Design and Implementation of Energy monitoring section for Prepaid Charge Controller

Deepthi.M.S and N.M Renukappa, PhD
Dept. of ECE, SJCE,
Mysuru, India

Ezhilmaran Ranga
Dept. of Access to energy
Schneider Electric
Bengaluru, India

ABSTRACT
In this paper a method is proposed to develop and design an energy monitoring unit for prepaid charge controller. The energy recharge is achieved by master unit through dual tone multi frequency (DTMF) signal for prepaid charge controller. The energy recharge information is received by the prepaid charge controller and it monitors the energy consumption of the loads and disconnects the input power once the prepaid charge controller is out of balance. The amount of balance is stored on EEPROM of microcontroller**.** Based on energy consumption, it decrements the recharged energy units and displays the remaining energy units on the liquid crystal display (LCD). The energy monitoring section is tested and verified at 35W load. This is a more convenient way of purchasing energy credits and recharging the prepaid charge controllers in dc micro-grid system.

General Terms
EEPROM, LCD, dc micro-grid.

Keywords
DTMF, prepaid charge controller, recharging unit, TPS2481 IC, MSP430 microcontroller, TPS62160 IC

1. INTRODUCTION
The dc micro-grid system connects households in a village to a dc transmission network where the power is generated from solar panels at a central location and is distributed to individual households through a charge controller unit. The drawback of existing system is, the charge controller installed in each house is non prepaid unit; it continuously uses the energy from grid free of cost and does not monitor the energy consumed by loads. The proposed system attempts to provide cost effective solution to the problem found in existing non prepaid dc micro-grid system. A prepaid charge controller is developed to overcome the drawback of non prepaid dc micro-grid system. This prepaid system avoids the misuse of grid energy. Just like conventional mobile recharging, the master unit recharges the prepaid charge controllers in the grid using DTMF communication technology for a specific amount and the units of energy can be used according to the energy units recharged. These prepaid units will decrement the energy units consumed and display remaining energy units which provide an alarm to user when the amount is to be recharged again for the continuation of the electricity use from grid and is disconnected from the grid when the amount balance reaches to a nil value. Energy monitoring unit is a device that measures the amount of electrical energy consumed by a residence, business, or an electrically powered device. They are typically calibrated in billing units and the most common one is the kilowatt hour, which is equal to the amount of energy used by a load of one kilowatt over a period of one hour, or 3,600,000 joules. Electricity meters operate by continuously measuring the instantaneous voltage (volts) and current (amperes) .The product of which gives the instantaneous electrical power (watts) which is then integrated against time to give energy used. A Prepaid energy monitoring unit enables power utilities to collect electricity bills from the consumers prior to its consumption. The prepaid meter is also attributed with prepaid recharging ability and information exchange with the utilities pertaining to customer's consumption details [1].

2. METHODOLOGY
Energy monitoring section in the prepaid charge controller (slave unit), measures the amount of energy consumed by the consumer loads. It contains an energy monitoring TPS2481 IC which measures the current, shunt and bus voltage signals and calculates instantaneous power. The calculated power values are continuously updated to power register of energy monitoring IC, the value of which is periodically accessed by the microcontroller via inter integrated circuit (I2C) protocol. The I2C isolator provides isolation between energy monitoring section and microcontroller ground. The microcontroller uses the retrieved power register value to calculate the energy consumed by the load connected to prepaid charge controller. The microcontroller is programmed to read power data from the metering IC every second and accumulates it for duration of 3600 second. Resultant value is the energy consumed in Watt hour and microcontroller decrements energy units accordingly. The energy calculation in kilo Watt hour relation is, Energy = Power × 3600 sec (kWh). The block diagram of energy monitoring section is shown in Figure 1. In the present study, the bus voltage of 12V/4A is the input of the energy monitoring unit and for the consumer loads. The energy monitoring unit records energy consumption in Watt hour and displays remaining energy units.

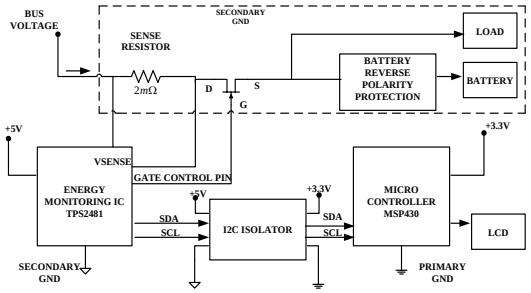

Figure 1: Block diagram of energy monitoring section

3. ANALYSIS OF HARDWARE COMPONENTS

3.1 Power Supply

The prepaid charge controller system requires an isolated dc regulated power supply of 5V/350mA and 3.3V/100mA. The regulated power supply was designed by working principle of fly back converter. The energy monitoring IC operates at 5V/350mA power supply. The microcontroller operates at 3.3V/100 mA regulated dc power supply. The 3.3V is derived from available +5V isolated power supply by using TPS62160 step down converter IC [2].

3.2 Energy Monitoring IC

Energy monitoring TPS2481 IC monitors shunt voltage on the bus that varies from 9V to 26V. It controls external N channel MOSFET switch and provide accurate voltage, current and energy monitoring using 12 bit configurable A/D converter through an I2C interface. An external timer capacitor set the fault time to help immunize the system from shutdowns during sudden transient events. The internal gain of the A/D converter can be configured to scale the current, voltage and power readings according to the application. Multiplying register will calculate the power in Watts. With the help of the calibration register we can configure the bus voltage range, gain, ADC resolution, averaging. The calibration register makes it possible to set the scaling of the current and power registers to whatever values are most useful for a given application [3].

3.3 Microcontroller

Microcontroller is a programmable device which contains a microprocessor, memory, input-output ports etc which can be compared with the microcomputer. Microcontroller is a single chip computer.

As microcontroller is a low cost programmable device. It is used in the automatic control application. The MSP430F5336 microcontroller from Texas instrument is used in this application [4]. Microcontroller reads the register value of the energy monitoring IC using I2C interface. The average power values are taken to calculate the energy consumption. Microcontroller manages to accumulate the total energy consumption and decrements the energy according to the energy consumed by the loads. The available energy units displayed through liquid crystal display (LCD). The balance energy units are stored in the EEPROM of the microcontroller.

3.4 IC Isolator

Two bidirectional lines, serial clock (SCL) and serial data (SDA), connect the TPS2481 to the microcontroller through I2C isolator. Both SCL and SDA are open-drain connections. The device that initiates the transfer is called a master, and the devices controlled by the master are slaves. The bus must be controlled by a master device that generates the SCL, controls, the bus access, and generates START and STOP conditions. Isolation between microcontroller and energy monitoring IC is provided by low power bidirectional I2C isolator IC.

3.5 Liquid Crystal Display

LCDs are preferred as display devices compared to light emitting diode (LED) because of lower power consumption, flexibility in display content and compact structure suitable for embedding in the hardware unit. A 16x2 LCD is used in prepaid charge controller to display the balance energy units.

4. INPUT POWER DISCONNECTION

Prepaid charge controller is connected to the input transmission line as long as it has sufficient balance. Once the energy balance becomes zero, the prepaid charge controller is disconnected from the micro grid. This function is implemented by input disconnection circuit controlled by the microcontroller. Microcontroller decrements and updates the tariff counter as the energy units are consumed. When the tariff counter is decremented to zero the microcontroller generates a logic high signal at one of its GPIO pins .This logic high signal disconnects the input power and battery supplies energy to load until its voltage is above its minimum set point of 11.8V. As the master unit loads the slave unit with the recharge amount the slave unit is reconnected back to the main line. The block diagram of the input disconnection section is shown in the Figure 2.

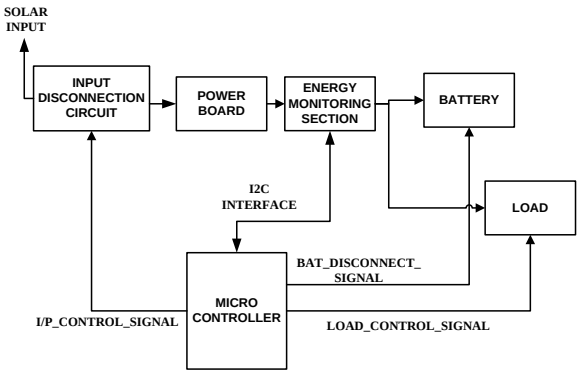

Figure 2: Input power disconnection block diagram

4.1 Energy Monitoring Software

The software provides the users to monitor the energy data in the prepaid charge controller. Its functions include real-time data exchange with MSP430, data storing, data processing and analysis. Energy monitoring software sends request the microcontroller to collect the voltage, current and power data from energy monitoring IC through I2C interface. The microcontroller manages to accumulate the energy consumption by the loads and updates the remaining energy units on the display. Thus, users can see remaining energy data on the LCD. Figure 3 shows the energy monitoring software's operational flow chart. The program is developed for the verification of energy monitoring section at laboratory level. Algorithm for energy monitoring section is given below.

- If remaining energy units is zero, disconnect the input power of the prepaid charge controller unit and make power disconnect flag high.
- If remaining energy units is greater than zero, check the energy units consumed and power disconnect flag status.
- If energy units consumed is greater than remaining energy and power disconnect flag is low, check whether energy units consumed is greater than remaining energy units, if yes make remaining energy units zero and update the display else subtract the energy units consumed from remaining energy units and make energy units consumed equal to zero. Display the remaining energy units.

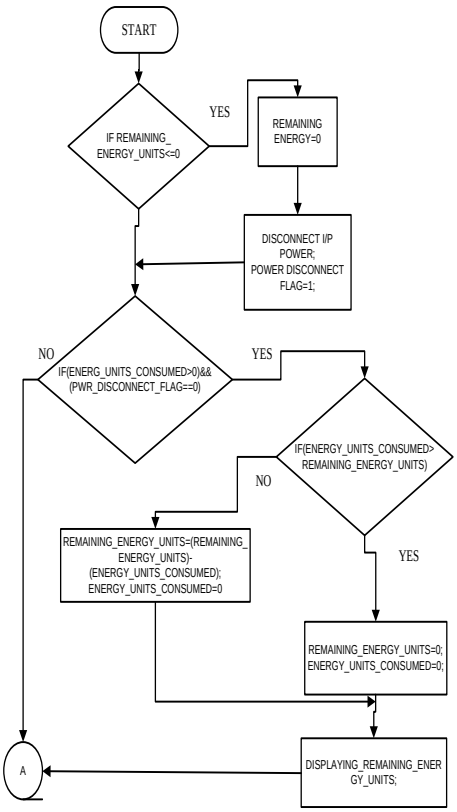

Figure 3: Energy monitoring flowchart

Algorithm for reconnection of input power:

- If the power disconnect flag is high and remaining energy units is greater than zero connect the input power to the prepaid charge controller and clear the power disconnect flag.
- Else stay in idle state until an interrupt occurs. Flow chart for input power reconnection is shown in Figure 4.

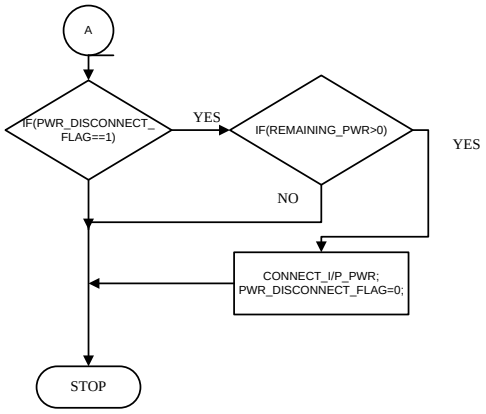

Figure 4: Input power reconnection flowchart

5. RESULTS

The energy consumed was tested with lamp load of 35W at 12V for duration of 2 min. The consumption of energy was sensed by the microcontroller every 1second and displayed at an interval of 10seconds on the LCD. The consumed energy values are tabulated in the Table 1.

Table 1.Energy meter readings

Time (sec)	Consumed energy (kW-sec)
0	0
10	0.27
20	0.55
30	0.83
40	1.11
50	1.38
60	1.66
70	1.94
80	2.22
90	2.50
100	2.77
110	3.04
120	3.32

From the Table it is observed that, energy consumed values increases with increase in time over a duration of 120 seconds. Further it is confirmed that the repeatability of energy consumption for every 10 seconds with error less than 1%.

6. CONCLUSIONS

This proposed simple and economic digital prepaid energy meter controlled by DTMF communication can cover rural areas. The entire system can be cost effective and significant amounts of time and money can be saved by implementing it, as opposed to one involving the human element. Human errors in billing would be totally eliminated and a more convenient way of purchasing energy credits and recharging the prepaid charge controller. It is reliable as consumers are only allowed to use what they pay for thereby reducing revenue loss due to unpaid bills. This will improve the revenue of the dc micro-grid entrepreneur

7. REFERENCES

[1] Bourdillon.O.Omijeh, Godwin.I.Ighalo "Design and Simulation of Single Phase Intelligent Prepaid Energy Meter", Vol. 4, 2013.

[2] TPS62160, 3V-17V 1A Step-Down Converters with DCS-Control", Texas Instruments Datasheet.

[3] TPS2481-Positive Voltage Intelligent Protection Device Hotswap Controller and I2C Current Monitor", Texas Instruments Datasheet.

[4] MSP430F5336 Mixed Signal Controller", Texas Instruments Data