International Journal of Engineering Sciences & Emerging Technologies, Dec. 2012.
ISSN: 2231 – 6604 Volume 4, Issue 1, pp: 100-107 ©IJESET

MONITORING STACK OF BATTERIES FOR EV THROUGH CONTROLLER AREA NETWORK GATEWAY

V. Thiyagarajan[1], Sukumar Puhan[2]

[1]Ph.D Research Scholar, Department of EEE, CMJ University, Shillong, Meghalaya, INDIA
[1]trpthiyagarajan@gmail.com
[2]CEO, Brooklynn Innovative Research & Development, Chennai, INDIA
[2]info@birdindia.co.in

ABSTRACT

Electric Vehicles [EV] of next generation are pushing the development of new battery technologies. To minimize cost and maximize efficiency of batteries, the vehicle system should have effective usable battery storage capacity. Remarkable progress has been achieved on battery technologies for EVs. Battery energy densities have steadily been increased, when batteries today can be reliably charged and discharged thousands of times. If designers effectively exploit, these advancements in energy capacity in EVs have the potential to be competitive with traditional vehicles in terms of cost, reliability and longevity. An important consideration for the battery pack monitoring system is the communications interface. For communication within a PC board, common options include the Serial Peripheral Interface (SPI) bus and Inter-Integrated Circuit (I^2 C) bus. Each has low communications overhead, suitable for low interference environments. Another option is the Controller Area Network (CAN)[01,02] bus, which has widespread use in vehicle applications. The CAN bus is very robust, with error detection and fault tolerance, but it carries significant communications overhead and high materials cost. While an interface from the battery system to the main vehicle CAN bus may be desirable, SPI or I^2C communications can be advantageous within the battery pack[02].

KEYWORDS: *Electric Vehicle [EV], Hybrid Electric Vehicle [HEV], Microcontroller, Controller Area Controller [CAN], CAN Gate way, CAN Bus, LTC6802 [Battery Monitor], Galvanic isolation transformer.*

I. INTRODUCTION

An electric vehicle battery pack consists of dozens of batteries stacked in series. A typical pack might have a stack of 96 or so batteries. While the vehicle power system sees the battery pack as a single, high-voltage battery charging and discharging the entire battery pack at once the battery control system must consider reach battery's condition independently. If one battery in a stack has slightly less capacity than the other batteries, then its SOC will gradually deviate from the rest of the batteries over multiple charge/discharge cycles. If that cells SOC is not periodically balanced with the rest of the batteries, then it will eventually be driven into deep discharge, leading to damage, and eventually complete battery stack failure [03]. To prevent that from happening, each cell's voltage must be monitored to determine SOC. In addition, there must be a provision for cells to be individually charged or discharged to balance their SOCs.

Moreover, a battery's specified capacity refers to the amount of charge the battery can supply from 100% State of Charge (SOC) to 0% SOC. Charging to 100% SOC or discharging to 0% SOC will quickly degrade a battery's life. Instead, batteries are carefully managed to avoid complete charge or discharge conditions. Operating between 10% SOC and 90% SOC (80% of capacity) can reduce the total number of charging cycles by a factor of 3 or more, when compared to operating between 30% and 70% SOC (40% of capacity). The trade-off between effective battery capacity and battery lifetime creates challenges for battery system designers. Consider the above case of 40% cycling versus 80% cycling. If a system limits batteries to only 40% cycling in order to increase battery longevity by a factor of 3, the battery size must be doubled to achieve the same usable capacity as the 80% cycling case [04]. This would double the weight and volume of the battery system, increasing costs and reducing efficiency. In this section, Battery monitoring requirements, Accuracy of battery, Reliability of battery , Manufacturability, cost of battery and power of battery are briefly discussed which really strengthens the quality of this study

II. BATTERY MONITORING REQUIREMENTS

There are at least five major requirements that need to be balanced when deciding between battery monitoring system architectures. They are Accuracy, Reliability, Manufacturability, Cost and Power. Their relative importance depends on the needs and expectations of the end customer [05].

2.1.1 . Accuracy

To take advantage of the maximum possible battery capacity, the battery monitor needs to be accurate. A vehicle, however, is a noisy system, with electromagnetic interference over a wide range of frequencies. Any loss of accuracy will adversely affect battery pack longevity and performance**.**

2.1.2 . Reliability

Automobile manufacturers must meet extremely high reliability standards, irrespective of the power source. Furthermore, the high-energy capacity and potentially volatile nature of some battery technologies is a major safety concern. A failsafe system that shuts down under conservative conditions is preferable to catastrophic battery failure, although it has the unfortunate potential of stranding passengers. To minimise both false and real failures, a well-designed battery pack system must have robust communications, minimised failure modes, and fault detection.

2.1.3. Manufacturability

Adding sophisticated electronics and wiring to support an EV/HEV battery system is an additional complication for automobile manufacturing. The total number of components and connections must be minimised to meet stringent size and weight constraints and ensure that high volume production is practical.

2.1.4. Cost

Minimising the number of relatively costly components, like microcontrollers, interface controllers, galvanic isolators, and crystals can significantly reduce total system cost.

2.1.5. Power

The battery monitor itself is a load on the batteries. Lower active current improves system efficiency and lower standby current prevents excessive battery discharge [Ref: Fig 2] when the vehicle is off. Linear Technology has introduced a device that enables battery system designers to meet these difficult requirements. The LTC6802 is a battery stack monitor integrated circuit that can measure the cell voltages of up to 12 stacked cells. The LTC6802 also has internal switches that provide for the discharge of individual cells to bring them into balance with the rest of the stack.

III. RESULTS AND DISCUSSION

In this paper, the overall life of a battery is expected to be increased to a considerable extent by following a certain monitoring techniques as specified in the previous sections. When the life of a battery is getting is improved, indirectly it reduces the cost of battery operation through which the overall operation and maintenance cost of the Electric vehicle comes down to a satisfactory level. Four architectures for battery monitoring systems are depicted in Figures 1-4 and described below. Table 1 summarises the pros and cons of each architecture assuming a 96-battery system organised into 8 groups of 12 batteries.

Table 1. Pros and Cons of each architecture assuming a 96-battery system organised into 8 groups of 12 batteries.

Features	Parallel Independent CAN Modules	Parallel Modules with CAN Gateway	Single Monitoring Module with CAN Gateway	Series Modules with CAN Gateway
Accuracy	+ LTC6802s local to battery module	+ LTC6802s local to battery module	- Sensitive analog wires routed to single board	+ LTC6802s local to battery module
Reliability	+ CAN provides robust communications over cables, but extra circuitry gives increased failure modes	+ SPI interface not as robust as CAN over cables, but parallel communications minimizes negative impact	++ Communications local to a single board, minimizing cable connections and sensitivity to communications interference	- SPI interface not as robust as CAN over cables
Manufacturability	- Significant parallel communications wiring required	- Significant parallel communications wiring required	- Single precision board, but analog sensitivity can create wiring challenges.	+ Communications wiring in series between modules.
Cost	- - Microcontrollers, CAN Interfaces and isolation in every module, plus a main controller board	- Single Microcontroller and CAN transceiver but separate precision PC boards with digital isolators.	+ + Single Microcontroller CAN transceiver and isolator on one precision PC board	+ Single Microcontroller CAN transceiver and isolator but separate precision PC boards
Power	- - Multiple Microcontrollers and CAN Interfaces require excessive power consumption	- High speed digital isolators have significant current draw	+ + Minimal circuitry with low power SPI interface	+ Minimal circuitry but SPI interface requires more power to communicate between boards.

In every case, one LTC6802 monitors each group of 12 batteries. For example, using 4.2 V Li-Ion batteries, the bottom monitoring device would straddle 12 batteries with potentials scaling from 0 V to 50.4 V. The next group of batteries would have voltages ranging from 50.4 V to 100.8 V, and so forth, up the stack. Each architecture is designed to be an autonomous battery monitoring system [05]. Each provides a CAN bus interface to the vehicle's main CAN bus and is galvanic ally isolated from the rest of the vehicle [06].

3.1 Parallel independent CAN modules

Each 12-battery module contains a PC board with an LTC6802, a microcontroller, a CAN interface, and a galvanic isolation transformer. The large amount of battery monitoring data required for the system would overwhelm the vehicle's main CAN bus, so the CAN modules need to be on local CAN sub-nets. The CAN sub-nets are coordinated by a master controller that also provides the gateway to the vehicle's main CAN bus. Figure 1 shows the block diagram of parallel independent CAN modules [06].

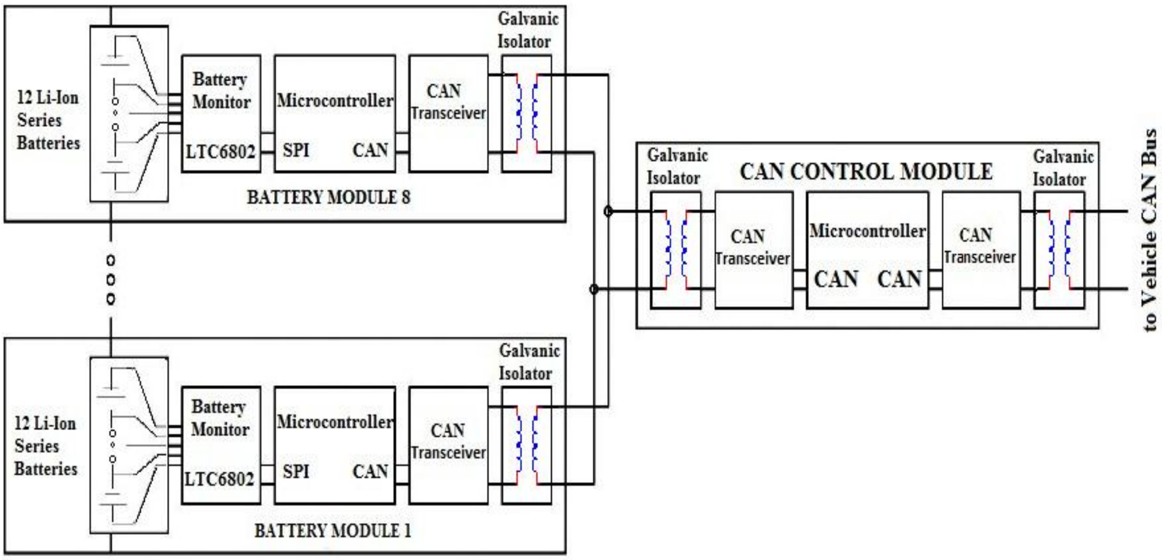

Figure 1. Parallel Independent CAN modules

3.2 Parallel modules with CAN gateway

Each 12-battery module contains a PC board with an LTC6802 and a digital isolator. The modules have independent interface connections to a controller board containing a microcontroller, a CAN interface, and a galvanic isolation transformer. The microcontroller coordinates the modules and provides the gateway to the vehicle's main CAN bus [07, 08]. Figure 2 shows the parallel modules with CAN gateway.

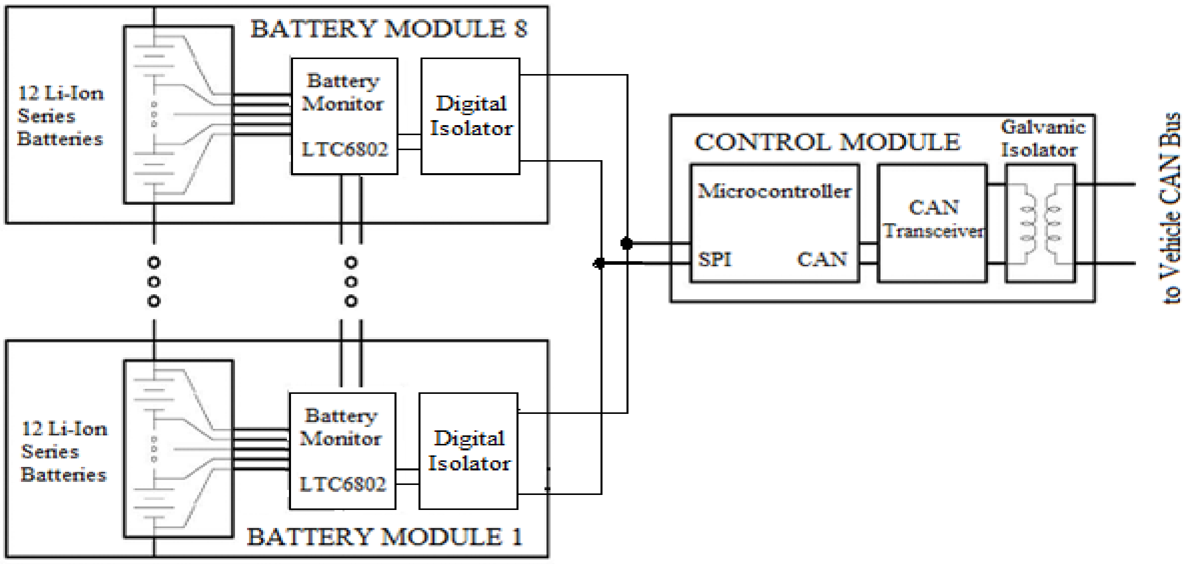

Figure 2. Parallel modules with CAN gateway

3.3 Single monitoring module with CAN gateway

In this configuration, there is no monitoring and control circuitry within the 12-battery modules. Instead, a single PC board has 8 LTC6802 monitor ICs, each of which is connected to its battery module. The LTC6802 devices communicate through non-isolated SPI-compatible serial interfaces. A single microcontroller controls the entire stack of battery monitors via the SPI compatible serial interface, and it also is the gateway to the vehicle's main CAN bus. A CAN transceiver and a galvanic isolation transformer complete the battery monitoring system [09]**.** Figure 3 shows the single monitoring module with CAN gateway.

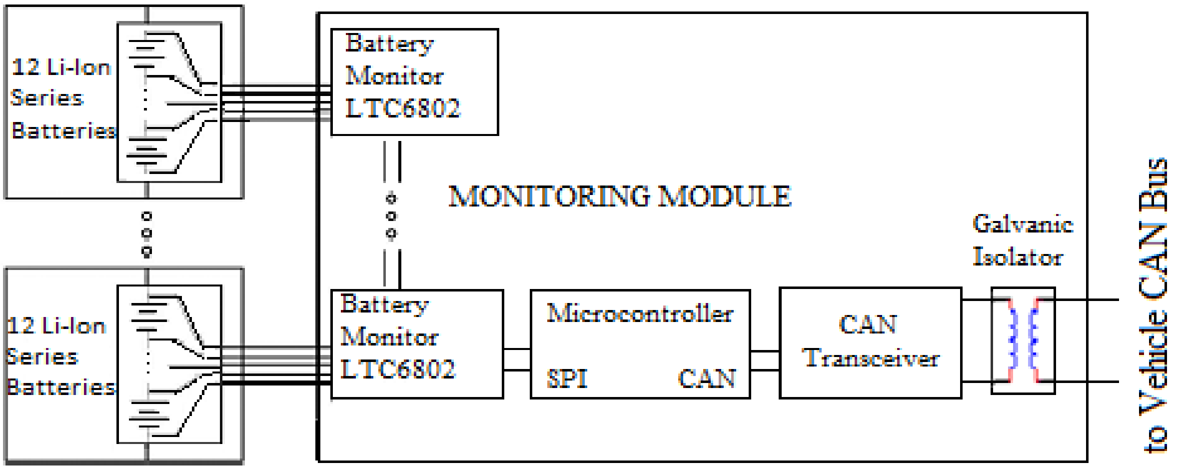

Figure 3. Single monitoring module with CAN gateway

3.4 Serial modules with CAN gateway

Each LTC6802 is on a PC board within its 12-battery module. The 8 modules communicate through the LTC6802 non-isolated SPI-compatible serial interface, which requires a 3- or 4-conductor cable to be connected between pairs of battery modules[13]. A single microcontroller controls the entire stack of battery monitors via the bottom monitor IC, and also acts as the gateway to the vehicle's main CAN bus. Once again, a CAN transceiver and a galvanic isolation transformer complete the battery monitoring system. Figure 4 shows the serial modules with CAN gateway.

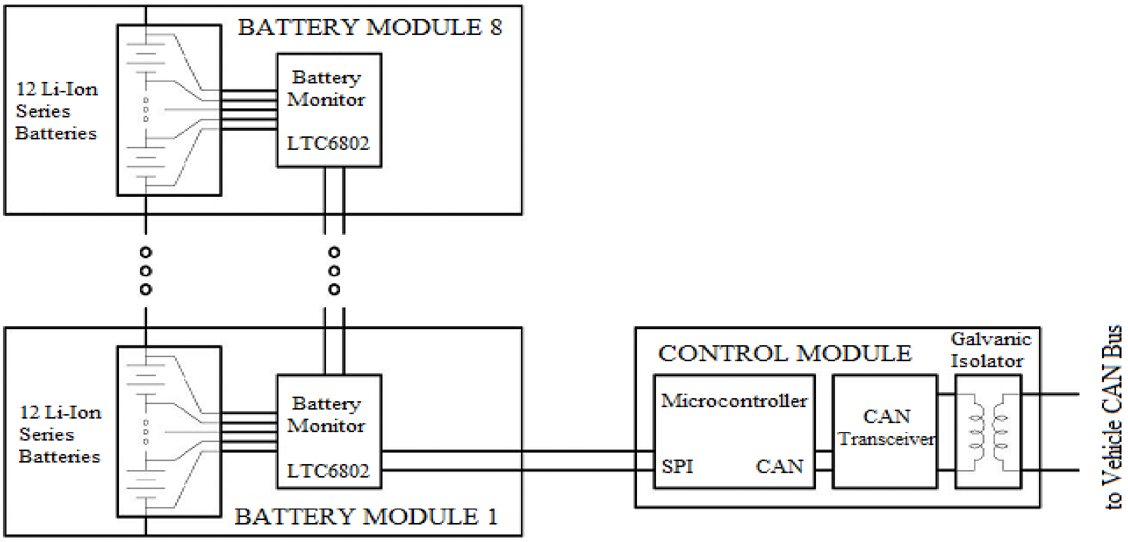

Figure 4. Serial modules with CAN gateway

3.5 Galvanic Isolation

Galvanic isolation is the principle of isolating functional sections of electric systems so that charge-carrying particles cannot move from one section to another, i.e. there is no electric current flowing directly from one section to the next. Energy and/or information can still be exchanged between the sections by other means, however, such as by capacitance, induction, electromagnetic waves, optical, acoustic, or mechanical means[14].

Galvanic isolation is used in situations where two or more electric circuits must communicate, but their grounds may be at different potentials. It is an effective method of breaking ground loops by preventing unwanted current from travelling between two units sharing a ground conductor. Galvanic isolation is also used for safety considerations, preventing accidental current from reaching the ground (the building floor) through a person's body.

The galvanic isolator relies on the fact that electrolysis voltages are quite low - usually less than one volt - whereas electrical failure voltages are quite high. Silicon diodes, which are used to conduct electricity in one direction but block it in the reverse direction, have a built in forward voltage drop of about 0.6 volts. It is not like a resistor voltage drop - no current has to flow to create the drop - so below 0.6 volts it is disconnected, above this it conducts with very little resistance to current flow.

Since we don't know the polarity of the fault voltage, and if it is an AC fault, it will be flowing both ways, two diodes are placed in parallel pointing opposite directions so there is always one available to conduct, but at low voltages, both are switched off and no electrolytic current can flow.

Since some electrolytic voltages are higher than 0.6 volts, a good galvanic isolator should have two diodes in series in each direction to give 1.2 volt isolation [15]. Some also add a capacitor to increase the ability to conduct AC current, however I personally think this is a mistake as it does allow low level AC currents to flow and cause electrolytic type activity, even if not true electrolysis[16]. This activity can remove paint from the fitting and generate chlorine bubbles that damage surrounding antifouling paint.

The diodes have to have enough capacity to pop a shore power circuit breaker if there is a short on your boat. This can require a capacity of more than 100 amps. Galvanic isolator diodes are designed to carry this current for a very short time - long enough to blow the circuit breaker plus a safety margin - but they cannot carry it for very long without overheating[17]. They should be able to stand the shore power current rating indefinitely.

3.6 Battery Monitoring LTC6802

The LTC6802 is a complete battery monitoring IC that includes a 12-bit ADC, a precision voltage reference, a high voltage input multiplexer and a serial interface is shown in Figure 5.

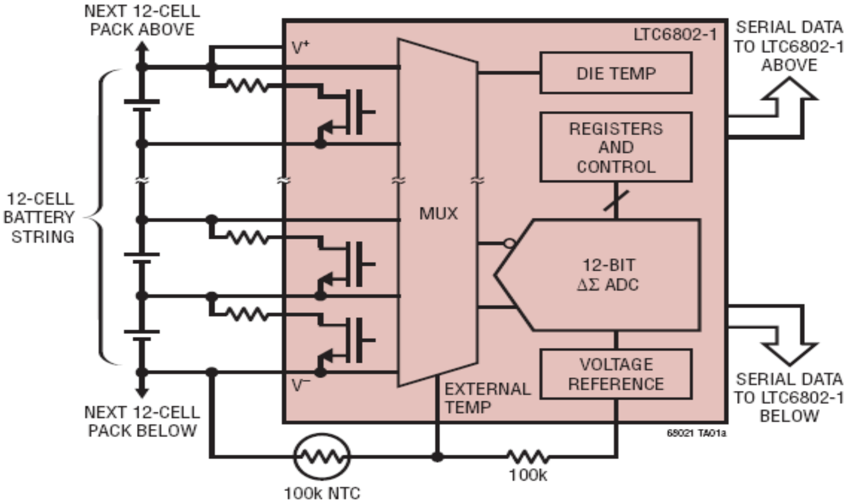

Figure 5 Multi cell Battery stack monitor

Each LTC6802 can measure up to 12 series connected battery cells with an input common mode voltage up to 60V. In addition, multiple LTC6802 devices can be placed in series to monitor the voltage of each cell in a long battery string [18]. The unique level-shifting serial interface allows the serial ports of these devices to be daisy-chained without opto-couplers or isolators.

When multiple LTC6802 devices are connected in series they can operate simultaneously, permitting all cell voltages in the stack to be measured within 13ms. To minimize power, the LTC6802 offers a measure mode, which simply monitors each cell for overvoltage and under voltage Conditions. A standby mode is also provided. Each cell input has an associated MOSFET switch for discharging overcharged cells[21]. For large battery stack applications requiring individually addressable serial communications, see the LTC6802.

3.7 Battery Monitoring Architecture Selection

The first and second architectures are generally problematic due to the significant number of connections and the external isolation required for the parallel interface [22]. For this added complexity, the designer has independent communication to each monitor device. The third (single monitoring module with CAN gateway) and fourth (series modules with CAN gateway) architectures are simplified approaches with minimal limitations. The LTC6802 can address all four configurations, leaving the choice to the system designer.

Two variants of the LTC6802 have been created, one for series configurations and one for parallel configurations. The LTC6802-1 is designed for use in a stacked SPI interface configuration. Multiple LTC6802-1 devices can be connected in series through an interface that sends data up and down the battery stack without external level shifters or isolators [12]. The LTC6802-2 allows for individual device addressing in parallel architectures. Both variants have the same battery monitoring specifications and capabilities.

IV. CONCLUSION

In this paper, a CAN controller unit of an embedded system is used and it is applied to an experimental set-up for battery bank efficiency monitoring. Next generation vehicles usually require a lot of communication data between subsystems or ECUs [Electronic Control Units] to improve the battery economy and the advanced safety. Unexpected transmission delay on a data bus may be a cause for an unstable operation of a vehicle which may also yield a serious result.

Moreover, in this paper, a simple timing analysis method has been presented and applied to the experimental set-up for CAN-based subsystem of electric vehicles. The analysis was done using a PCI-CAN board and a Windows platform-based monitoring program to calculate the computation time and communication time for each task. The worst case response time to determine the sampling period for stable operation in a vehicle was found and it was shown that the predetermined sampling time can be effectively modified in the event of high priority task occurrence in the network.

REFERENCES

[1]. M. Farsi, K. Ratcliff, and M. Barbosa, "*An overview of Controller Area Network*," Computing & Control Engineering Journal.

[2]. G. Cena and A. Valenzano, "*An improved CAN fieldbus for industrial applications*", IEEE Trans. Ind. Electron.

[3]. L. B. Fredriksson (2002), "CAN for critical embedded automotive networks," *IEEE Micro*, vol. 22, no. 4, pp. 28-35.

[4]. C. L. Liu and J. W. Layland (1973), "Scheduling Algorithms for Multiprogramming in Hard Real-Time Environment," *Journal of ACM*, vol. 20, no.1.

[5]. M. S. Shin, W. T. Lee, M. H. Sunwoo (2003), "Holistic scheduling analysis of a CAN based body network system," *Trans. KSAE*, Vol. 10, No. 5, pp.114-120.

[6]. Caumont, O. And Moigne, P. (2000), " Energy Gauge for Lead Acid Batteries in Electric Vehicles", *IEEE Transactions on Energy Conversion*,Vol.15, 3 September .

[7]. Dhameja, S. (2001), *Electric Vehicle Battery Systems*. New Delhi.

[8]. Ibáñez J and Dixon J (2004), "Monitoring Battery System for Electric Vehicle, Based On 'One Wire' Technology", *IEEE Vehicular Power Propulsion*, pp - 6-8.

[9]. A. Muetze, Y. C. Tan (2005), "Performance evaluation of electric bicycles", *Industry Applications Conference*, Vol. 4, pp 2865 – 2872 .

[10]. E. Starschich, A. Muetze (2007), "Comparison of the Performances of Different Geared Brushless-DC Motor Drives for Electric Bicycles", IEEE International Conference Electric Machines & Drives, Volume 1, pp - 140 – 147.

[11]. N. Somchaiwong, W. Ponglangka (2006), "Regenerative Power Control for Electric Bicycle", *SICE-ICASE International Joint Conference*, pp - 4362-4365

[12]. *"Designing an Electric Vehicle Conversion"* – Southcon/95. IEEE Conference Record

[13]. Cervi M., Pappis D., Marchesan T.B.., Campos A., Do Prado R.N.(2005), "A semiconductor lighting system controlled through a LIN network to automotive application*", Industry Applications Conference*, Vol. 3 , pp 1603 – 1608.

[14]. Marinkovic S., Spagnol, C., Popovici, E.., (2009), "Energy-Efficient TDMA-Based MAC Protocol for Wireless Body Area Networks", *Sensor Technologies and Applications*, pp - 604 – 609.
[15]. Lim, D., Anbuky, A., (2004), " A distributed industrial battery managementnetwork*", IEEE Transactions on Industrial Electronics*, Vol. 51,pp - 1181 – 1193.
[16]. Po-Lun Chang, Yu-Xin Gu, Mu-Der Jeng (2011), "Telematics gateway and power saving method for electric vehicles", *IEEE International Conference on Systems, Man, and Cybernetics (SMC),* pp - 780 – 785.
[17]. Alminauskas. V., (1993), "Performance evaluation of lead acid batteries for use with solar panels", *Photovoltaic Specialists Conference*, pp - 1258 – 1263.
[18]. Wilkinson. H., (2005), "Avestor Lithium-Metal-Polymer Batteries Deployed throughout North America", *Telecommunications Conference*, pp - 217 – 221.
[19]. Xianlai Zeng, Jinhui Li, Yusen Ren,(2012), "Prediction of various discarded lithium batteries in China" , *IEEE International Symposium on Sustainable Systems and Technology (ISSST),* pp – 1-4.
[20]. Jian Gao, Longyun Yu, (2007), "Use of battery ohmic testing to improve network reliability and decrease battery maintenance cost", *International Conference on Telecommunications Energy* ,pp – 194 – 202.
[21]. Jun Su, Fossa, C., Mak, T., (2011), "On heterogeneous mobile network connectivity: Number of gateway nodes", *Military Communications Conference* , pp – 1915 – 1920.
[22]. Altmejd M., Fischer W., Pekarsky A., Spek E., (1989), "Sodium/sulphur batteries for EV propulsion", *Proceedings of Energy Conversion Engineering Conference*, vol.6, pp – 2769 – 2774.

Authors

V.Thiyagarajan, is working as Assistant Professor (Sl.Gr) in the Department of Electrical &Electronics Engineering, TRP Engineering College, Trichy. He received his Bachelor's degree in Electrical & Electronics Engineering from Regional Engineering college Trichy (NITT) and Master's degree in High Voltage Engineering from SASTRA University, Thanjavur. . He is having 21 years of experience in industries, teaching, and research and working in the field of Energy Conversion Process, Transformers Winding Fault Analysis and Building Energy. He has published 9 papers in the national and international journals.

Sukumar Puhan , A Mechanical Engineer coupled with successful completion of Masters of Engineering with specialization in Internal Combustion Engine, Doctor of Philosophy in Biodiesel Combustion, Furthermore depth expertise of over 13 years out of which 7 years in biodiesel process development, Quality Control, Numerical Modeling and Combustion, Performance and Emission Characteristics of Compression Ignition Engine. He has updated his knowledge expertise by PMP and Six Sigma (Green Belt) also. He has more than 35 international and National papers. Addition to this many paper published in national and International conferences. He has guided more than 5 PhD and 10 Masters students.