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# Integration of Ultra-Capacitor Using Bidirectional Converter with RES Applications


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*Abstract:*
***Renewable energy sources can be used to provide constant loads. Bidirectional dc-dc converters (BDC) have recently received a lot of attention due to the increasing need to systems with the capability of bidirectional energy transfer between two dc buses. The controller of the converter system has been designed and simulated based on the integration of both Current Mode Control and Linear Quadratic Regulator methods. The controller performance is tested under different modes of operating conditions in bidirectional converter using MATLAB/Simulink simulation package.***

*Key words:* ***Ultra-capacitor, bidirectional converter, Renewable energy sources, Voltage control.***

## INTRODUCTION

The widespread industrial use of induction motor (IM) has been stimulated over the years by their relative cheapness, low maintenance and high reliability. The control of IM variable speed drives often requires control of machine input voltage, which is normally achieved by using a voltage source inverter. And also we have so many different types of controlling methods like as v/f, FOC, DTC, PDTC etc… respectively based upon industries requirements[1]. The low cost applications usually adopt v/f scalar control when no particular performance is required. Variable-speed pumps, fans, air conditioners.

Here to run the Induction motor either home applications or industrial applications we are depending upon renewable sources why because there is a need to save the fossil fuels and maintains environment free. The output power obtained from renewable source is fed to a ultra-capacitor through DC-DC converter and that converter must have the capability to allow both directions of power flow between the ultra-capacitor and the DC link, and also the ability to increase or decrease the voltage level in each power flow direction; since the voltage level of the ultracapacitor and the DC link are different [2]. Therefore, a bidirectional DC-DC converter is used.

In bidirectional DC-DC converters, there are two modes of operation. The first mode is the boost mode, where the ultracapacitor is discharged to a higher voltage level at the DC link; in the second mode, namely the buck mode; here the excess power from the renewable source charges Ultracapacitor.

There is different types of controlling methods are present to interface the renewable energy source with a storage device and run an induction motor. The authors in reference applied the dynamic evolution control method to interface a fuel cell and the ultracapacitor. In literature, the PI controller was designed for the integration of wind energy conversion system and ultracapacitor. The current programmed mode (CPM) duty ratio control and linear PI compensator was reported in for controlling a bidirectional converter interfacing wind energy conversion and battery storage system [3]. A combination of both fuzzy and sliding-mode control strategies to interface the wind energy conversion system and the storage device has been proposed. Different from that available in the literature, the proposed controller in this paper introduces feedback paths that are calculated optimally to minimize an associated cost function, which is expected to improve the dynamic performance of the system.

Connecting the renewable source and the ultra-capacitor requires a power converter and a DC link. The converter must have the capability to allow both directions of power flow between the ultra-capacitor and the DC link, and also the ability to increase or decrease the voltage level in each power flow direction; since the voltage level of the ultra-capacitor and the DC link are different. Therefore, a bidirectional DC-DC converter is used.

In bidirectional DCDC converters, there are two modes of operation. The first mode is the boost mode, where the ultra-capacitor is discharged to a higher voltage level at the DC link; in the second mode, namely the buck mode; here the excess power from the renewable source charges ultra-capacitor. Various control methods have been proposed in the literature to interface renewable energy sources with a storage device using a bidirectional converter. In this project we observe the speed characteristics of induction motor fed by renewable sources like as wind and solar power.

## BIDIRECTIONAL DC/DC CONVERTER WITH ULTRACAPACITOR

Renewable energy is generally defined as energy that comes from resources which are naturally replenished on a human timescale such as sunlight, wind, rain, tides, wave’s andgeothermal heat. Renewable energy replaces conventional fuels in four distinct areas: electricity generation, hot water/space heating, motor fuels, and rural (off-grid) energy services. Based on REN21's 2014 report, renewables contributed 19 percent to our energy consumption and 22 percent to our electricity generation in 2012 and 2013, respectively.

A supercapacitor (SC), sometimes ultra-capacitor, formerly electric double-layer capacitor (EDLC)) is a high-capacity electrochemical capacitor with capacitance values up to 10,000 farads at 1.2 volt that bridge the gap between electrolytic capacitors and rechargeable batteries. They typically store 10 to 100 times more energy per unit volume or mass than electrolytic capacitors, can accept and deliver charge much faster than batteries, and tolerate many more charge and discharge cycles than rechargeable batteries. They are however 10 times larger than conventional batteries for a given charge.

Ultra-capacitor are used in applications requiring many rapid charge/discharge cycles rather than long term compact energy storage: within cars, buses, trains, cranes and elevators, where they are used for recovery energy from braking, short-term energy storage or burst-mode power delivery. Smaller units are used as memory backup for static random-access memory (SRAM). Ultra-capacitor doesn’t have a conventional solid dielectric. They use electrostatic doublelayer capacitance or electrochemical pseudo capacitance or a combination of both instead:

Electrostatic double-layer capacitors use carbon electrodes or derivatives with much higher electrostatic double-layer capacitance than electrochemical pseudo capacitance, achieving separation of charge in a Helmholtz double layer at the interface between the surface of a conductive electrode and an electrolyte. The separation of charge is of the order of a few angstroms (0.3–0.8 nm), much smaller than in a conventional capacitor. Electrochemical pseudo capacitors use metal oxide or conducting polymer electrodes with a high amount of electrochemical pseudo capacitance. Hybrid capacitors, such as the lithium-ion capacitor, use electrodes with differing characteristics: one exhibiting

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mostly electrostatic capacitance and the other mostly electrochemical capacitance. The electrolyte forms a conductive connection between the two electrodes which distinguishes them from electrolytic capacitors where the electrolyte is the second electrode (the cathode). Super-capacitors are polarized by design with asymmetric electrodes, or, for symmetric electrodes, by a potential applied during manufacture.

A comparison of ultra-capacitor circuit models has previously been made in reference [4]. In this paper, the equivalent circuit of ultra-capacitor model as reported in [5] is applied to simulate the ultra-capacitor. As represented in Fig.1, the model consists of a capacitance Cuc, an equivalent parallel resistance Rp, and an equivalent series resistance Rs.

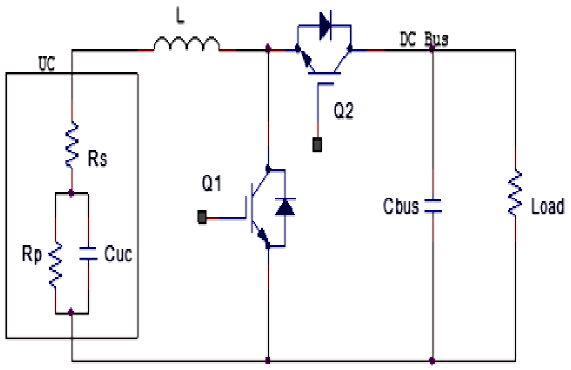


**Fig.1: The electrical circuit of ultra-capacitor-bidirectional DC-DC converter topology**

To realize the reversible direction of power flow in bidirectional DC-DC converters, the switch should ideally carry the current in both directions. Therefore, it is usually implemented with a unidirectional semiconductor power switch connected in parallel to a diode [6]. In the first direction, the converter transfers the energy from the ultra-capacitor to the DC bus when starting up the renewable generation system, and during the transient load conditions. When there is an excess energy at the DC bus, the converter charges the ultra-capacitor in its low-side. According to literature [7-9], the buck charging and boost discharging current modes share the same power plant transfer function; therefore, sharing a unified controller is tolerable.

## SIMULATIONRESULTS

In this section, the MATLAB/Simulink simulation results for different operation modes of the bidirectional converter that interfaces the ultra-capacitor to the DC bus are depicted and discussed. The simulated system diagram is shown in Fig. 4, and the used parameters for the converter and the ultra-capacitor are listed in Table I. The initial voltage of the capacitor is 48V, and the LQR-CMC controller.

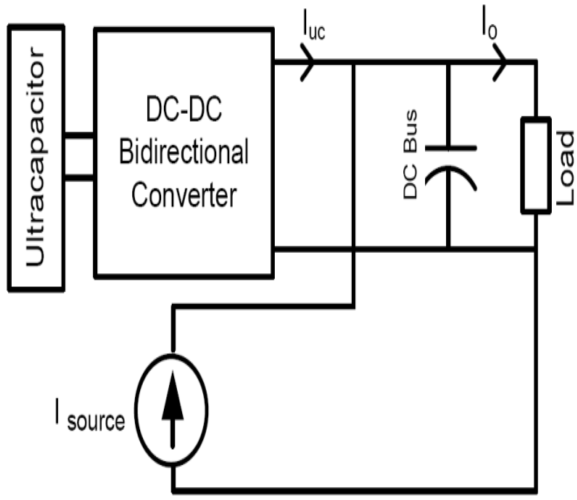


**Fig 2: the block diagram of the proposed interfacingsystem**

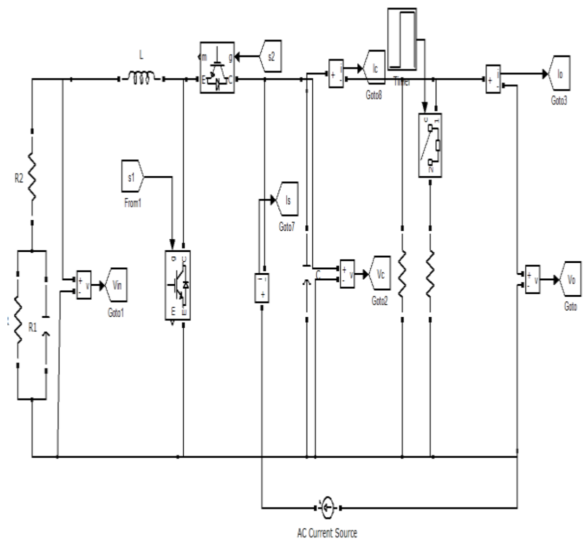


**Fig 3: simulation circuit step variation in the load current from 5 A to 15 A and then to 5 A of**

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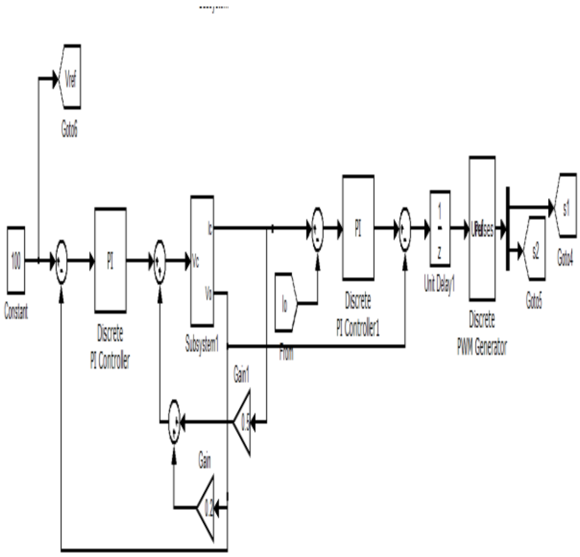
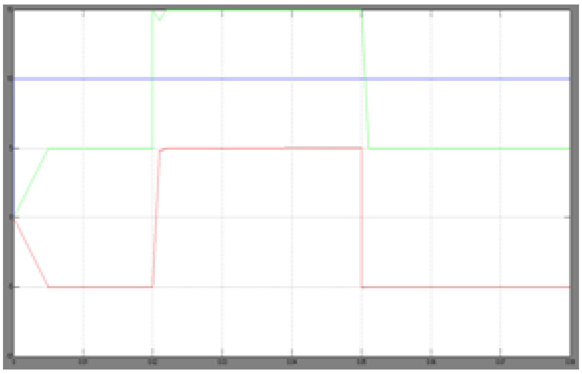
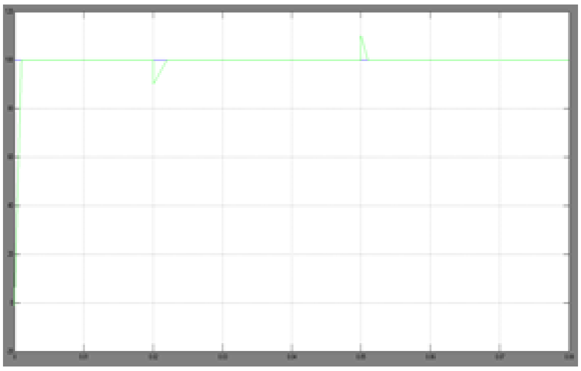



Fig 4: control strategy step variation in the load current from 5 A to 15 A and then to 5 A of



(a)



(b)

Fig 5: The responses of a step variation in the load current from 5 A to 15 A and then to 5 A of: (a) Load and ultra-capacitor currents (Io, Iuc), (b) Output and reference voltages (Vo, Vref).

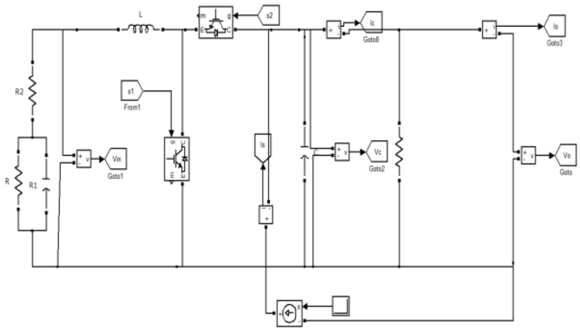


Fig 6: simulation circuit step variation in the output voltage reference from 100 V to 110 V and then to 90 V of:

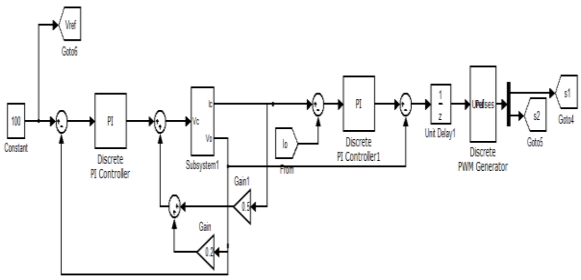
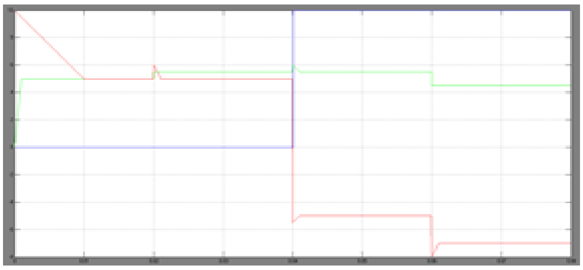
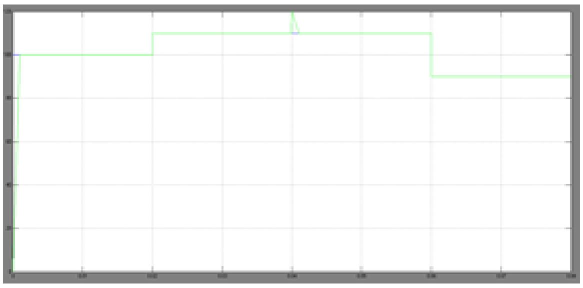



Fig 7: control circuit step variation in the output voltage reference from 100 V to 110 V and then to 90 V of:



(a)



(b)

Fig 8: The responses of a step variation in the output voltage reference from 100 V to 110 V and then to 90 V of: (a) Load and ultracapacitor currents (Io, Iuc), (b) Output and ultracapacitor voltages (Vo, Vuc).

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## CONCLUSION

The LQR-CMC method hasbeen successfully applied to control the bidirectional converterin the case of boost and buck modes. The objectives of thecontroller were to regulate the output voltage and to achieve asmooth transition between the two operation modes of thebidirectional converter, namely buck and boost modes.Inaddition, the proposed controller ensures continuous powersupply the load, regardless of the load and renewable energypower changes.

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