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Smart Energy Monitoring Node

Balkrishna Limaye[1], Dr. S. G. Tamhankar[2]

PG Student (Electronics), Walchand College of Engineering Sangli, India[1]

Assistance Professor, Walchand College of Engineering Sangli, India[2]

ABSTRACT: With the advancements in the automation sector, the machines used in the market are growing to be more and more smart than usual and thus have an impact on their energy utilisation. Smarter the machine, more its energy use. Based on the active and reactive components of power utilised by the loads in an industry, the overall energy efficiency for the plant is calculated. With age, material specific impurities, usage statistics and other energy dynamics during the life of a machine, the amount of energy loss caused due to it, increases. This loss ultimately results in poor power factor of the machine and thereby increasing its energy utilisation. This excess amount of energy use increases the capital expenditure of the industry and thus reduce the overall profit.

This project aims to develop a smart system which could identify areas of high energy losses and notify the person in-charge with its energy usage statistics. Along with the notification, it also aims at providing a portable design, simple user interface &experience to monitor the usage and loss characteristics. To achieve the abovesaid goals, the system uses an embedded system powered by an 8-bit microcontroller CPU, AC power measuring sensors including AC voltage and AC current sensor, a Wi-Fi communication module to transmit the real-time data to a RDB structured using MySQL. It uses the real-time RMS power calculation method to calculate the AC power. It takes into account, the instantaneous power and calculates the energy for a fixed window of time which is repeated after every fixed amount of time. This data is then processed and then routed to the database and then displayed it to the client-side in a locally hosted flask server.

KEYWORDS: Embedded Systems, Energy Conservation, Smart Energy Monitoring, Flask Server, SQL Database, RMS AC Power Measurement, Real-time Database

I. LITERATURE REVIEW

The studies and surveys taken at [1]proved to be interesting and one of the most important facts regarding the energy losses taking place throughout the energy generation to energy distribution stages were highlighted. According to the study,the average loss of power between the power plant and consumers ranges between 8-15%. The stage-wise energy losses found are as follows:

1. 1-2% of energy was found to be lost during the step-up transformer from when the electricity is generated to when it is transmitted.
2. 2-4% of energy is lost in the transmission lines
3. 1-2% of energy is lost during the step-down of the transform from the transmission line to distribution.
4. 4-6% of energy is lost during the distribution

To realise how much power gets lost during the transmission stages, let's consider a machine for an example which works at optimum power with an input of 230V AC potential and AC current of 2A which comes out at approximately 460W of power. Now, ideally the machine must receive the optimum power but, practically it faces let's say min. losses of 8%, the fed power to the machine turns out to be 368W approx. which leads us to a loss 92W!

It's better if we do not imagine how much losses the industrial appliances might be facing!

Another important study carried out by [2] gives us the energy losses that take place inside a simple mobile charger. According to the study, around 1-3W of power is wasted as heat at an input of 5W of power. This calculates to be around 50-60% of power which gets wasted as heat energy. As per the research and study, the main reason for this wastage is step-down losses taking place at the charger level. Every time the charger is switched ON, it steps-down the potential from a higher 110V or 230V to the required 12V-15V and then use the buck-boost principle in order to boost the current to increase the charging speed of the charger. Every stage penalises the charger with a loss of around 1-2%.

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So, twice per cycle gives us around 4-5% of power loss. With respect to the time period that they are kept ON, the energy losses tend to increase thus wasting more energy each cycle.

According to the current research and surveys carried out by the[2]state that, Oil and Gas extraction industry lists at position 1 in highest energy wasting industries. The extraction process requires a lot of raw and crude power which is either powered through fossil fuels like coal, petrol or petroleum products or by electrical generators where the energy requirements are comparatively less. Power generation industry lists at 4^{th} rank on the list of highest energy wasting industries at 33% energy wastage that of generated. This proves to be the very first reason why measurement of energy loss is necessary.

The book Industrial Power Systems[3]describes the need of energy for today's complex electrical power systems and the use of small-scale, locally operated renewable energy sources. It discusses about the requirement of additional tools and operative methods that be included in the current grid for residential and industrial users. It examines the integration of the new, dispersed sources with the legacy systems of centralised generation, as well as how the new technologies can operate effectively in isolated systems. Industrial power distribution, lighting, motor control and protection are discussed in detail. It also helps us identify the areas where we need to replace the pre-existing systems with the new ones.

The work done in Smart Energy Monitor [4] discusses aboutthe ability of the embedded systems to convert the traditional energy meters into smart meters by integrating Wi-Fi, relay modules and other necessary hardware circuitry for integrating the IoT application interface with the embedded system. The microcontroller board acts as the MPU of the system, Wi-Fi being the connecting tissue between the hardware and the database. This provides a platform for the user to monitor and control the appliances.

II. PROBLEM IDENTIFICATION

The current phase of Industry 4.0 aims to develop advanced and sophisticated machines which are not only more efficient but also energy conserving and environment friendly. The only method by which the energy consumption of a machine or a system of machines is calculated is by the traditional means of the ESP (Electricity Service Provider) meters which are not the true indicators of the energy consumption. The reason being the fact that, they work on an ***Output-to-Output** method of measurement.

For e.g. – Let's consider a washing machine which requires say 220V-230V of potential and say 15A of AC current min. power = 220x15=3300W) to work optimally and utilizes a total of say 'x' Units of Energy for a fixed amount of time period, the sub-station provides a single phase of 230V-250V to the machine. Now, the ESP meters only give us the statistics of the energy consumption of the machine i.e., 'x' Units, it does not tell us how much potential and current were drawn from the source by the machine. There could be chances that, the machine used 180V and 18-19A of current or say 250V and 13-14A of current to work. The reduced amount (180-190V) of potential utilised by the machine could be an indication of a potential loss taking place during the transmission of power or could be the excessive loss of power taking place inside the machine due ageing, part failure, or any other specific reason. Similarly, the increased potential draw from the source (250V) could lead to loading effect issues in the distribution sections which could lead to potential failure of the machine or the entire transmission system. The higher potential could possibly be an indication of lower source voltage problems, excessive throughput losses or even an inductive load effect or could be any other possible reason.

This problem leads the way very closely with the energy/power loss calculations. Since, the meters only give us the energy consumed by the machine, it does not take into consideration the energy loss experienced. Ideally the input received from the ESP must be utilized completely by the machine which can be mathematically expressed as:

$$Energy\ Consumed\ =\ Input\ Energy$$

But practically if we want to find out the efficiency of the machine or the energy consumption, we need to consider the losses that take place inside the machine or outside the machine. The losses outside the machine include the transmission losses, connector losses etc. whereas the internal losses include internal resistive losses, inductive losses, current coupling losses etc. Thus, mathematically the practical energy consumption should be calculated as:

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$$Energy\ consumed\ =\ Actual\ Energy\ Consumption\ +\ \boldsymbol{Losses}$$

***Output-to-Output method –**

This is the traditional method of calculating the energy consumption of a machine or a group of machines. It simply calculates between the energy output of the electricity sub-station and the energy output of the machine. It does not take into consideration the input that is actually taken in by the machine during its entire cycle of operation. Thus, they act as the surrogate markers of the energy consumed by the machines.

III. CURRENT SYSTEMS

The measurement instruments which are currently used in the market work on the traditional energy measurement method wherein the total energy consumed by a machine or a system of machines is calculated based upon the energy used by those machines. None of the ESP meters take into consideration, the amount of energy which is fed into the machine or how much does it actually need to work optimally.

There are certain measuring systems which are developed with an idea in mind which would modify the current meters into “smart” meters as reviewed in the work done in the [5]and[6] but, those meters do not redefine the actual method of energy measurement. They have automated the process of energy measurement and calculation using certain IoT platforms and communication protocols connected through modules. Thus, they in turn lead to the traditional measurement methods.Few other projects try to develop an algorithm which can predict the energy utilisation based on the historical data but, the energy measurement method used still remains the same.

IV. PROPOSED SYSTEM

The proposed system includes 2 major blocks:

1. Hardware block – It includes the hardware electronic circuits, sensors and microcontroller (MPU)
2. Software block – It consists of the backend data management and processing systems and algorithms.

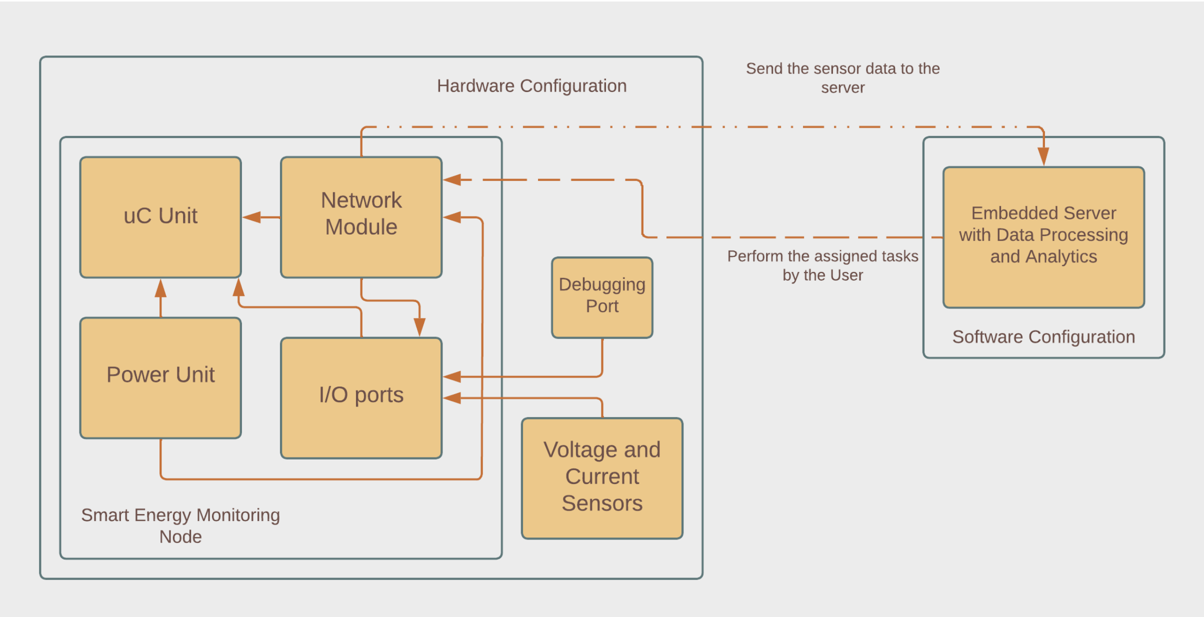

Figure 1– Block Diagram of the Smart Energy Monitoring Node

The main difference between the current systems and the proposed one is that, unlike others this system is based on a different perspective of energy measurement. This system calculates the energy that is supplied into the system and then simultaneously calculates the energy consumed by the machine.

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The hardware block consists of the Voltage and Current sensors which are utilised for sensing the power from local, individual appliance port. It also consists of the required amplifiers and allied circuitry for signal processing.The MPU is the microcontroller which functions as the integrating thread of the entire sensing, processing and data management system. The data that is generated from the sensors gets processed into the MPU and then routed to the software section over Wi-Fi.

The software block consists of a database where all the energy values get stored and then are routed to the client-side UI. The client-side UI consists of a webpage which helps the user to identify the high-power consuming areas along-with the time period in which those machines worked.

V. RESULTS

The proposed solution was tested upon a variety of workloads including purely resistive, inductive and Level Switched loads. The following data was acquired and analysed.

Sr No.	Test Load	Actual AC Voltage		Actual AC Current		Sensor measured AC Voltage		Sensor measured AC Current	
		ON	OFF	ON	OFF	ON	OFF	ON	OFF
1.	Heating Iron (1600W)	220-224V	235-240V	5.9-6.02A	0.00A	221-225V	236-241V	6.0-6.08A	0.00A
2.	200W Bulb Level 1	233-237V	234-238V	0.14-0.16A	0.00A	234-236V	234-237V	0.13-0.15A	0.00A
3.	200W Bulb Level 3	230-235V	233-238V	0.31-0.33A	0.00A	229-234V	233-237V	0.32-0.34A	0.00A
4.	200W Bulb Level 5	229-234V	234-239V	0.7-0.8A	0.00A	229-234V	233-237V	0.69-0.81A	0.001A
5.	Drilling Machine	225-232V	235-239V	1.2-1.5A	0.0005 A	224-233V	236-238V	1.1-1.6A	0.000A
6.	700W Food Processor	220-225V	237-240V	2.8-3.1A	0.00A	222-226V	236-241V	1.7-2.1A	0.00A

Table 1 – Experimental Result analysis of the Proposed System

The input power measurement and calculation fed to the machine were done using industry standard multiple DVMs and Digital Ammeters. For the purpose of efficiency and calculation feasibility, all the values were calculated in their RMS (Root Mean Square) values.

From the sensor value obtained experimentation and result analysis the proposed solution tends to provide a reliable alternative to the current electricity measuring meters with better working principle and operating characteristics.

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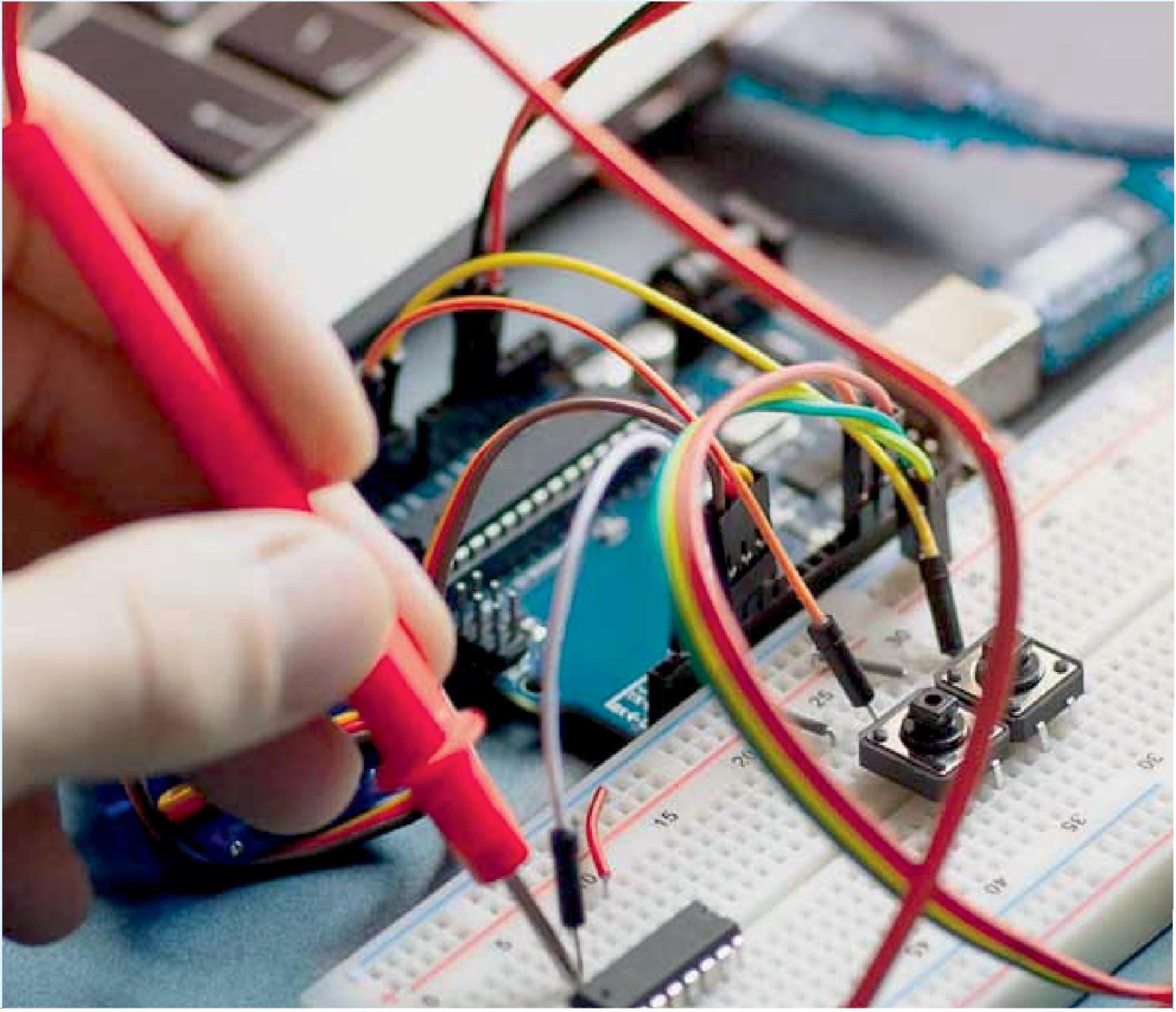

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