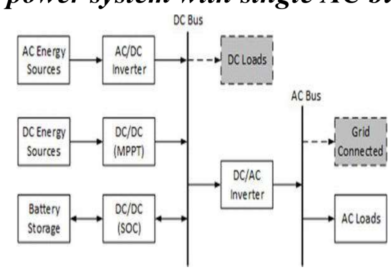
However, its voltage range is quite narrow thus it is unfit for use in a EV/PHEV application. A CLLC topology with wide voltage range was proposed and employed in the uninterrupted power supply system with an input/output range of 400V/48V. Nevertheless, in battery charging applications, its transformer ratio is unrealistic because of the considerable difference between the input and output voltages. In this paper, a CLL-LC type bidirectional DC/DC converter to fulfil all the requirements of on-boar.

Hybrid Power System Bus

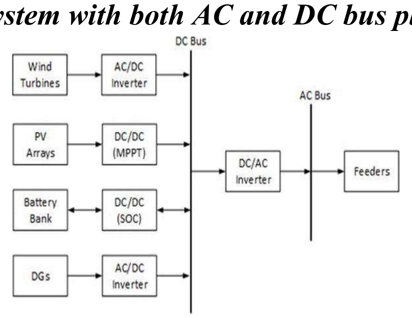
Electricity bus is a good conductor in made into a bus-bar for transporting energy from power generator/converter to the grid. Hybrid renewable energy power system (HRES) has two levels of voltage bus the DC and AC produced by the mixture and crossbreed of energy resources.



Series hybrid RE power system with single AC bus for all AC load.

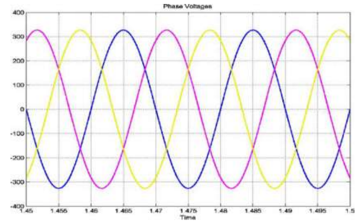


Parallel (hybrid) RE power system with both AC and DC bus plus AC and DC loads



Parallel hybrid RE system with both AC and DC bus for only all AC loads

The above figures are in one line/block schematic representing three phase system for hybrid RE resources to produce output voltage waveform shown in Figure 1.5. However, hybrid RE can be also be designed to supply single phase system for smaller single phase load demand and its output voltage wave is single implied.



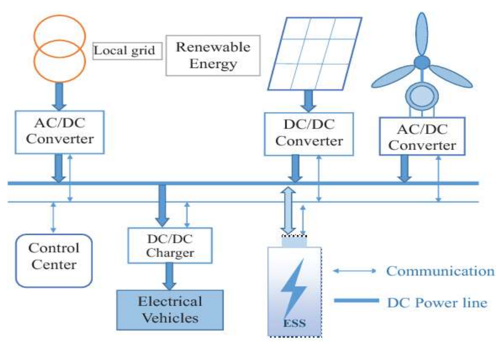
Hybrid RE three phase output voltage waveforms.

Hybridizing is a common strategy for improving the sizing of renewable resource (RER) energy resources; it is also known as crossbreeding in the SPV. The optimum scale of renewable energy resource to harvest energy reliably depends on the optimal design of conversion model. Energy converters are RER and come with assorted characteristics, sizes, and brands guide in the design and the implementation of projects. The RER characteristics of solar photovoltaic and micro hydro are the main focal area to be considered for discussion and analysis in this study.

Problem Statement

Bidirectional DC micro-grids are becoming more popular due to high power handling capability, flexibility to connect many renewable energy sources (RES), reliability, and adaptable to connect loads of two different voltage levels. To handle the bipolar DC micro-grids with energy storage systems, an appropriate DC-DC converter with high voltage gain with simple control strategy is required. To operate at higher voltage and high-power levels with less voltage stress across the switches, a high gain bipolar bidirectional dc-dc converter is proposed but it offered same voltage gain as that of the uni-polar bidirectional converters and also produces electromagnetic interference (EMI). The flying capacitor-based bipolar bidirectional converter proposed in has less voltage stress across the switches but the voltage gain is same as that of the uni-polar bidirectional converter. The switched capacitor based bipolar bidirectional converter proposed which achieves high voltage gain but offer high current stress across the device and also high current ripple. The bipolar bidirectional converter based on neutral point clamped three levelinverters proposed in it has limited duty ratio with high voltage gain. A dc-dc converter of a bidirectional medium voltage "ladder" is proposed in to achieve high voltage.

BLOCK DIAGRAM AND EXPLANATION



Electricity cannot be mined from the ground like coal. So it is called a secondary source of energy, meaning that it is derived from primary sources, including coal, natural gas, nuclear fission reactions, sunlight, wind, and hydropower. Most direct uses of primary energy are limited to generating heat and motion. Electricity, by contrast, is extremely versatile, with a wide range of complex applications. Electricity plays such an essential role in contemporary

American life that its supply and demand are often examined separately from the primary sources used to produce it.

SOLAR ENERGY

The amount of sunlight that strikes the earth's surface in an hour and a half is enough to handle the entire world's energy consumption for a full year. Solar technologies convert sunlight into electrical energy either through photovoltaic (PV) panels or through mirrors that concentrate solar radiation. This energy can be used to generate electricity or be stored in batteries or thermal storage. Below, you can find resources and information on the basics of solar radiation, photovoltaic and concentrating solar-thermal power technologies, electrical grid systems integration, and the non-hardware aspects (soft costs) of solar energy. You can also learn more about how to go solar and the solar energy industry. In addition, you can dive deeper into solar energy and learn about how the U.S. Department of Energy Solar Energy Technologies Office is driving innovative research and development in these areas.

WIND ENERGY

Wind is used to produce electricity by converting the kinetic energy of air in motion into electricity. In modern wind turbines, wind rotates the rotor blades, which convert kinetic energy into rotational energy. This rotational energy is transferred by a shaft which to the generator, thereby producing electrical energy .Wind power has grown rapidly since 2000, driven by R&D, supportive policies and falling costs. Global installed wind generation capacity – both onshore and offshore – has increased by a factor of 98 in the past two decades, jumping from 7.5 GW in 1997 to some 733 GW by 2018 according to IRENA’s data. Onshore wind capacity grew from 178 GW in 2010 to 699 GW in 2020, while offshore wind has grown proportionately more, but from a lower base, from 3.1 GW in 2010 to 34.4 GW in 2020. Production of wind power increased by a factor of 5.2 between 2009 and 2019 to reach 1412 TWh.

Solar Micro DC/DC converter

The Solar Micro DC/DC Converter is a DC/DC converter per module which maximizes solar energy generated per system by performing Maximum Power Point Tracking (MPPT) per module. The Solar DC Micro converters can boost the total solar energy produced up to 30%. The Solar DC Micro converters measure the power and the energy produced per module, as well as the temperature and the voltage of the module. Each The Solar DC Micro converters is equipped with arc detection and determination, which automatically shuts down the module’s DC voltage in case either the module’s temperature or voltage is too high. [350V or 380V DC bus supported.

DC–DC power converters

Various isolated bidirectional DC–DC power converters have been proposed, such as resonant converters, dual fly back, dual-Cuk, dual push–pull, and DAB [72]. Among them,the DAB converter is the most usable one in the DC–DC power stage of DC SST-based ultra fastcharging stations. The advantages of the DAB converter can be listed as bidirectionalpower flow capability and fast power flow mode changing, wide voltage conversion range to interface different voltage levels, and ZVS capability to increase the efficiency.

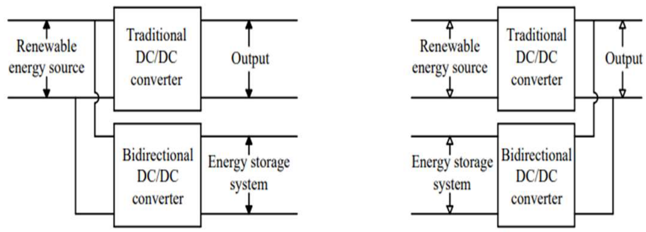
EXISTING SYSTEMS

Traditionally, the renewable energy source is connected to the load through a traditional

DC-DC converter and then the energy storage system is connected to either the input port or the output port of the traditional DC-DC converter through a bidirectional DC-DC converter for charging and discharging as shown in Fig. 1 (a) and Fig. 1 (b) . The main disadvantage of these traditional solutions is the low efficiency due to the utilization of the additional converter for the energy storage system. Also, the multi-stage architecture may result in increased size, low power density, and relatively high cost.

Traditional power electronic systems in renewable energy system, (a) type 1, (b) type 2

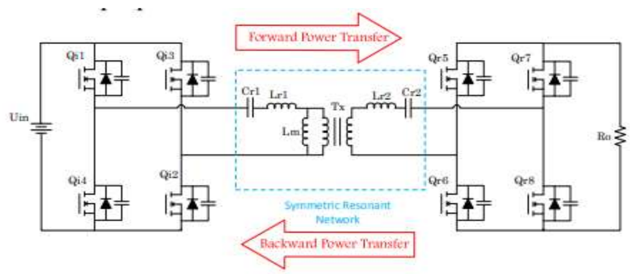
A multi-input converter is a solution to satisfy the requirements of some applications that require the integration of several different types of input energy sources such as fuel cells, wind



turbines, and solar PV . This type of converter can be used to provide the demanded power of the load with a single stage technique; however, no energy storage system is included in these multi-input converters, and hence the system may not be able to meet the required load demand when the output power is greater than the input power. For fuel cell operation, this may happen when there is a sudden increase in load and the chemical reaction of the fuel cell is not fast enough to follow the increase in load. Similarly for solar PV application, there may be fast PV output fluctuation during passing cloud causing the PV output to be less than the load demand or when there is no sun irradiation at night. Wind power output also .Since all of the three ports are connected directly, this type of converter can only be used in those applications where the galvanic insulation is not required. Another disadvantage of the non-isolated three-port converters is that most of these converters have a limited voltage gain since the freedom of modulation of the voltage conversion ratio is only the duty cycle. Some reported papers use coupled-inductor to extend the voltage conversion ratio to overcome this issue. Compared to the non-isolated three-port converters, partly-isolated three-port converters, which use a transformer to isolate one port from the other two common-grounded ports, can obtain higher voltage gain with a larger turn's ratio of the transformer. However, the energy storage system in these converters continues operating in all operating modes, which can shorten the lifespan of the energy system and lower the reliability of the overall system.

Proposed System

The proposed converter is illustrated in It has a symmetric structure: the primary side circuit resembles the secondary side circuit connected by a symmetric high-frequency transformer. The switches Qi1 … Qi4 in the primary inverting stage convert power from dc to ac to transfer it through the high frequency transformer. Using this transformer, the converter achieves galvanic isolation between the primary side and the secondary side. The leakage inductance of the transformer's primary and secondary windings is incorporated into the resonant inductors Lr1 and Lr2, respectively. In addition, Fig. 4.1 shows power flow directions in the converter, which are defined as follows: power being transferred to the load from source



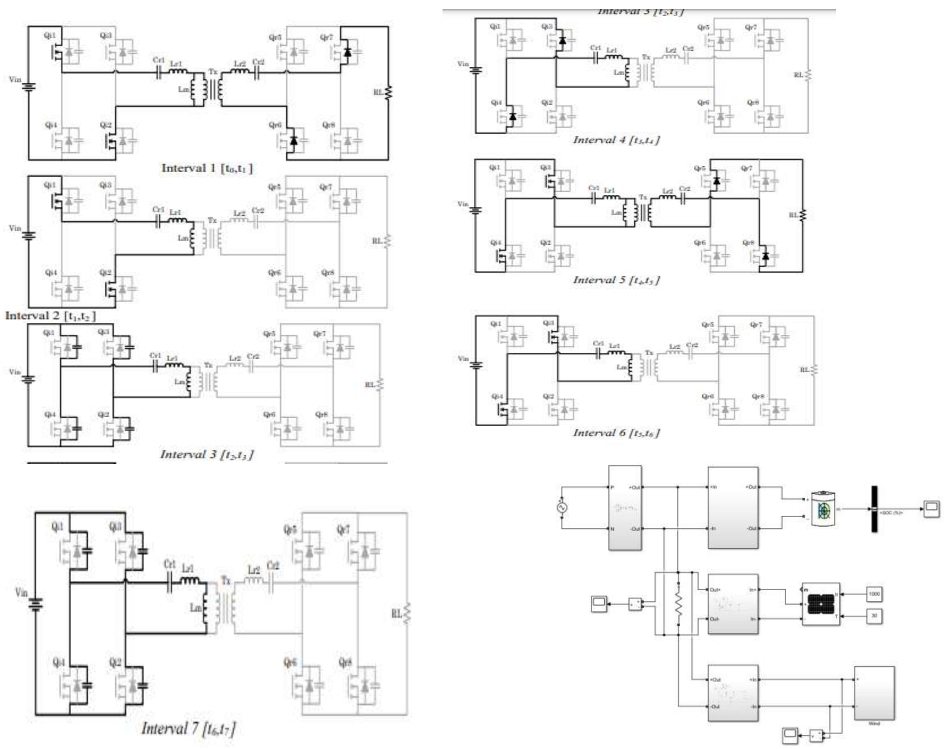
(forward power flow direction) and power being transferred from source to load (backward power flow direction).

Operation

The different operational intervals of the proposed bi directional CLL-LC resonant converter. This converter's operation has been divided into eight operational intervals during a single switching cycle. Intervals 1, 2, 3 and 4 repeat to intervals 4, 5, 6 and 7 with different inverting and rectifying switch pairs. Intervals 2,3 and 4 are dead-time durations, intervals 1 and 5 are power transfer modes. The primary switches work in the inverting mode when power is transferred from the primary to the secondary side; however, the secondary switches remain OFF and the anti parallel diodes operate as rectifiers on the secondary side. Error! Reference source not found. Gives theoretical waveforms showing the behaviour of the converter for all intervals during a single switching cycle. In Error! Reference source not found., there are only the waveforms of the charging mode. However, in the discharging mode, the waveforms are precisely the same as the waveforms of the charging mode, because the primary inverting side and the secondary rectifying side are symmetric. Detailed explanation and description of the operational intervals are given below: Interval 1 [t0 ,t1]: At the instant t0 , the switches Qi1 and Qi2 are conducting and power is transferred from the primary stage to the secondary stage. Resonance takes place between the series elements Cr1, Lr1, Lr2 and Cr2, and the resonant current iLr1 rises in a sine-wave curve. The current in magnetizing inductor iLm also increases but resonates considerably slower than iLr1. Thus Lm does not take part in the resonance phenomenon in this interval. On the secondary side, the rectified currents iQr6 and iQr7, which are carried by the anti-parallel diodes of Qr6 and Qr7 , are proportional to the difference between the terms iLr1and iLm. Interval 2 [t1 ,t2]: After attaining its peak value, iLr1 begins to decline and at the instant t1 becomes equal to the slowly rising magnetic current iLm.

The rectifier current on the secondary side decreases to zero, and the anti-parallel diodes of Qr6 &Qr7 turn off under ZCS. The voltage on the resonant capacitor Cr2 also resonates to its peak with the absolute value of VCr2. It will remain unchanged unless it excites again in the next resonance. The free resonance between Cr1, Lr1, and Lm on the primary side is availed by the disconnection of Cr2 and Lr2. Interval 3 [t2 ,t3]:At time t2 , Qi1 and Qi2 turn off. iLr1 begins to charge the parasitic capacitance of Qi1 and Qi2, and discharge that of Qi3 and Qi4 simultaneously. Since the value of the parasitic capacitance is small compared with that of the resonant capacitor Cr1, this time period is rather short with respect to the total switching period. Thus, the corresponding voltages on the aforementioned capacitance rise/decrease rapidly. This stage ends up with vdQi1,2 reaching the input voltage and vdQi3,4 decreasing to zero. At the end of this stage, the voltage applied on the resonant tank has changed polarity from positive U in to negative.

Interval 4 [t3 ,t4]: When Qi3 and Qi4 are completely discharged, the resonant current iLr1 immediately starts flowing through the anti-parallel body diodes of Qi3 and Qi4, and is fed back to the input source. When the voltage of the magnetic inductor Lm resonates to reach the voltage of V2 –VCr2, the rectifier switches Qr5 and Qr8 conduct, and the resonant capacitor Cr2 and Lr2 participate the resonance with the primary side again. At time t4 , Qi3 and Qi4 turn on under ZVS conditions, the first-half switching period ends, and the converter enters the next (the second) half. Interval 5 to 8: In the next half cycle, the operation of the converter is the same as in the first half cycle, except that the other pair of switches in both the inverting and rectifying stages are operating in the second half.



Operation of the converter for different intervals

MATLAB Simulation & Results

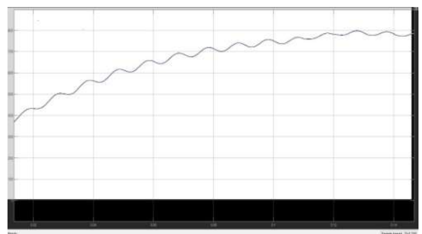
MATLAB is the high-level language and interactive environment used by millions of engineers and scientists worldwide. It lets you visualize ideas disciplines including signals and image processing, communications, control systems, and computational finance. In SIMULINK, it is very straight forward to represent and then simulate a mathematical model representing a physical system. Models are represented graphically in SIMULINK as block diagrams. A wide array of blocks are available to the user in provided libraries for representing various phenomena and models in a range of formats. One of the primary advantages of employing SIMULINK (and simulation in general) for the analysis of dynamic systems is that it allows us to quickly analyse the response of complicated systems that may be prohibitively difficult to analyse analytically. SIMULINK is able to numerically approximate the solutions to mathematical models that we are unable to, or don't wish to, solve "by hand." In general, the mathematical equations representing a given system serve as the basis for a SIMULINK model can be derived from physical laws.

Introduction to Simulink

SIMULINK is a software add-on to mat lab which is a mathematical tool developed by The Math works,(http://www.mathworks.com) a company based in Natick. MATLAB is powered by extensive numerical analysis capability. Simulink is a tool used to visually program a dynamic system (those governed by Differential equations) and look at results. Any logic circuit, or control system for a dynamic system can be built by using standard building blocks available in SIMULINK Libraries. Various toolboxes for different techniques, such as Fuzzy Logic, Neural Networks, DSP, Statistics etc. are available with SIMULINK which enhance the processing power of the tool. The main advantage is the availability of templates building blocks, which avoid the necessity of typing code for small mathematical processes.

RESULTS AND DISCUSSION

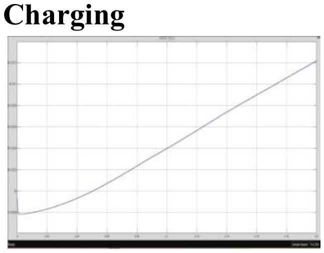
PV Output Waveform



PV Output Waveform MPPT

I have developed a mathematical model of PV module (200W) in discrete form. According to mathematical equations, a feedback is required thus, i have connected a unit delay block as feedback loop for voltage across terminals of current source. For an individual PV module it is working fine as desired and getting correct output waveform for current, voltage, power and IV/PV characteristic also. Then i connected an individual PV module with Boost converter and constant duty cycle is given for a selected set of parameters, then also the system is working properly. After that i connected PV module and Boost converter with MPPT (based on P&O method), anyhow the waveform of voltage, current and power is attending desired value after some delay and got IV-PV characteristic. But the problem arises when i am connecting 8 PV modules to form a 4x4 PV array (3.2KW), with Boost converter and MPPT controller (based on P&O method). In this case for the selected set of parameters, the voltage waveform is not responding and current waveform drops instantly to ZERO after 0.005 sec. Also, the duty cycle is settled down at fixed lower value. I tried for different set of values for associated parameters but result remains same, waveform is not responding after 0.005 sec.

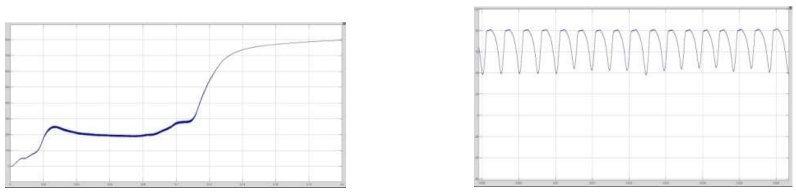
Output and Storage Of Battery Charging



Output and Storage of Battery Charging

Small power battery chargers for devices such as mobile phones, tablets and power tools are ubiquitous. All of these devices are examples of AC/DC converters. Sample 1 is a battery charger for an 18 V power tool battery whilst Sample 2 is a charger for a mobile phone. Both current waveforms, but especially that for Sample 2, have high distortion out to high order harmonics. A battery charger consists of a rectifier circuit, power circuit, ripple monitoring, control circuit, regulator circuit, and fault detection circuit. This charger can also be used as a DC source for a control and protection circuit of a substation during normal operation, or to charge the battery in floating mode. When there is a problem in the AC system, then the battery supplies the DC loads in a substation. There are two types of charging modes: the first is the fast charging for a new or unused batteries, and the second is the floating charge to charge the batteries in service and supply a load to compensate for the small charge lost by the battery in service.

Wind Grid Generating Power



Output Power for Wind Energy

CONCLUSION

The CLL-LC bidirectional DC-DC converter presented in this paper, which has a symmetric resonant tank, offers soft switching as zero voltage switching for the inverting stage and zero current switching for the rectifier switches irrespective of the direction of flow of power. Thus, when MOSFETs are employed as the main switches, the converter has decreased switching losses and is totally snubber less offering reduced size, weight and volume. The operation principles and simulations of the proposed converter have been analysed and depicted. It has been shown that the simulated converter exhibits ZVS for the inverting stage and ZCS for the rectifying stage. The simulation results validate the theoretical analysis and the merits of the converter. Keeping this in view, the converter offers itself as an alternative choice with wide input range, improved efficiency, and high-power density particularly suited for on-board battery charging/discharging applications in electrical vehicles.

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