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Research Article

Hybrid Multi-Port Converter Based Electric Vehicles Using Renewable Energy with Microcontroller

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Abstract: This paper presents to design a hybrid multiport converter using renewable energy sources applied in electric bike. The renewable energy sources used as input to the multiport converter include solar energy, chemical energy from fuel cell and battery. The renewable energy source input is used in order to obtain high fuel economy, low emissions and silent operation. The hybrid multiport converter serves as a bi-directional converter within the electric bike. The cascaded structure of buck-boost converter, transfers the energy stored in battery of a driving motor in the braking mode, and recycles the energy as a result of the Back Electromotive Force (BEMF) in order to charge battery in the operation mode. Moreover, the proposed converter can also serve as a charger by directly connected to AC line. All the experimental results are used to demonstrate the performance of the vehicle via Regenerative Braking system where the energy being utilized is allowed to be stored in the battery or ultra-capacitor. The PIC 16F882 microcontroller is utilized for controlling the gate driver circuit within the hybrid multiport converter and also deals with the switching modes of energy within the battery. The State of Charge (SOC) estimation helps the proposed converter to serve as a charging battery.

Keywords: Back Electromotive Force, electric vehicle, State Of Charge, PIC16F882.

INTRODUCTION

Renewable energy is the energy which comes from natural resources such as sunlight, wind, rain, tides and geothermal heat. These resources are renewable and can be naturally replenished. Therefore, for all practical purposes, these resources can be considered to be inexhaustible, unlike dwindling conventional fossil fuels. The global energy crunch has provided a renewed impetus to the growth and development of Clean and Renewable Energy sources. Clean Development Mechanisms (CDMs) are being adopted by organizations all across the globe. Apart from the rapidly decreasing reserves of fossil fuels in the world, another major factor working against fossil fuels is the pollution associated with their combustion. Contrastingly, renewable energy sources are known to be much cleaner and produce energy without the harmful effects of pollution unlike their conventional counterparts. Solar energy can be utilized in two major ways. Firstly, the captured heat can be used as solar thermal energy, with applications in space heating. Another alternative is the conversion of incident solar radiation to electrical energy, which is the most usable form of energy. This can be achieved with the help of solar photovoltaic cells or with concentrating solar power plants.

Also, fuel cell system can always produce electric power regardless of climate conditions as long as hydrogen and oxygen are supplied. A fuel cell is an electrochemical device, which converts chemical energy directly to electric energy. The power converter converts a low voltage DC from the fuel cell to high voltage DC or AC. Fuel cell is a DC power source of safe, clean and efficient electric power generation. Types of fuel cells are categorized according to the electrolyte used: Proton-Exchange-Membrane (PEM), Phosphoric Acid (PA), Molten Carbonate (MC), Solid Oxide (SO) and Zinc-Air (ZA) fuel cells, etc. The low DC output voltage is boosted to and it is used as an input to microcontroller to produce higher AC voltage for power distribution system. The developments of electric vehicles are becoming important in many countries. The secondary batteries are the main energy sources of the electric vehicles (EV).

Thus, energy management[1] is the most important key factor in EV design[2]. Nowadays, bidirectional converter applied in electric vehicles can provide energy stored in battery for driving motor and offer battery charging or energy recovery. The power management and circuit apologies of single-phase and multi-phase bidirectional converters[3, 4] including non-isolated type and isolated type are all detailed. The non-isolated converters can be categorized into: buck, boost, and buck-boost types, which are low cost, compact size, without transformer, and easy to control due to having common ground. However, a transformer is still essential based on safety considerations, e.g. the voltage ratio between the primary side and secondary side is high enough or these two sides cannot be grounded together. Moreover, flyback type[5] bi-directional converter is commonly used in many related applications. The buck-boost type bidirectional converters not only possess step down and step up functions, but also can control the energy flow to achieve energy recovery[7], which is also suitable for many EV.

The control circuit controls the charging and discharging of the battery. Among the existing power batteries lithium batteries[7-9] possess higher energy density and compact size. The lead acid batteries[10, 11] are not good for its future design trend because of its weight and volume. The proposed bi-directional converter[12, 13] not only transfers the energy stored in battery for driving motor, but also recycles the energy resulted from the back electromotive force (BEMF)[11] to charge battery. Moreover, the charger having SOC[14, 15] estimation function is also integrated in the proposed bidirectional converter to compact size and to reduce cost.

SYSTEM ANALYSIS

Exisiting System:

- In the existing system only one renewable energy are used. The wasted energy during braking cannot be regenerated and reused. Single input source is used which reduces the reliability of the system at various times.
- The existing system does not contain bidirectional converter for regeneration.
- The use of lead-acid battery can offer higher instantaneous output current, very low cost, and more safety, even though its volume and weight are not good for feature design trend.

Proposed System:

- Driving, charging and electric capacity estimation strategies are all embedded in proposed the system. As the semiconductor technology has increased in greater extended, it's possible to compose number inputs into single embedded network.
- To promote system reliability.
- The proposed converter can also serve as a charger by connecting with AC line directly.
- Multi-port concept is being used to get the input from different source at a time. More than one renewable energy can be used as source.
- Regenerative concept is adopted to store the energy back into the battery at the time of braking.

SYSTEM DESIGN

Hardware Design:

Overall Block Diagram:

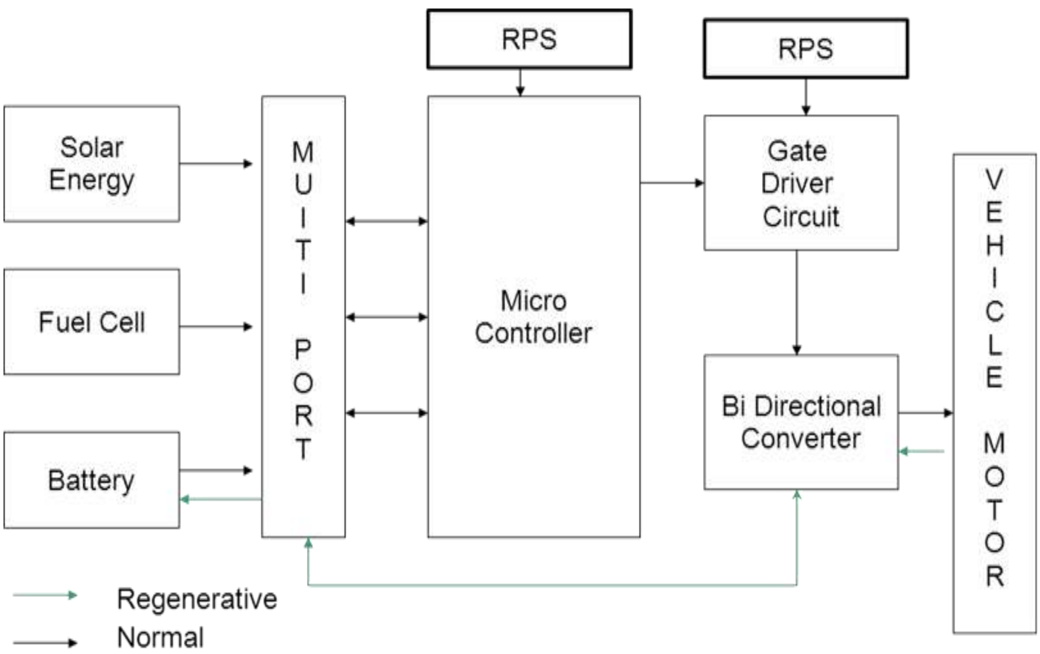

Fig. 1: Overall Block Diagram.

- Three types of energy is given to multiport comparator then the comparator selects the prioritized energy with the help of microcontroller.
- Then from the multiport the energy is given to bidirectional converter which is used to drive the motor.
- When the break is applied the lost energy is regenerated and saved in the battery.
- The gate driver is used to provide isolation between MOSFET and microcontroller
- The bidirectional converter is used for buck and boosts the energy.

PIC16F882: PIC microcontroller is widely used for experimental and modern applications because of its low price, wide range of applications, high quality and ease of availability. It is ideal for machine control applications, measurement devices, and study purpose and so on.

Peripheral Features:

- Timer 0: 8 bit timer/counter with pre-scalar.
- Timer 1: 16 bit timer/counter with pre-scalar.
- Timer 2: 8 bit timer/counter with 8 bit period registers with pre-scalar and post-scalar.
- Two Capture (16 bit/12.5ns), Compare (16 bit/200ns), Pulse Width Modules (10/bit).
- 10 bit multi-channel A/D converter.
- Synchronous Serial Port (SSP) with SPI (master code) and I2C (master/slave).
- Universal Synchronous Asynchronous Receiver Transmitter (USART) with 9 bit addresses detection.
- Parallel Slave Port (PSP) 8 bit wide with external RD, WR and CS controls (40/46pin).

Key Features:

- Maximum operating frequency is 20MHz.
- Flash program memory (14 bit words), 8KB.
- Data memory (bytes) is 368.
- EEPROM data memory (bytes) is 256.
- 5 input/output ports.
- 3 timers.
- 2 CCP modules.
- 2 serial communication ports (MSSP, USART).
- PSP parallel communication port.
- 10 bit A/D module (8 channels).

Architecture of the PIC 16F882:

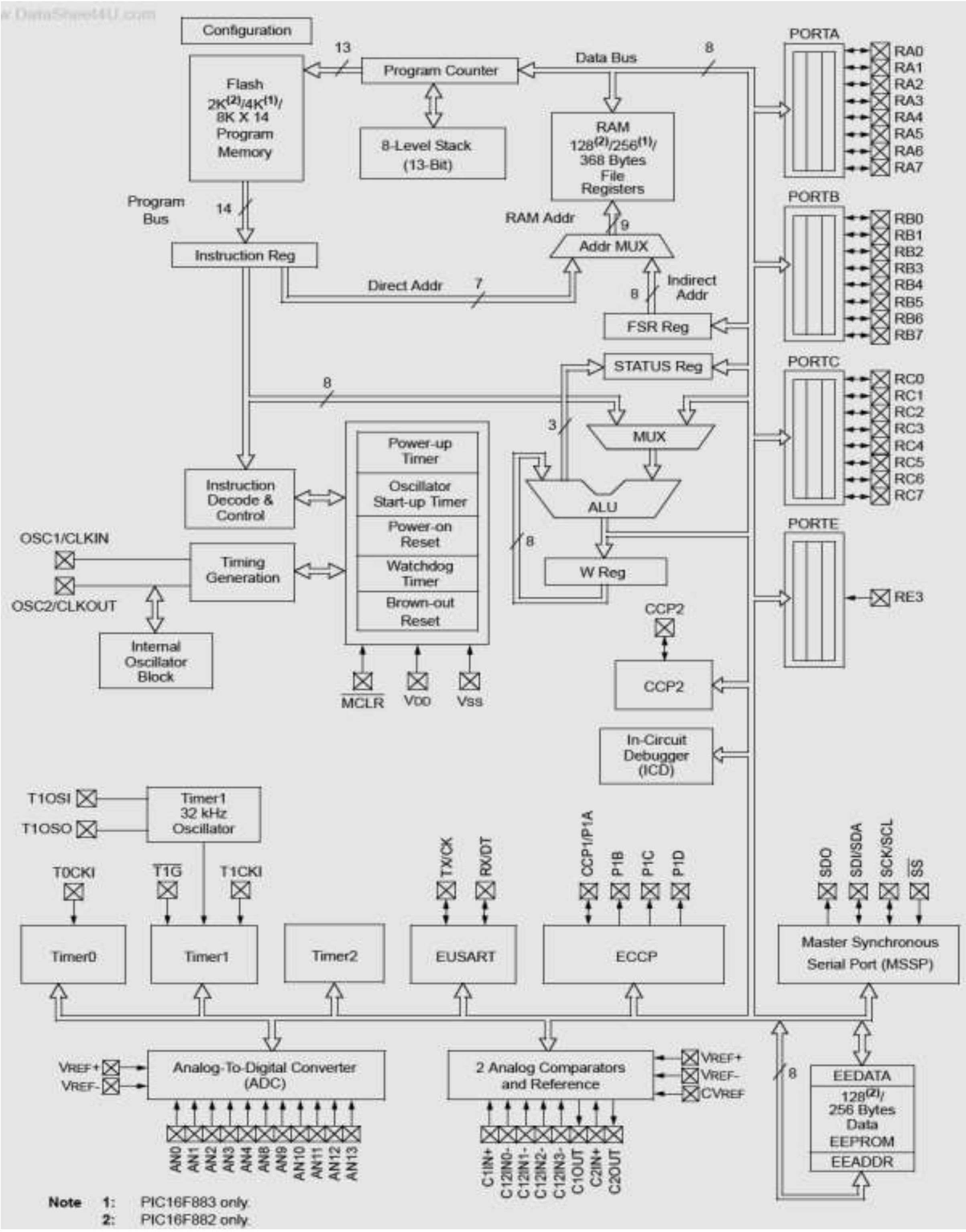

Fig. 2: Architecture of PIC16F882**.**

PIC 16F882 has 5 input/ output ports. They are used for the input/ output interfacing with other devices/circuits. All the port chips are bidirectional. Most of these port pins are multiplexed for handling alternate function for peripheral features on the devices.

Timer-0 Module:

- The main timing/counting features of Timer-0 module are given below.
- Timer-0 module has built in 8 bit timer/counter
- It can be easily readable/writable
- Built in 8 bit software programmable pre-scalar functions
- Easily select internal/external clock pulses
- Interrupt with overflow from the value FFh to 00h
- Edge selection for external clock pulse

Timer 0 interrupt: Timer0 will generate an interrupt when the TMR0 register overflows from FFh to 00h. The T0IF interrupt flag bit of the INTCON register is set every time the TMR0 register overflows, regardless of whether or not the Timer0 interrupt is enabled. The T0IF bit must be cleared in software. The Timer0 interrupt enable is the T0IE bit of the INTCON register.

Timer 1 Module: The operating mode of timer 1 module is selected by using the clock select bit (TMR1CS), in timer mode. The timer 1 increases on every instruction cycle. But in counter mode, it increases on every rising edge of the external clock input. Timer 1 pin can be enabled/disabled easily by setting/clearing the control bit (TMR1ON). This timer1 pin also has an internal reset input function. It can be generated by either of the two CCP modules.

Timer 1 Oscillator: A low-power 32.768 kHz crystal oscillator is built-in between pins T1OSI (input) and T1OSO (amplifier output). The oscillator is enabled by setting the T1OSCEN control bit of the T1CON register. The oscillator will continue to run during Sleep. The Timer1 oscillator is identical to the LP oscillator. The user must provide a software time delay to ensure proper oscillator start-up. TRISC0 and TRISC1 bits are set when the Timer1 oscillator is enabled. RC0 and RC1 bits read as ‘0’ and TRISC0 and TRISC1 bits read as ‘1’.

Timer 2 Module: Timer 2 is an 8-bit timer with a pre-scalar and a post-scalar. It can be used as the PWM (pulse width modulation) time base for the PWM mode of the CCP module(s).

Timer 2 Operation: The clock input to the Timer2 module is the system instruction clock (FOSC/4). The clock is fed into the Timer2 prescaler, which has prescale options of 1:1, 1:4 or 1:16. The output of the prescaler is then used to increment the TMR2 register. The values of TMR2 and PR2 are constantly compared to determine when they match. TMR2 will increment from 00h until it matches the value in PR2.

ENHANCED UNIVERSAL SYNCHRONOUS ASYNCHRONOUS RECEIVER TRANSMITTER (EUSART):

The Enhanced Universal Synchronous Asynchronous Receiver Transmitter (EUSART) module is a serial I/O communications peripheral. It contains all the clock generators, shift registers and data buffers necessary to perform an input or output serial data transfer independent of device program execution. The EUSART, also known as a Serial Communications Interface (SCI), can be configured as a full-duplex asynchronous system or half-duplex synchronous system. These devices typically do not have internal clocks for baud rate generation and require the external clock signal provided by a master synchronous device.

EUSART Asynchronous Mode: The EUSART transmits and receives data using the standard non-return-to-zero (NRZ) format. NRZ is implemented with two levels: a VOH mark state which represents a ‘1’ data bit, and a VOL space state which represents a ‘0’ data bit. NRZ refers to the fact that consecutively transmitted data bits of the same value stay at the output level of that bit without returning to a neutral level between each bit transmission.

EUSART Synchronous Mode: Synchronous serial communications are typically used in systems with a single master and one or more slaves. The master device contains the necessary circuitry for baud rate generation and supplies the clock for all devices in the system.

Synchronous Master Mode: The following bits are used to configure the EUSART for Synchronous Master operation:

- SYNC = 1
- CSRC = 1
- SREN = 0 (for transmit); SREN = 1 (for receive)
- CREN = 0 (for transmit); CREN = 1 (for receive)
- SPEN = 1

Setting the SYNC bit of the TXSTA register configures the device for synchronous operation. Setting the CSRC bit of the TXSTA register configures the device as a master. Clearing the SREN and CREN bits of the RCSTA register ensures that the device is in the Transmit mode, otherwise the device will be configured to receive. Setting the SPEN bit of the RCSTA register enables the EUSART. If the RX/DT or TX/CK pins are shared with an analog peripheral the analog I/O functions must be disabled by clearing the corresponding ANSEL bits.

Synchronous Slave Mode: The following bits are used to configure the EUSART for Synchronous slave operation:

- SYNC = 1
- CSRC = 0
- SREN = 0 (for transmit); SREN = 1 (for receive)
- CREN = 0 (for transmit); CREN = 1 (for receive)
- SPEN = 1

Setting the SYNC bit of the TXSTA register configures the device for synchronous operation. Clearing the CSRC bit of the TXSTA register configures the device as a slave. Clearing the SREN and CREN bits of the RCSTA register ensures that the device is in the Transmit mode, otherwise the device will be configured to receive. Setting the SPEN bit of the RCSTA register enables the EUSART. If the RX/DT or TX/CK pins are shared with an analog peripheral the analog I/O functions must be disabled by clearing the corresponding ANSEL bits.

Bidirectional Converter: A buck-boost converter/regulator provides an output voltage that may be less than or greater than the input voltage. Hence it is called as “buck-boost”.

Buck Converter:

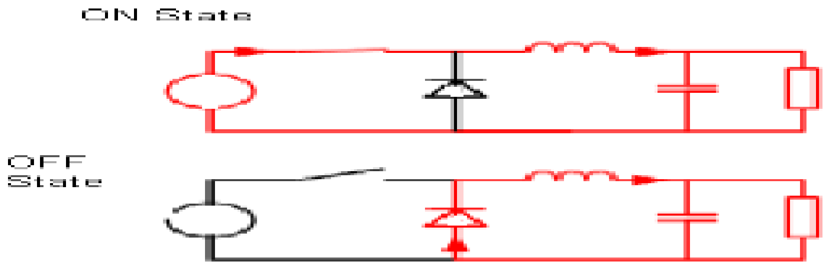

Fig. 3: Buck Converter.

Boost Converter:

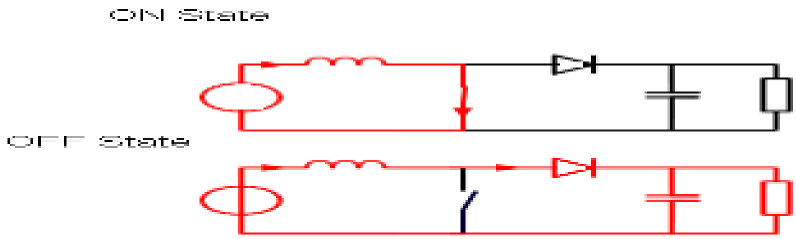

Fig. 4: Boost converter.

$$E_{dc} = \frac{\Delta IL}{T_{ON}}$$

$$E_{O} = \frac{-\Delta IL}{T_{OFF}}$$

Inductor selection

$$I = \frac{E_{dc}D}{Lf}$$

Capacitor Selection

$$Vc = \frac{I_{O}D}{Cf}$$

E_{dc} – input voltage

E_o –output voltage

I -charging & discharging of inductor

D –duty cycle

f –frequency of duty cycle

L ,C –inductor , capacitor

The DC mains (provided by the AC mains), when presented, powers the downstream load converters and the bidirectional converter which essentially operates in the buck mode to charge the battery to a nominal value of 48 V. On failure of the DC mains (derived from the AC mains), the converter operation is comparable to that of a boost and the battery regulates the bus voltage and thereby provides power to the downstream converters. An efficiency of 86.6% is achieved in the battery charging mode and 90% when the battery provides load power. The converter exhibits good transient response under load variations and switchover from one mode of operation to another. Input to the bi-directional converter is fed from various sources and the output is given to the motor. At the time of regenerative braking, the energy from the motor is safely charged through bi-directional converter.

Gate Driver: A gate driver is a power amplifier that accepts a low-power input from a controller IC and produces a high-current drive input for the gate of a high-power transistor such as an IGBT or power MOSFET. The isolated gate-electrode of the MOSFET forms a capacitor (gate capacitor), which must be charged or discharged each time the MOSFET is switched on or off. When a transistor is switched on or off, it does not immediately switch from a non-conducting to a conducting state; and may transiently support both a high voltage and conduct a high current. Consequently, when gate current is applied to a transistor to cause it to switch, a certain amount of heat is generated which can, in some cases, be enough to destroy the transistor. Therefore, it is necessary to keep the switching time as short as possible, so as to minimize switching loss. Typical switching times are in the range of microseconds. The switching time of a transistor is inversely proportional to the amount of current used to charge the gate. For typical gate voltages of approximately 10-15V, several watts of power may be required to drive the switch.

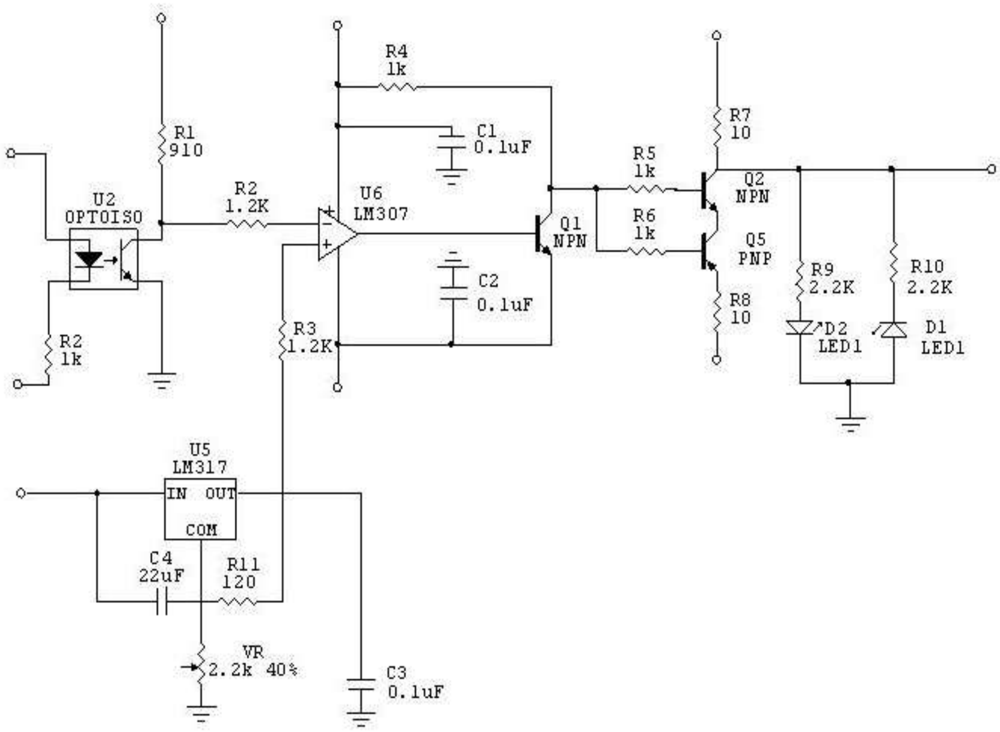

Fig. 5: Circuit diagram of Gate Driver.

Hybrid Multiport Selector: It is used to compare the input source value. It selects which source to be given to the bi-directional converter block. Nowadays world is shifting its concentration towards Electric Vehicle such as the advantages of using renewable energy and free from atmosphere pollution as no carbon emission from the vehicle. The number of sources (eg Solar cell, Fuel Cell, Battery and so on...) is connected to port selector. The main function of the port selectors is that select the source to the converter block. The different sources are assumed to have priority. The source with high priority and source with as high voltage in it are connected to the converter block for the driving operation. When the voltage requirement of the converter is high and charge available in the source is low. The port selector switches to the other source connected to it. At the time of regenerative braking the port selector is connected to the battery so as the battery get charged with the voltage induced at the time of braking.

Circuit Diagram of multiport selector:

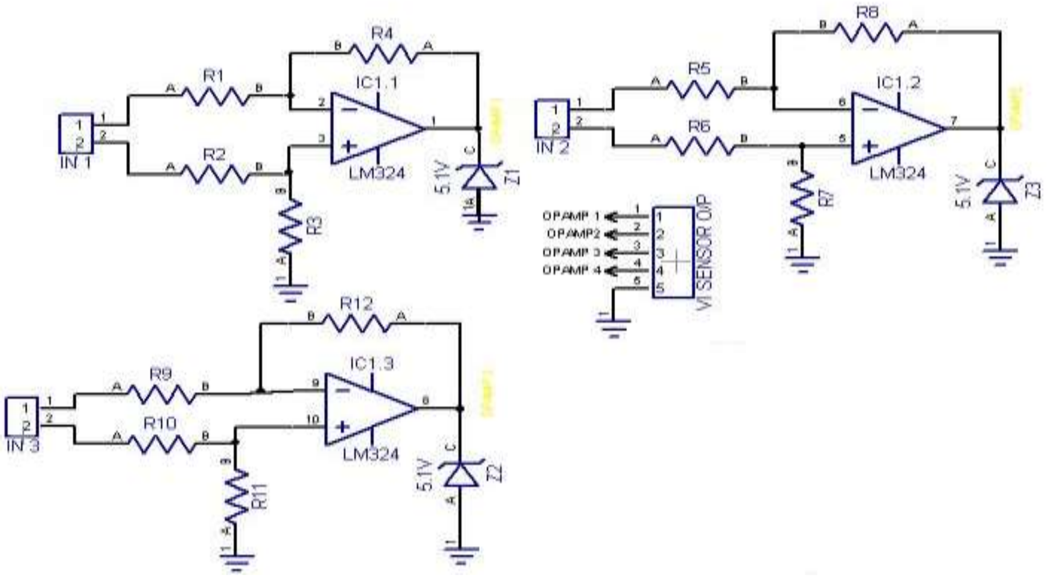

Fig.6: Circuit diagram of multiport selector.

Power supply unit: All the electronic components starting from diode to Intel IC's only work with a DC supply ranging from -+5v to -+12v. We are utilizing for the same, the cheapest and commonly available energy source of 230v-50Hz and stepping down, rectifying, filtering and regulating the voltage. AN7812 is the Positive Voltage Regulator. It regulates the voltage from (almost) 24vDC to 12vDC (accurate). AN7912 is the Negative Voltage Regulator. It regulates the voltage from (almost) -24vDC to -12vDC.A transformer output must be between 12vAC to 24vAC @ 500mA. Input of transformer (Primary) should be about 110vAc-220vAC. It also includes some capacitors to filter the current.

Step down Transformer: When AC is applied to the primary winding of the power transformer it can either be stepped down or up depending on the value of DC needed. In our circuit the transformer of 230v/15-0-15v is used to perform the step down operation where a 230V AC appears as 15V AC across the secondary winding. The current rating of the transformer is 2A. Apart from stepping down AC voltages, it gives isolation between the power source and power supply circuitries.

Voltage Regulators: The voltage regulators play an important role in any power supply unit. The primary purpose of a regulator is to aid the rectifier and filter circuit in providing a constant DC voltage to the device. Power supplies without regulators have an inherent problem of changing DC voltage values due to variations in the load or due to fluctuations in the AC liner voltage. IC7812 and 7912 is used in the circuit for providing +12v and –12v DC supply.

Rectifier Unit: In the power supply unit, rectification is normally achieved using a solid state diode. Diode has the property that will let the electron flow easily in one direction at proper biasing condition. A bridge rectifier of four diodes (4*IN4007) are used to achieve full wave rectification. Two diodes will conduct during the negative cycle and the other two will conduct during the positive half cycle. For a positive cycle, two diodes are connected to the positive voltage at the top winding and only one diode conducts. At the same time one of the other two diodes conducts for the negative voltage that is applied from the bottom winding due to the forward bias for that diode.

Filtering Unit: Filter circuits which are usually capacitors acting as a surge arrester always follow the rectifier unit. This capacitor is also called as a decoupling capacitor or a bypassing capacitor, is used not only to 'short' the ripple with frequency of 120Hz to ground but also to leave the frequency of the DC to appear at the output.

SOFTWARE DESIGN

Embedded C Language: Embedded C is a set of language extensions for the C Programming language by the C Standards committee to address commonality issues that exist between C extensions for different embedded systems. It includes a number of features not available in normal C, such as, fixed-point arithmetic, named address spaces, and basic I/O hardware addressing. Embedded C use most of the syntax and semantics of standard C, e.g., main () function, variable definition, datatype declaration, conditional statements (if, switch. case), loops (while, for), functions, arrays and strings, structures and union, bit operations, macros, unions,etc.

Simulink: Simulink is an environment for multidomain simulation and Model-Based Design for dynamic and embedded systems. It provides an interactive graphical environment and a customizable set of block libraries that let you design, simulate, implement, and test a variety of time-varying systems, including communications, controls, signal processing, video processing, and image processing. Simulink is integrated with MATLAB, providing immediate access to an extensive range of tools that let you develop algorithms, analyze and visualize simulations, create batch processing scripts, customize the modeling environment, and define signal, parameter, and test data.

Conditionally Executed Subsystems: Conditionally executed subsystems let us to change system dynamics by enabling or disabling specific sections of your design via controlling logic signals. Simulink lets you create control signals that can enable or trigger the execution of the x subsystem based on specific time or events.

RESULTS AND DISCUSSIONS

PWM[16] techniques are dealt in detail and it obtains ZVS[17, 18] with the proposed modulation strategy, the buck boost inductance is selected and the switches are gated in a way that the inductor current has a negative offset current at the beginning and the end of each pulse period. It reduces the component requirements. The development of soft-switching power converters for electric vehicle (EV) propulsion[18] and recent research trends will also be discussed, with emphasis on soft-switching converters for dc motor drives, soft-switching inverters for ac motor drives and soft-switching converters[2, 19] for switched reluctance motor (SRM) drives. The proposed converter[20] circuit provides low voltage stresses across the switches, higher step-up and step-down voltage gains and efficiency is also high. Air pollution is controlled by using the renewable energy source as input. Regeneration concept[13] is also implemented.

Renewable Energy Trends Across The Globe: Renewable energy accounted for 60% of the newly installed power capacity in Europe in 2009 and nearly 20% of the annual power production. Wind and biomass occupy a major share of the current renewable energy consumption. Recent advancements in solar photovoltaic technology and constant incubation of projects in countries like Germany and Spain have brought around tremendous growth in the solar PV market as well, which is projected to surpass other renewable energy sources in the coming years. By 2009, more than 85 countries had some policy target to achieve a predetermined share of their power capacity through renewable. This was an increase from around 45 countries in 2005. The European Union's target of achieving 20% of total energy through renewable by 2020 and India's Jawaharlal Nehru Solar Mission, through which India plans to produce 20GW solar energy by the year 2022.

PHOTOVOLTAIC SYSTEM COMPONENTS

Photovoltaic Cell: A photovoltaic cell or photoelectric cell is a semiconductor device that converts light to electrical energy by photovoltaic effect. If the energy of photon of light is greater than the band gap then the electron is emitted and the flow of electrons creates current. However a photovoltaic cell is different from a photodiode. In a photodiode light falls on channel of the semiconductor junction and gets converted into current or voltage signal but a photovoltaic cell is always forward biased.

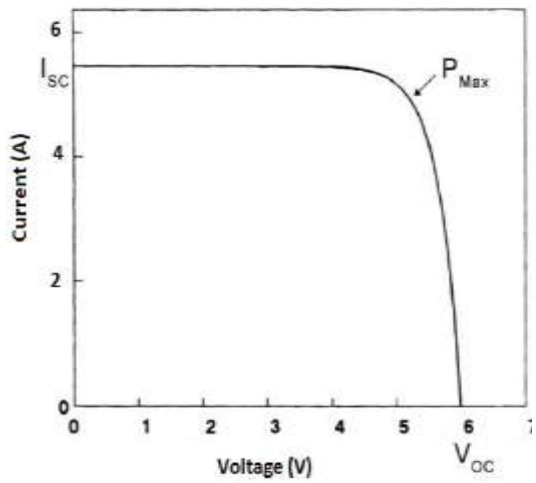

Fig. 7: I-V characteristic of a solar panel

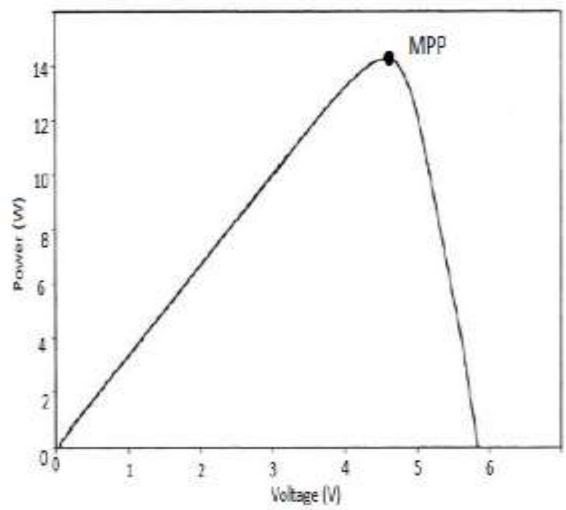

Fig. 8: P-V characteristic curve of photovoltaic cell

CONCLUSION

This paper proposes the improved performance of the hybrid multiport converter applied in electric bike using more than one renewable energy sources as input. It also implements the high efficiency of the performance of the vehicle through the regenerative braking system where the energy is stored back to the battery for future use. The proposed converter can also serve as a charger by connecting with AC line directly. Multi-port concept is being used to get the input from different source at a time. Hence the experimental results demonstrate the feasibility of the vehicle with low fuel economy and silent operation.

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