AN AUTOMATED INTEGRATED SOLAR/WIND BASED BATTERY CHARGING SYSTEM FOR SUPERCAPACITOR STACK USED IN HYBRID ELECTRIC VEHICLE

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Abstract: *The scarcity and cost of fossil fuels combined with their greenhouse gas emissions, make the development of non-fossil fuel-based methods of transportation a high-priority task. This paper proposes the designing and sizing of an Integrated solar and wind based Hybrid Charging System (ISWHCS) along with super capacitors to be used in Hybrid Electric Vehicle (HEV) propulsion. It includes a solar cell charger, Internal Combustion Engine (ICE), wind propeller on-board sources and a combined Energy Storage System (ESS) comprising a battery stack and super capacitor. Based on the speed, load and availability of proposed sources, number of batteries and super capacitors are automatically selected for propulsion by using computer and interfacing circuits. To realize this logic, a program has been developed in 'C' language. This logic also helps in controlling the charging and discharging times of the batteries and super capacitor placed in the energy storage system.*

Key Words: *charging system, Super capacitors, system integration, Hybrid Electric Vehicle.*

1. Introduction

With the spiraling fuel costs and the environmental concerns due to the use of conventional, non-renewable fossil fuels, automobile engineers have had to develop more economical and environmentally safer alternatives to the internal combustion engine that powers most cars and huge trucks. This has led to the birth of the hybrid automobile. Hybrid Electric Vehicle (HEV) as shown in figure.1 combines a conventional internal combustion engine (ICE) propulsion system with an electric propulsion system. The presence of the electric power train is intended to achieve either better fuel economy than a conventional vehicle, or better performance or both. Emissions from hybrid electric motor vehicles are also substantially lower than conventionally powered motor vehicles."Hybrid-Electric Drive" (HED) systems are promising up to 30 – 40 percent savings, compared to current internal-combustion engines. [1]. The electrical energy storage typically consists of a battery with more or less complex support-electronics for charge control and error prevention. The storage unit has to store relatively large amounts of energy and handle high power. With current battery technology, the energy storage capacity comes at a cost of decreased power capability and the lifetime of the modern batteries is dependant of the charge cycles. By introducing a super capacitor as aid, the battery could be spared from the power peaks and thus allow the battery to be optimized for energy storage or extend the lifetime of a given battery, which in turn could lower the cost of the entire unit. With this technique, it is also possible to have sophisticated control of the energy storage power flows, which can improve the system if proper strategies are used.

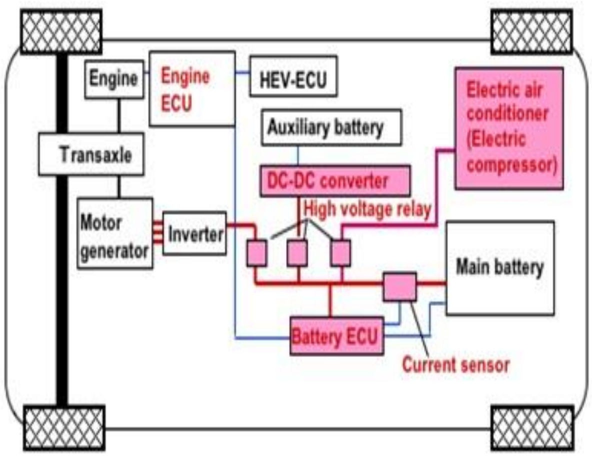

Fig.1 Block diagram of Hybrid Electric Vehicle

2. Super Capacitors

Battery is suitable to provide the energy buffer to the HEV due to that battery has the ability to store relatively high levels of electrical energy. In the market of today there exist several model and sizes. The problems with batteries are mainly the cost, lifetime and size.The storage of electrical charge in the interface between a metal and an electrolytic solution has been studied by chemists since the nineteenth century, but the practical use of double-layer capacitors only began in 1957, when a patent was placed by General Electric for an electrolytic capacitor using porous carbon electrodes. Later, in 1966, The Standard Oil Company, Cleveland, Ohio (SOHIO) patented a device that stored energy in the double layer interface. By the 1980's a number of companies were producing electrochemical capacitors. Matsushita Electric Industrial Co., (otherwise known as Panasonic in the Western world), had developed the "Gold capacitor" since 1978. By 1987 ELNA had begun producing their own double-layer capacitor under the name "Dynacap". The first high-power double-layer capacitors were developed by PRI. The Super capacitors also called ultra capacitors with capacitance values greater than any other capacitor type available today. Capacitance values reaching up to 400 Farads in a single standard case size are available. Super capacitors have the highest capacitive density available today. Super capacitors are not as volumetrically efficient and are more expensive than batteries but they do have other advantages over batteries making the preferred choice in applications requiring a large amount of energy storage to be stored and delivered in bursts repeatedly. "PRI Ultracapacitor," developed from 1982, incorporated metal-oxide electrodes and was designed for military applications such as laser weaponry and missile guidance systems . News of these devices triggered a study by the United States Department of Energy (DoE) in the context of hybrid electric vehicles, and by 1992 the DoE Ultracapacitor. [2] Development Program was underway at Maxwell Laboratories. It is necessary to have a storage utility, which could be a battery or supercapacitor or a combination of the both, to work as the source of energy and power In this paper, a combination consisting of a supercapacitor in parallel with a battery is studied. The supercapacitor has the merits of a rapid charge and discharge of energy and a longer life cycle, because of electrostatic nature of capacitor rather than chemical reaction. The most significant advantage supercapacitors have over batteries is their ability to be charged and discharged continuously without degrading like batteries do. This is why batteries and supercapacitors are used in conjunction with each other. The supercapacitors will supply power to the system when there are surges or energy bursts since supercapacitors can be charged and discharged quickly while the batteries can supply the bulk energy since they can store and deliver larger amount energy over a longer slower period of time.

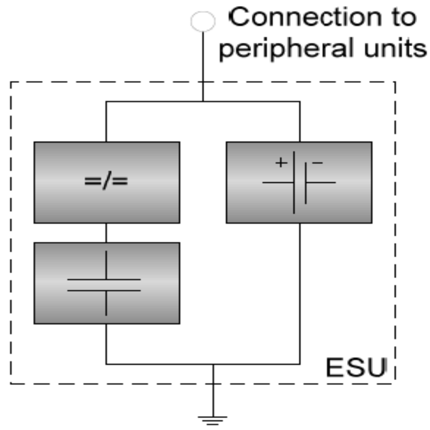

Fig.2 Equivalent circuit diagram of super capacitor

3. Proposed Block diagram of Charging system

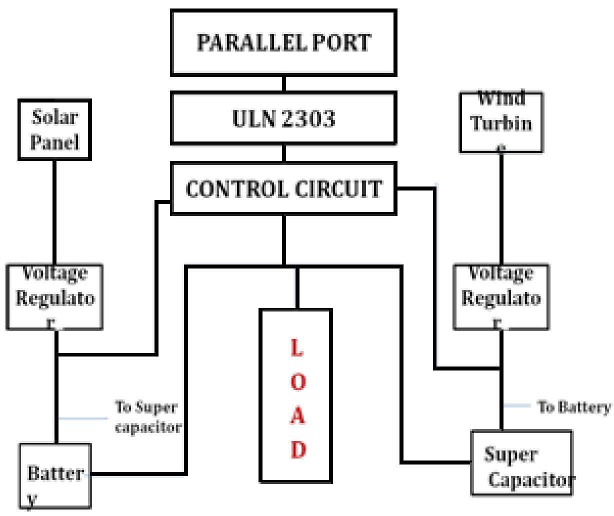

Fig.3 Block diagram of charging system

The proposed block diagram for charging system in Hybrid Electric Vehicle is shown in figure.3. It comprises of parallel port, voltage regulator, battery, super capacitor, solar panel and wind turbine. The parallel port as shown in figure.4 allows an input of up to 9 bits and gives an output of 12 bits at any given time, thus requiring minimal external circuitry to implement many simpler tasks. The port comprises four control lines, five status lines and eight data lines, and is found at the back of any PC as a D-type 25 pin female connector. The port addresses are needed to communicate the PC to driver circuit .The parallel port has three commonly used base addresses. The 378h and 278h addresses are commonly used for parallel ports. The lowercase 'h' denotes that it is in hexadecimals.

These addresses may differ from machine to machine. The PC parallel port is a 25-pin D-shaped female connector at the back of the computer connecting computers to printers, but many other types of hardware for that portage available today. Not all 25 pins are needed always. Usually, it can be done with only eight output pins (data lines) and a signal ground. [4]. The LM317 is an adjustable 3–terminal positive voltage regulator is capable of supplying in excess of 1.5A over an output voltage range of 1.2 V to 37 V. This voltage regulator is exceptionally easy to use and requires only two external resistors to set the output voltage. Further, it employs internal current limiting, thermal shutdown and safe area compensation, making it essentially blow–out proof. The LM317 serves a wide variety can be used as a precision current regulator.[5]. The LM317 is an adjustable 3–terminal positive voltage regulator as shown in figure 5 is capable of supplying in excess of 1.5 A over an output voltage range of 1.2 V to 37 V.

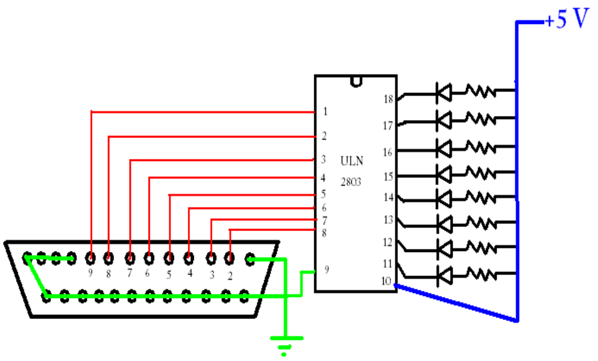

Fig.4 Parallel port connection with ULN 2803

The interfacing block is used to connect the hardware circuit to the program executing in PC. This interfacing block consists of Parallel Port, and . ULN driver. The interconnection of parallel port with the ULN driver circuit is as shown in fig.4

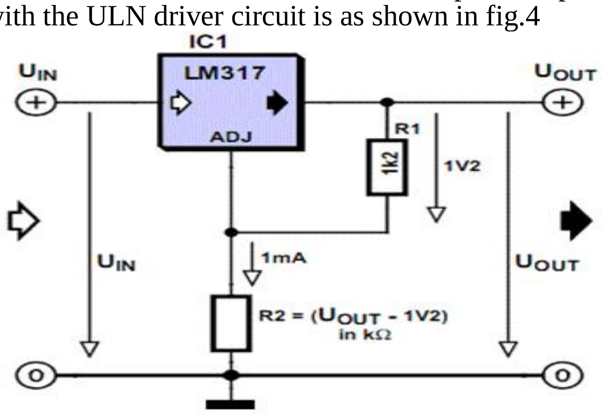

Fig.5 Voltage regulator circuit

The output voltage of this regulator circuit is given by

$$V_{out} = 1.25V\left(1 + \frac{R_2}{R_1}\right) + IR_2\text{--------}(1)$$

A solar panel is placed in the circuit which is used to trap the solar energy throughout the day. [6] The output of the solar panel is given to a voltage regulator since the voltage output of the panel depends on solar energy which is not constant throughout the day. Thus the regulator fixes the output of the panel at the desire value i.e, 12V in this case. In additional to the solar energy, wind energy is also used to propel the vehicle. The kinetic energy of the wind is converted into electrical energy by means of a wind turbine and a dynamo assembly. The output of the dynamo is entirely dependent on the velocity of the wind. But, the velocity of wind is not constant. So, a wind stabilizer circuit is used to maintain the constant output from wind source. Both the outputs from the solar energy and the wind energy are connected across the two charging devices battery and super capacitor. Apart from theses renewable sources, an onboard supply is also provided which is used to charge battery and super capacitor. A plug in supply can also be used to charge the HEV during the rest conditions. The load i.e, the motor of the HEV is connected across both the battery and super capacitor. Now the HEV can be propelled using either battery or super capacitor according to the input provided by the user. Similarly, the battery and super capacitor can be charged using either wind or solar energy according to the availability of the sources and the choice of the user. The battery, super capacitor and load are interconnected through a control circuit consisting of relays. These relays are controlled with the output of the ULN2803 driver circuit. [7],[8]. The ULN driver is used to connect the output of the parallel port to the relay circuit. The output of the parallel port is the port address generated based on the operation to be performed to charge and propel the HEV according to the choice of user.

4. Software and hardware implementation of Proposed Charging system

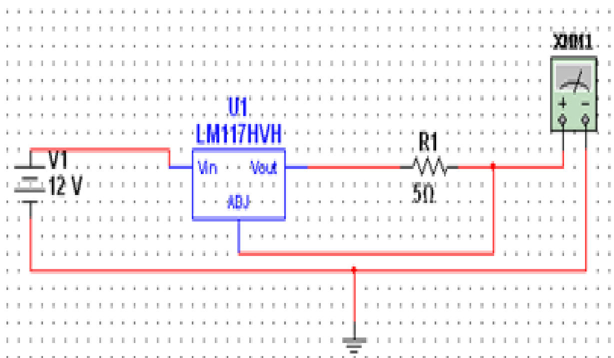

Fig.6 Voltage regulator simulation circuit

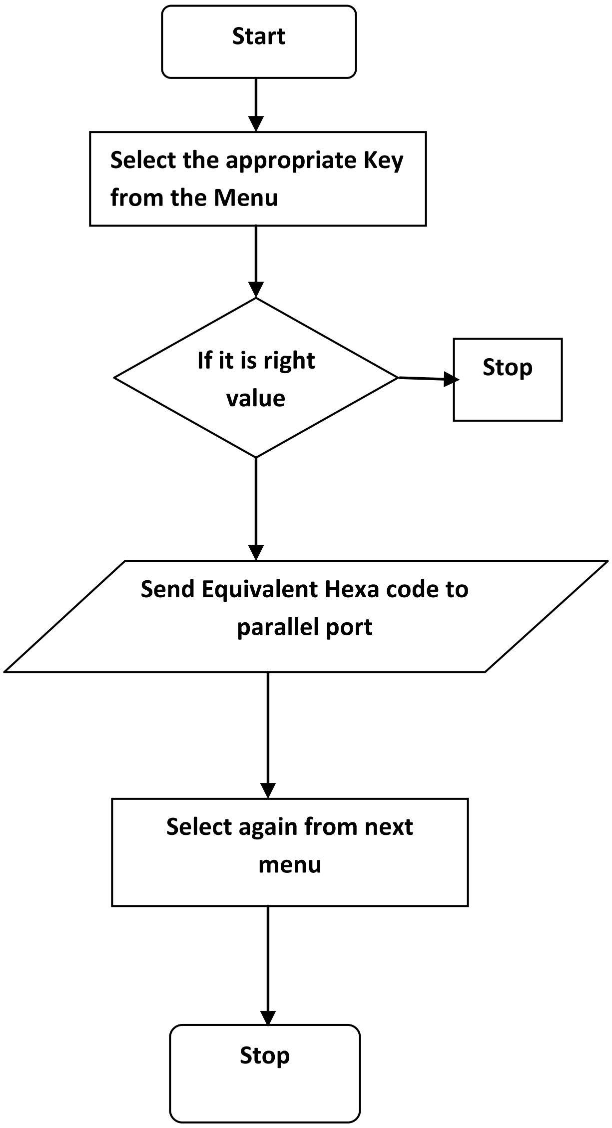

Fig. 7 Algorithm for controlling the charging system of HEVs

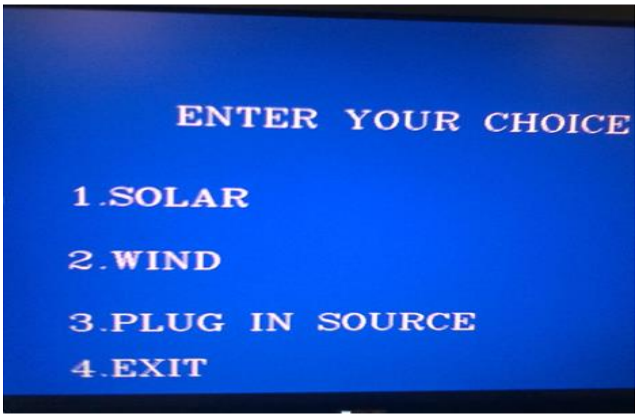

Fig.8 Main menu of software system

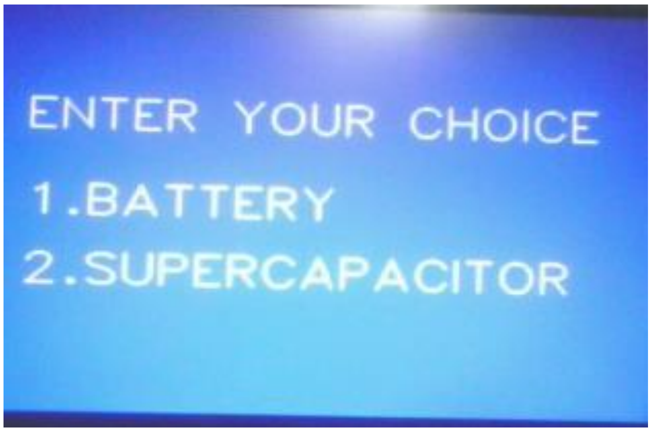

Fig.9 Choice selection page for Battery

Pspice software is used for simulating various circuit diagrams. There are many things that Pspice just does better than most schematic capture and simulation packages. Ease of use is one of the most important features. Simulation of proposed charging system and logic required for system integration are given from figure.10 to figure.11 respectively. Simulation of Voltage regulator is shown in figure.6 The algorithm used for realizing this logic is shown in Figure.7. Based on the instructions received from the printer port shown in figure 8 and figure.9, the HEV and charging circuit of the vehicle are controlled. To verify the operational principles of the proposed method, a prototype is implemented which are given from figure12 to figure.14. The hardware part of an ISWHCS is implemented and tested in the laboratory and is found to work satisfactorily [9],[10]. The various components of the project are placed on a wooden plank. The pins 1-8 of the ULN 2803 driver is connected to the pins 2-9 of the parallel port. The parallel port is connected to the PC through a 25 pin D connector. Four 12V relays are connected to the ULN driver such that the relay becomes active only when it receives a signal from the parallel port. To achieve this, one of the supply terminals of all the four relays are connected to positive 12V supply and the negative is connected through the driver. [11-13] . The output of the solar panel and wind turbine is given to a voltage regulator circuit. Now the battery and super capacitor are connected to the solar and wind sources through relays. The load i.e, the motor of the HEV is connected across battery and supercapacitor through another two relays. Thus by giving proper port addresses from the Personnel Computer (PC) through 'C' program , the relays operate in sequence to charge the charging system and to propel the HEV. Charging time of battery and super capacitor are shown graphically in figure.15. Simulation results are used while designing and fabrication of the various circuit diagrams proposed in this paper.

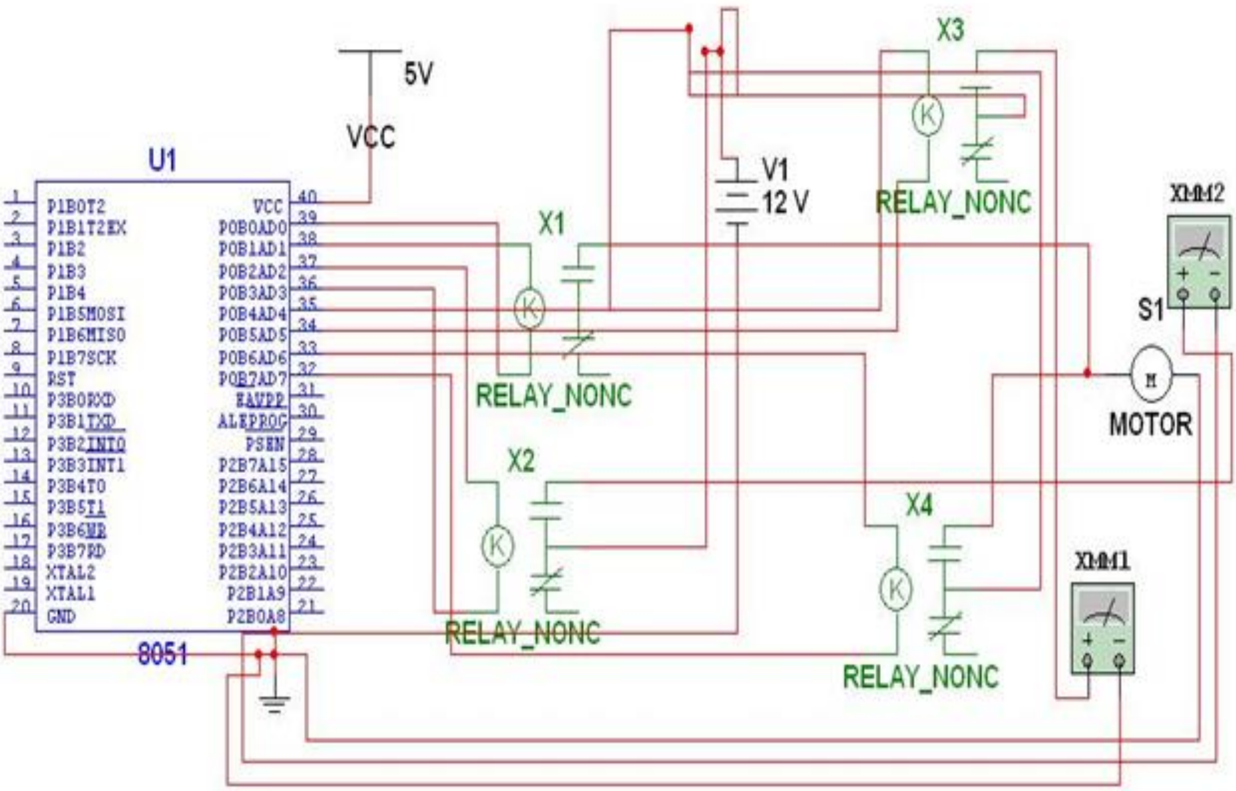

Fig.10 Entire circuit imulation using psipce

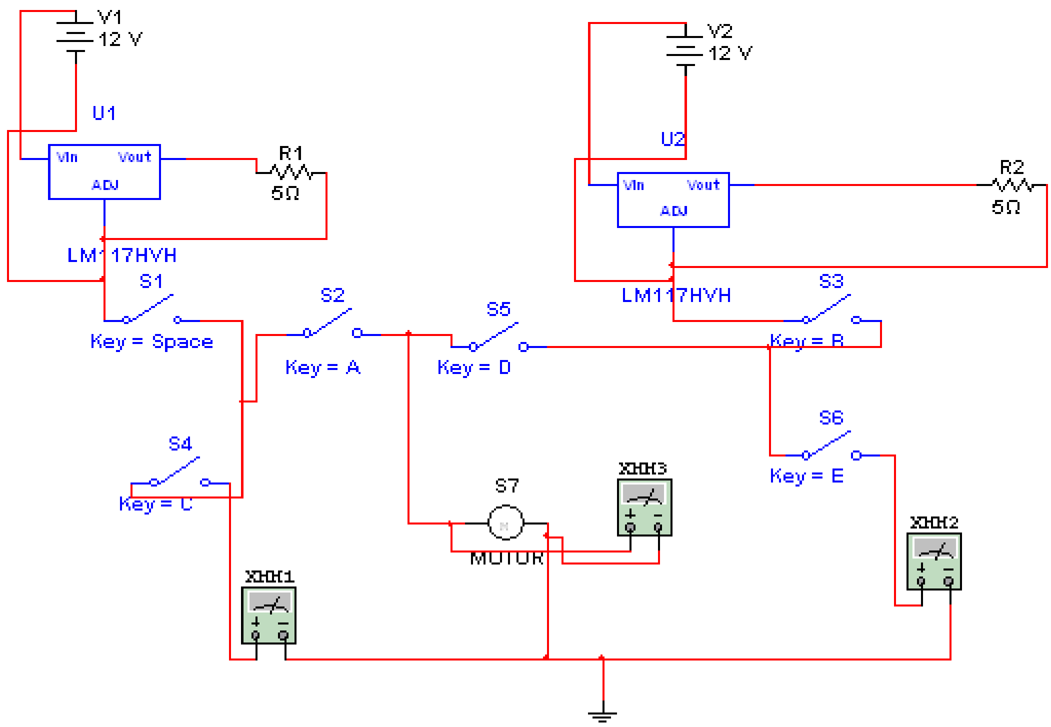

Fig.11 Logic simulation

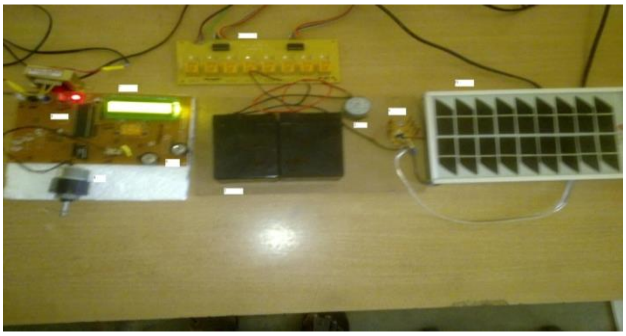

Fig.12 Battery/ super capacitor charging using Solar Energy

Fig.13 Battery/ super capacitor charging using Wind energy

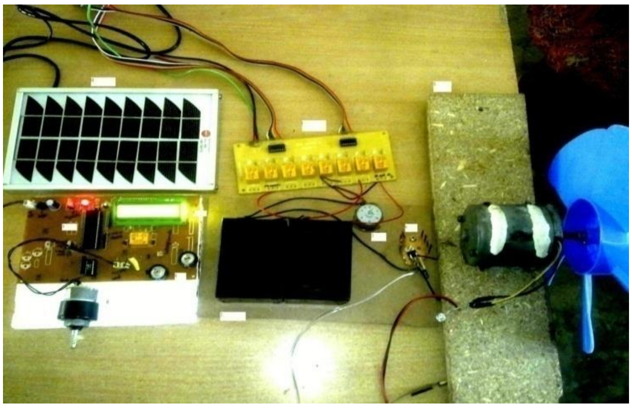

Fig.14 Battery/ super capacitor charging using both solar and wind energy

5 . Conclusion

The simulation and hardware implementation of the processor based battery charging system for hybrid vehicle using super capacitor stack is realized. The simulation and hardware results are almost satisfactory. A conclusion has been made that by connecting the super capacitor and battery with solar and wind controlled with processor is efficient method for the hybrid Electric Vehicle This is a simple heuristic methodology, a user-friendly and fast-acting system for use in controlling hybrid auto-rickshaws and hybrid cars.

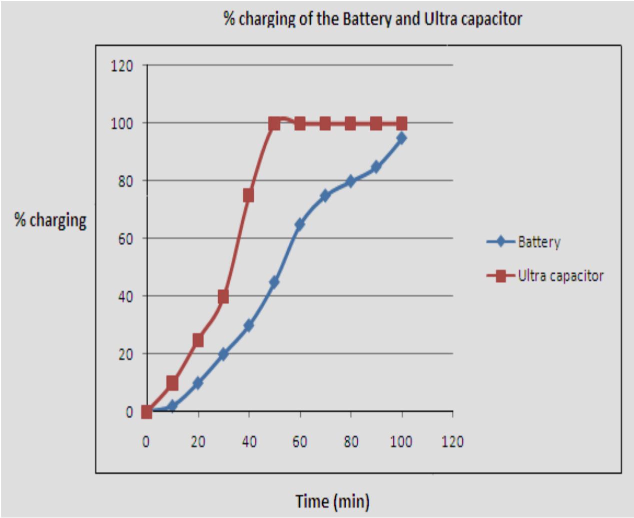

Fig.15 Percentage of charging in Battery/ super capacitor using both solar and wind energy

6.Acknowledegment

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References

1. **Xialonghe and Hodgosonj.W** "*Modelling and simulation for hybrid electric vehicles*". IEEE Transactions on Intelligent Transportation Systems, Volume3,Issue 4, p.p:235 – 243 (2012).

2. **Bindu K.V ,S.Munikrishnan and B. Justus Rabi** "*A Novel Multi Source Electrical Energy System* ", journal of Electrical Engineering ,Vol 12, issue 4,(2012).

3. **Y.GAO, L.CHEN, M.EHSANI** "*Investigation of the effectiveness of regenerative braking for EV & HEV,SAE international SP*"IEEE transactions on modeling of vehicles,page-2901-2910,(1999).

4. **Ricardo Faria, Pedro Moura,Joaquim Delgado and Anibal T. de Almeida** , "*A sustainability assessment of electric vehicles as a personal mobility system*" published in the journal of Energy Conversion and Management, Volume 61, P.P 19–30.(2012).

5. **Abbas Shiri and Abbas Shoulaie** "*End effect braking force reduction in high-speed single-sided linear induction machine*" published in the journal of Energy Conversion and Management, Volume 61, P.P 43–50(2012).

6. **D. Gewald,S. Karellas,A.** Schuster and H. Spliethoff, "*Integrated system approach for increase*

of engine combined cycle efficiency" published in the journal of Energy Conversion and Management, Volume 60, Pages 36–44 (2012).

7. **Rong-Chang Jou, Yu-Chiun Chiou and Ju-Ching Ke,** "*Impacts of impression changes on freeway driver intention to adopt electronic toll collection service* "published in the journal of Transportation Research , Part:c Emerging Technologies, Volume 19, Issue 6, P.P 945–956 (2011).

8. **Ruimin Li' Geoffrey Rose**"*Incorporating uncertainty into short-term travel time predictions*" published in the journal of Transportation Research, Part:c Emerging Technologies, Volume 19, Issue 6**,** December 2011, P.P 1006–1018 (2011).

9. **Nathaniel S. Pearre, Willett Kempton, Randall L. Guensler and Vetri V. Elango** "*Electric vehicles: How much range is required for a day's driving?* " published in the journal of Transportation Research , Part:c Emerging Technologies, Volume 19, Issue 6, P.P 1171–1184(2011).

10. **BOSE B.K**."*Power electronics and motor drives recent technology advances*", Proceedings of IEEE International symposium on industrial Technologies., pp 22-25(2002).

11. **Tabbache, B. Kheloui, A, Benbouzid, M.E.H.** , "*An Adaptive Electric Differential for Electric Vehicles Motion Stabilization* ", IEEE Transactions on Vehicular Technology, 60 , Issue: 1,**pp:** 104-110(2011) .

12. **Ing. Adriana TRAISTARU and ing. Ioan SORA** "*studies concerning lithium ion battery thermal behavior in low temperature environment* ", journal of Electrical Engineering ,Vol 10, issue 1,(2010).

13. **Pawan sarma** "*Application of Ultracapacitors in an Electric Toy Vehicle* " journal of Electrical Engineering ,Vol 9, issue 2,(2009).