LOW COST INDUSTRIAL ENERGY MONITOR AND USAGE DATA LOGGER WITH PEAK DEMAND CONTROLLING

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ABSTRACT

This paper proposes a development of a system that monitors three phase power line. In modern world electricity cost of industries is considered as a non-avoidable expense. Therefore, extra consideration on energy consumption is essential. Using the proposed and implemented system, industries can monitor the energy usage and log the usage data at user desired intervals for further reference. Industries are capable of coming up with a suitable energy plan for their facilities using the system. System switches the power line to generator when peak demand attempts to exceed the user desired level, reducing the demand charge. The cost of the product is less than 75 US dollars at small scale production and can be further reduced if mass produced.

***Key words*:** Three phase power, Energy monitoring, Data logging, Peak demand controlling, Low Cost

1. INTRODUCTION

The demand for energy in the world has increased exponentially over the years due to development of industries. But Energy supply in world has not met the demand. In order to maintain demand at lower rate, utility companies have introduced concepts such as “peak demand charge” and “time of use charge”. Since industries in the world have continued to be challenged by rising energy costs, careful consideration on energy consumption is essential. Monthly electricity bill lacks information regarding energy consumption.

Energy consumption depends upon the power factor and the demand. In order to bring energy consumption down, Industries need to check the power factor and demand regularly. If power factor is bad, the correction is needed. If demand exceeds the cost effective limit, industries are capable of switching their power line to generators to save energy consumption cost. However, electricity generation from a generator might not be cheaper than electricity provided from the utility. Roughly it costs 25 – 30 rupees per 1kWh. Therefore, consideration about this fact is significant.

The overall aim of this study is to design and develop a low cost device that aids industries to minimize their energy cost. The device is capable of Monitoring and logging energy consumption data real time. The device enables the option of switching the power line to generator when demand exceeds the limit and switch back to main power line when demand is less.

2. BACKGROUND OF STUDY

2.1 Three-phase electric power

Three-phase electric power is a common method of alternating-current electric power generation, transmission, and distribution. It is a type of polyphase system and is the most common method used by grids worldwide to transfer power. It is also used to power large motors and other heavy loads. A three-phase system is generally more economical than others because it uses less conductor material to transmit electric power than equivalent single-phase or two-phase systems at the same voltage [1].Voltage and current readings for each phase are obtained and applied to the eq.(01) below to calculate Apparent three phase power.

$$\text{Apparent Power} = V_{rms(1)}I_{rms(1)} + V_{rms(2)}I_{rms(2)} + V_{rms(3)}I_{rms(3)} \quad (01)$$

Phase angle is calculated by measuring the time instances of the first peaks of the phase voltage and the phase current. Then the time difference is calculated as a reference to the period of the waveform and converted to degrees .When θ is the phase angle of current with respect to voltage, power factor can be defined as eq. (02).

$$\text{Power Factor} = \text{Cos}\,(\theta) \quad (02)$$

The resulting real power can be computed as in eq. (03).

Real Power=Apparent Power× Power Factor (03)

2.2 Industrial Energy Demand in Sri Lanka

According to the Central Bank Sri Lanka, Sri Lanka's power demand is increasing by 7-8% annually. Industrial sector constitutes of 29% of Gross Domestic Product (GDP) and 74% of exports are industrial exports. To sustain this trend in a turbulent international climate, effective management of cost is essential. Global competitiveness is not achievable by either compromising on product quality or through slashing the workforces. Therefore, the key to success is to trim the major production cost components such as energy. Energy efficiency is the feasible approach for a lower cost [2].

Domestic customers are billed only for consumption. But when it comes to Industrial sector, customers are billed for both peak demand and the consumption. Demand charge is the maximum number of kilowatts (kW) a facility uses during the desired time period during the month. This time period depends on the utility company. It may be 15 - 30 minutes for some utilities.

2.3 Literature Review

Stephen Underwood, Frangline Jose and Vincent Chan wrote an application report on "Three-Phase Electronic Watt-Hour Meter Design" Using MSP430 microcontrollers in March 2008 for Texas Instruments. In this, they have mentioned all the hardware implementations with reference circuits. Software implementations with necessary flow charts and basic theories required to develop the program. This document contains a complete test report of their design. The design is capable of showing rms voltage (V_{rms}), rms current (I_{rms}), power, frequency and temperature via LCD display [3].

Stephen English and Rachel Kaplan wrote an application note on "A 3-Phase Power Meter Based on the ADE7752" for Analog Devices. This document contains reference hardware designs, design calculations, meter calibration, design test reports etc. Unlike MSP430, this doesn't require programming and the meter output is analog (can be directly interfaced with an electromechanical counter). This device only shows energy consumption via counter [4].

"Maximum Demand Controller PCM9006" by Industrial Controls & Drives (India) PVT Ltd is available in the market. This device controls 3 outputs. This can be interfaced using RS485. However, this specified product doesn't provide detailed energy usage data. Only five demand values are stored in this device. High cost of these devices is a major drawback in this field.

3. METHODOLOGY

3.1 Block diagram of the developed system

Following Figure 1 illustrates the block diagram of the proposed system.

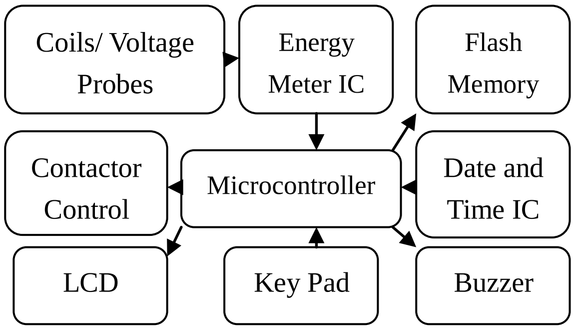

Figure 1: Block diagram of the proposed system

ADE7752A Energy metering IC calculates power consumption data based on the readings obtained via CT Coils and voltage probes. Then, it sends data to microcontroller as digital pulses. Microcontroller counts and measures time between pulses. Based on that, it calculates energy consumption and demand value. Between user defined time intervals, microcontroller is programmed to save current energy consumption reading with the date and time obtained from DS1305 RTC Date and Time IC. In meantime, microcontroller checks current demand value with user defined value and issue operating signal for contactor control if demand is exceeded.

In idle, LCD displays current energy reading and demand. User can access internal menu via keypad to change user defined demand values, date and time etc. Buzzer will generate alarms when exceeding the demand.

3.2 Analysis of the Methodology

ADE7752A IC was chosen for energy metering because it calculates energy consumption data based on voltage and current. It generates pulses according to the energy consumption. For the current sensing function, locally available 60/5A current transformer is used.

Although initially EEPROM was chosen as the storage media, due to limitations of Read/Write cycles and capacity it was rejected. Instead SD

Card was chosen as storage media. This can be easily interfaced via SPI. Large data capacity and almost unlimited number of read/write cycles are achievable by this. DS1305 RTC was chosen for date and time information. This also can be easily interfaced via SPI. With a 3V battery, a backup is kept even the power isn't available. Since SD cards require lot of RAM, PIC16F87X microcontroller range and below cannot be used. Considering the input/output and memory requirement, PIC18F2520 was chosen as the microcontroller.

3.3 Calculations in the design

Since this device use Current transformers which can handle up to 60A, the maximum power that can be measured is calculated as 51.84 kW taking 288 V_{rms} from component specifications.

Max power=3× 60 A_{rms} × 288 V_{rms}= 51.84 kW

Current transformers were chosen with rating 60/5A. Maximum current output from CT Coil is 5 A_{rms}.ADE7752A can handle inputs between -500 mV to +500 mV. Since the input signal is differential for each channel, the burden resistor is split in two to yield and calculated as 0.0215Ω. Practically available 0.022Ω resistor is used in the design.

Using the specifications, attenuated input to each channel is calculated as 0.107 V. Therefore, a resistor divider has been used to attenuate 288 V to 0.107 V. Demand was calculated using output of ADE7752A's CF pin. Time difference between two pulses varies with the demand.

4. RESULTS

Even though this is a three phase device, testing was performed using single phase power, due to unavailability of a three phase power line. First, device was checked for the demand values with some rated electrical appliances. Table 1 shows the results.

Table 1: Demand Values for tested appliances

Electrical appliance	Average by Device
40W Light Bulb	30 VA
60W Fan	48 VA
300W Grinder	111 VA
400W Electric Drill	224 VA
500W Halogen lamp	328 VA
900W Hot plate	905 VA
1000W Iron	2490 VA

Following Figure 2 illustrates the relationship between the average demand value computed from the device and the rated value of the electrical appliances. The brown color graph represents the rated values of the electrical appliances while the blue color graph represents the average value computed by the device.

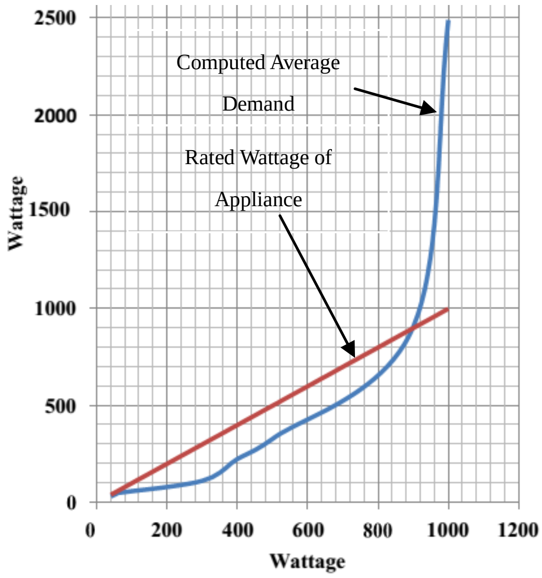

Figure 2: Relationship of Computed Average Power and Rated Power

The current transformer used in this design was a low quality one. Values become incorrect due to high non – linearity in the current transformer. This can be resolved by using proper current transformer which is suitable for energy metering.

5. COSTING OF THE DESIGN

Table 2: Costing of the design

Component	Cost(LKR)
Microcontroller	1690
PIC18F2520	580
PCB Processing	775
16x2 LCD Display	650
Plastic Casing	650
Current Transformer (60/5A)	700
500mA Transformer ×3	675
Others	2489
Total	**8209**

The low cost design is an exceptional achievement as can be seen in Table 2.The total cost of the design is just 8209 LKR which is less than 75 US dollars. This cost can be further reduced in mass production.

6. CRITIQUE

Industrial energy monitor with peak demand controlling is a timely attempt when energy costs are continuously rising. The device provides data for better understanding and monitoring of the energy consumption. Device is fully user customizable. Internal menu for the device is a good feature to view and edit device settings at any time. In idle, device shows number of units consumed and ongoing demand on the line. The user is provided with the feature of setting the demand value, date and time and logging interval using the keypad input.

Device is made with easy to clip on method. So the device can be easily installed and removed anywhere anytime. Power for the system was drawn from the measurement probes. No separate power supplies required. After a power failure, device automatically restores last saved settings and starts up immediately. Using SD card as storage gives user compatible with many devices. No separate ways required to obtain data.

7. CONCLUSION AND FURTHER WORK

The aim of this study was to design and develop a low cost device that aids industries to minimize their energy cost. Monitoring and logging energy consumption data real time, enabling peak demand controlling feature and the low cost design were main objectives. According to the results, it is clearly evident that the device can be successfully used for energy monitoring and logging with peak demand controlling for a considerable wattage range. This is a significant achievement considering the advantages and applications the device brings at a very low cost.

Following suggestions can be considered for further development of this design. Solid understanding about the power line is impossible to be obtained by just measuring energy consumption. Measuring line voltage, current, power factor, phase angle enables a more thorough power line analysis. It always assists auditors to suggest accurate solutions to reduce energy consumption. Energy metering IC used in this study is not suitable to achieve these extra features. A microcontroller which has capability to measure above aspects or ICs like ADE7758, 71M6513 or MCP3909 can be recommended for this purpose.

Further, Demand controlling algorithm used in this study was ineffective for demand controlling in real situation. Further research and testing should be performed to improve this. Embedding this device with PC will benefit with real time synchronization with better advantages. Further, microcontroller used is not fulfilling this requirement. ARM processor can be employed for this purpose. Compatibility of the design device can be enhanced by using a switch mode power supply and using Surface mount technology. The buzzer used in the project was not audible enough for noisy environments. So, better one should be fixed. Casing has to be dust proof to improve reliability and robustness of the device. These suggestions may definitely improve this design avoiding mentioned drawbacks developing this approach to a very high standard.

8. REFERENCES

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