Neuro Fuzzy Controller for Automatic Battery Charge-Discharge Management system of a Wireless Sensor Node

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Background: Wireless sensor networks (WSNs) are not same this year as past. Wireless sensor nodes of a network have major constraints due to their limited energy, storage capacity, computing power and frequent battery replacement factor, when they meant to collect the information from an unattended location using various sensors. The modern wireless sensor networks deals with power consumption by the sensor node, communication defects, mobility of nodes, size of the sensor node and importantly cost of the sensor node. Researchers’ preferably giving more attention to the power consumption of a sensor node as it is the main criteria in all wireless sensor networks (WSNs).

Objective: Hence the proposed research implements a novelty power management system by introducing pack of two solar powered batteries and an automatic battery switching system with LabVIEW based real time data acquisition. The battery charge – discharge management system is controlled by the Neuro-Fuzzy control system. Also this present work describes the implementation of the Backpropagation algorithm for use in Wireless Sensor Network (WSN) application.

Results: By implementing an Automatic Battery Switching System, a long life sensor node is designed and LabVIEW based real time data acquisition is achieved. Compared with conventional battery management techniques, the proposed research effectively avoids the frequent replacement of batteries in the sensor node about 95%.

INTRODUCTION

The huge decrease in power consumption and size of CMOS circuitry has led to a huge research effort based around the idea of omnipresent networks of wireless sensor nodes. As the cost and size of such wireless sensor nodes continues to reduce, the probability of their use becoming extensive in automobiles, buildings, aircraft, industrial environments increases. As their cost and size reduces, and as their occurrence increases, effective power provisions become a larger problem. The problem is that the scaling down in cost and size of electronics has put the scaling of power density in batteries, which are by the most common power supply presently used. Therefore, the power supply is usually the main and most costly component of the promising wireless sensor nodes being projected and designed. Normally, the power consumption includes the sensors placed in the nodes, Microcontrollers, wireless transceivers etc (M.T.Penella, 2007). Typically, the sensor node power consumption is calculated by monitoring the battery level of the corresponding node by some special sensors.

Those sensors will find out the power status and deliver the status through wireless transceiver. But if there are power shortages, the corresponding node will become a sleep node and data transmission is stopped. The possible techniques of providing power for wireless sensor nodes are grouped in to three. They are as follows,
1. store up the energy on the node (battery),
2. allocate power to the node (wire),
3. Scavenge existing ambient energy at the node (solar cell).

Fig1 shows a typical wireless sensor node. The wireless sensor node consists of microcontroller unit, sensor array, wireless transceivers and power supply (Battery).
Powering the wireless sensor node will include the Energy Reservoirs inside its architecture in order to power the WSN. As said, there are types of Energy Reservoirs. They are Macro-scale Batteries, Micro-scale Batteries, Micro-fuel Cells, Ultra capacitors, radioactive power sources. Unlike power sources that are basically power scavenging sources, energy reservoirs are typically characterized by their power density rather than energy density. Various attractive techniques to gather ambient energy have been recommended over the past few years. Practically, there are really four choices only. They are Differential, Temperature, Vibration Light and RF Energy. There is a restriction to using primary batteries to power WSNs though the capacity. The power consumption necessities for some WSN applications would be such that sizing a battery for the 5-year lifetime would require 66 pound and 12 volt deep discharge cell for a primary source. Occasionally that will work and in sometimes it will not. Hence the requirement of solar powered energy source is essential here. But the generated power ($P_g$) must be higher than that consumed by the node ($P_c$), on average when harvesting the energy from the ambient. The transducer converts ambient energy into electrical energy, with a given efficiency. For any arbitrary time period $T$ in which $P_c > P_g$, the storage unit must fulfill the condition.

Table 1 shows the comparison between the required size of both primary batteries and solar cells (Y. Hishikawa, 2009) in order to power the sensor node. We assume lithium primary batteries with an energy density 3 of 0.8 Wh/cm3. Sizes are given in square centimeters for solar cells and in cubic centimeters for batteries.

### Problem Definition:

Renewable energy sources have to be promising energy sources toward making a environment friendly energy economy in the next generations. Among these renewable energy sources, solar is the most promising renewable power production technology. Hence, a backup power system is essential to improve the energy supply consistency. However, the general solar powered wireless sensor node designed by only one rechargeable battery with charging unit. It doesn’t produce an optimized power supply to the sensor node in the bad weather conditions. Hence the inspiration of the research is focusing on implementing a, fully controlled, power optimized, solar powered, charging and discharging system to the sensor node by a designing a Neuro-Fuzzy controller (O. Gerard, 1999).

### Neuro-Fuzzy controller:

Neural networks and Fuzzy systems and have involved the attention of researchers in a variety of scientific and engineering areas. The main design of fuzzy logic control is to construct a model of a human control specialist who is capable of controlling the device without thinking in terms of a mathematical form. The control
specialist specifies the control actions in the form of linguistic rules. These rules are translated into the framework of fuzzy set theory. The good linguistic rules depend on the knowledge of the control specialist, but the translation of these rules into fuzzy set theory is not formalized (F. M. Ham, 2002). The worth of fuzzy logic controller can be affected by the variety of membership functions. Thus, methods for tuning fuzzy logic controllers are essential. Neural networks offer the opportunity of solving the problem of tuning. A fuzzy logic controller shown in fig.3 is intended to work with the prearranged knowledge in the form of rules and almost everything in the fuzzy system remains highly visible and easily interpretable. Nevertheless, there exists no proper framework for the choice of various design parameters and optimization of these parameters usually is made by trial and error.

Fig. 3: Typical Neuro-Fuzzy controller.

Conventional methods of battery life management, which deals with regulating the, protection, charging and monitoring of the battery, are ineffective for two reasons. First, they do not predict the battery charge level and second, they require the battery to be off-line for the period of the measurements of the battery parameters. The proposed battery models advances by combining elements of adaptive and static battery management techniques, dynamic elements drawn from fuzzy logic theory and neural networks (J.S.R. Jang, 1993) The use of neural networks and fuzzy logic control reduces the need for empirically derived constants for battery management.

Hence the proposed research implements a novelty power management system by introducing pack of two solar powered batteries and an automatic battery switching system. The automatic control of a battery charging and discharging system is fully under the control of proposed Neuro-Fuzzy Controller (NFC). The NFC gets power availability in the two batteries and it takes the decision that, on which battery the wireless sensor node will get the power. The logical NFC diagram is shown in the Fig 4.

Fig. 4: logical NFC diagram of proposed battery management system.

Solar powered charging and discharging system with the pack of two rechargeable batteries is shown in fig 5. It includes switches S1, S2, S3, S4, and S5 to control the Automatic battery switching system (ABSS) using (NFC). The switch status for charging and discharging the battery 1 and battery 2 respectively is listed in table 3. The proposed design introduced in this research proposes the use of two separate rechargeable battery units operating alternately. Thus, one of the batteries gets the current from the solar PV system while the other provides sensor node by all the energy required by it. But, in a conventional system the power source is used to recharge a single battery only. The BCDS (Battery Charging and Discharging System) is connecting electrically the charge and discharge paths between the batteries, the charger module, and the sensor node. It does two functions. In its first function it is routing the current from the solar panels to the charger and from the charging unit to the battery selected. In its second function it connects the selected battery to the sensor node. Therefore, the dynamic connections of the electric circuit are carried out according to table 3 conditions of switches conditions. In the first row, BCDS is programmed to charge battery 1 while it discharges battery 2. The main benefit of the dual selector system is that it allows hot swapping of separated power supplies. In addition, in case both batteries are fully discharged, it is programmed to supply the sensor node directly from the solar panels.

This system consists of a dc–dc synchronous-rectified converter and the charger unit controlled by a PWM signal is applied to one of its terminals and supplies each battery according to a programmed algorithm in the
micro controller (F. Reverter, 2005). Between the solar panel and the Battery charger system there are a voltage conditioning capacitor and the I/V sensor from AttoPilot with 0–3.3 V output.

![Fig. 5: Automatic Battery Switching System.](image)

**Table 3: Battery Charge Discharge Mode.**

<table>
<thead>
<tr>
<th>Charge/Discharge Condition</th>
<th>Switch Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Battery 1</td>
<td>S1</td>
</tr>
<tr>
<td>Charge</td>
<td></td>
</tr>
<tr>
<td>Discharge</td>
<td></td>
</tr>
</tbody>
</table>

The capacitor prevents voltage at the charger input pin from falling below the charge voltage of the battery cells when solar power is not capable of providing appropriate voltage level. The role of the I/V sensor is detecting the current and voltage levels that solar panels provide to the charger device.

![Fig. 6: Battery Charging and Discharging System.](image)

The BCDS (Battery Charging and Discharging System) is connecting electrically the charge and discharge paths between the batteries, the charger module, and the sensor node. It does two functions. In its first function it is routing the current from the solar panels to the charger and from the charging unit to the battery selected. In its second function it connects the selected battery to the sensor node. It works according to the NFC algorithm which always checks CA (Actual Code) and CLPP (Low Power Point Code). If the CA is equal to CLPP means it takes the automatic battery switching decision, else it is keeping the current battery on to charge the wireless sensor node.

Therefore, the dynamic connections of the electric circuit are carried out according to table 2 conditions of switches conditions. In the first row, BCDS is programmed to charge battery 1 while it discharges battery 2. The main benefit of the dual selector system is that it allows hot swapping of separated power supplies. In addition, in case both batteries are fully discharged, it is programmed to supply the sensor node directly from the solar panels.

Proposed Data Acquisition involves: Acquiring signals from real-world sensors, digitizing the sensor signals, Analyzing, displaying and saving the data and showing the battery conditions (Tasdelen, 2010).

### 5. LabVIEW Neural Network:

Using NI LabVIEW system design software to design feed-forward neural network with biased neurons, trained using a back-propagation algorithm is designed. LabVIEW weights each of the inputs Xn is by multiplying each by its respective weight value Wn. A sum of all these results is then calculated and to this a transfer function is applied that generates the neuron’s outputs. The LabVIEW diagram for implementing a neuron would look something like following figure.
4. Practical Considerations of WSN Data Acquisition:

   To effectively use this promising WSN technology, there is a need to overcome the challenges associated with configuring and managing data acquisition, storing data for future analysis, efficiently processing the collected data and showing data to the remote user in a useful way.

![Data frame structure used in sensor node](image)

Fig. 7: Data frame structure used in sensor node.

![LabVIEW Neural network diagram](image)

Fig. 8: LabVIEW Neural network diagram.

   When the simulation is over, the result files contain data over time which can be directly analyzed to present the results below result windows. Results are grouped into Sensors data, battery1 and battery2 data, charging discharging details of both battery date time and all other necessary data required in the WSN System. For each device the simulator provides the equipment value, equivalent graph the voltage, and the power. Thus, harvested energy, total consumed energy, battery changing time, battery conditions and power peaks are easily monitored and stored in the database.

![Battery voltage of sensor node](image)

Fig. 9: Battery voltage of sensor node.

6. Conclusion of the Proposed System:

   Battery management system has moved toward a lengthy way from the time of constant current chargers that did not attempt to check the battery to modern neural networks based models. This proposed Research focused on introducing the 3rd generation power supply management and control system with the inbuilt energy harvesting system. This energy harvesting system is not like a typical power system for nodes, but it is implemented with two rechargeable batteries with automatic battery charging discharging switching system.
Thus it provides a high performance energy management system for wireless sensor node for while comparing with single battery energy harvesting system. The replacement time of the battery is increased and the effort need for battery monitoring is decreased. Of all current research in this field, neural networks and fuzzy logic are in the best position to provide such an increase in efficiency.

![Temperature representation of sensor node](image1)

**Fig. 10:** Temperature representation of sensor node.

![Solar panel current analysis of sensor node](image2)

**Fig. 11:** Solar panel current analysis of sensor node

REFERENCES


