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Automation of Power Measurement using Integrated Architecture

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Abstract— Optimum use of power and electricity safety are today a major concern for the mankind. The efficiency with which we are meeting the energy service demands should be examined. This proposed system will be helpful in detection of abnormal power usage and analysing power consumption in organizations / buildings. It also has the potential to monitor the load and health of electrical appliances which encourages the sustainable city development and green campus concept. Our system is a prototype that will be gathering the power consumption data from electrical appliances via sensors and then analyse this data on a monitor interfaced with Raspberry pi using live charts. This will alert the user to make correct and timely decisions about the appliances being used. The data gathered from sensors is being transferred to Raspberry pi through Nordic (Nrf24L01) wirelessly. This methodology can be employed for many applications including faulty system detection/Quality Control in manufacturing industries and usage optimisation at home/buildings.

Keywords— Optimum, Power, Sustainable Development, Abnormal, Electric Consumption, Analyse, Raspberry Pi, Nordic.

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1. INTRODUCTION

Electrical energy is the most common and widely used type of energy in the world. It is the largest energy source for buildings, and this predominance has grown over many years, the two largest energy-using sectors being offices and retail. The service demands of buildings —warmth in the winter, cooking lighting, cooling in the summer, water heating, electronic entertainment, computing and refrigeration, require significant energy use, about 40 quadrillion British Thermal Units (Btu) per year. Overall, in general, the energy use is driven by factors like population, economic growth (GDP), building size, real energy prices.

With the continuous increase in population, the number of households has increased and so has the amount of commercial floor space. A key determinant of growth in the commercial floor space is overall economic activity. The technological developments and inventions have resulted in the rise of power consumption intensity of the buildings. This issue indicates the importance of educating the people on energy-efficient strategies and techniques because of their market impact. The most versatile fuel form, electricity is also the most expensive per equivalent Btu. Thus avoiding heavy consumption will also save the annual energy costs.

Unwatched buildings become less efficient with time. It is expected that equipment will break down or lose efficiency, and that people will forget the good usage habits. Users who know exactly when and where energy consumption occurs and takes place are able to take more informed decisions about how to lower their building energy consumption rates.

Moreover, we should not ignore the fact that when we save energy, we not only save money, we also reduce the demand for fossil fuels like coal, oil, and natural gas. Less burning of fossil fuels also means lower emissions of carbon dioxide (CO2), the primary contributor to global warming, and other pollutants. We are using million dollar worth of energy at every instance of time. Thus, by exercising a few wise habits of energy consumption, we can significantly lower our individual annual emissions and energy bills.

In the light of the above arguments, we hereby propose a prototype which aims at recognising the faulty or abnormal working of appliances and eventually take the necessary actions. The system to be designed requires collection of the power consumption data of the various devices through sensors and analysis of that data in the form of dynamic graphs and charts on a screen. The analogue sensor data is digitised and then transferred wirelessly through Nordic module to the Raspberry pi processor. The processor then displays the charts on the screen which helps the user to know the efficiency of his/her appliances and decide whether a better and efficient alternative is possible.

2. BACKGROUND

Current Transformer Sensors are equipments which sense the electric current (AC/DC) flowing through a wire, and proportional to which a signal is generated. Different types of current sensors are designed using different mechanisms- Hall effect sensors, Current transformer sensors, Resistor sensors, Fibre optic current sensor. Current Transformers or, CT sensors measure the alternating current flowing through any electronic device.

Fig 1. CT Sensor

Arduino Uno, a microcontroller which is based on the chip ATmega328P. It is robust and makes the task quite easy. It has 14 digital input/output pins and 6 analogue inputs, a 16 MHz frequency of machine cycle, a USB port, a power jack, ICSP(In-Circuit Serial Programming) header and a reset button. Resetting the Uno board is possible automatically through software, without the need of physical press of the reset button. The board is programmed using Arduino Software (IDE) which

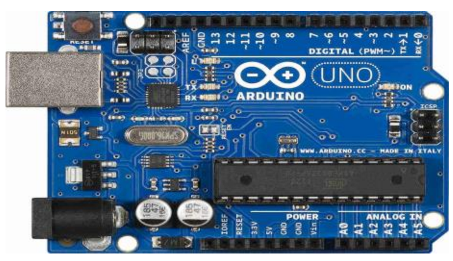

Fig 2. Arduino UNO

can be downloaded free of cost. The ATmega328 chip, initially, comes pre-programmed with the boot loader, due to which we can upload new code without any external hardware programmer. Hence, the biggest advantage of using this board can be that it saves us from a heavy task of circuitry building and tons of lines of coding by giving a pre-wired circuit and free code libraries.

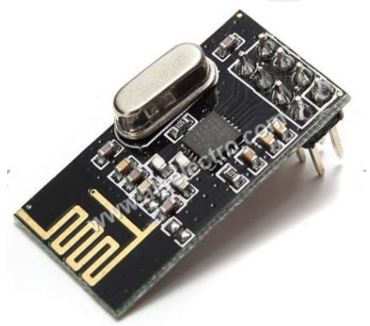

Fig 3. Nordic (Nrf24L01) module

This module based on Nordic nRF24L01is highly integrated and ultralow power (ULP) 2Mbps RF transceiver for the 2.4GHz ISM (Industrial, Scientific and Medical) band. Nordic nRF24L01 integrates a complete 2.4GHz RF transceiver, RF synthesizer, and baseband logic including the enhanced shock burst hardware protocol accelerator supporting a high-speed SPI interface for the application controller. The transmission range is 50-60 meters indoor and around 100 meters in open area. The dimensions of this module is given as 15x29 mm.

Raspberry Pi is a credit-card sized processor developed by Raspberry Pi Foundation UK Charity. It was launched with the idea of educating children and adults in the field of computer science. Later on, it became very famous among experts and

Fig 4. Raspberry Pi (model B+)

professionals for making DIY projects. This miniature marvel packages in itself a considerable amount of computing power into a footprint. The processor it uses is Broadcom BCM2835 system-on-chip (SoC) multimedia processor i.e. most of the system's components are built onto that single component hidden under the memory chip central to the board. This processor uses ARM's generation of ARM11 architecture, designed around instruction set architecture ARMv6 which is lightweight and powerful. Raspberry Pi can run GNU/Linux operating system. The open source development ethos of Linux makes it quickly modifiable to run on Raspberry Pi. The mini processor is able to operate with just a power supply of 5V 1A provided through the micro-USB port. It supports all other features like display, audio, RJ 45 port which all other larger size computers do.

Fig 5. DS 3231 RTC

The DS3231 is a low-cost and an extremely accurate I²C real-time clock (RTC) with an integrated temperature-compensated crystal oscillator (TCXO) and crystal. The device maintains accurate timekeeping when main power to the device is interrupted and incorporates a battery input. The DS3231 is offered in a 16-pin, 300-mil SO package and is available in commercial and industrial temperature ranges. The integration of the crystal resonator enhances the long-term accuracy as well as reduces the piece-part count in a manufacturing line of the device.

3. LITERATURE SURVEY

The prototype uses Raspberry Pi, relay board and CT current sensors as the hardware to control the electrical devices energy. The proposed system makes use of ARM to act as a virtual computer to send data on the internet cloud and replaces the computers being used only to keep record of data. The application is mainly built using Laravel PHP framework, Javascript with MySql database [1]. The proposed system allows users to perform remote and parallel workflow execution, whose tasks are efficiently scheduled and distributed in cloud computing environment. It is a technique to identify the kind of events happening in a building, without the help of cameras or motion sensors, etc. By providing scaling structure and parallel processing features utilizing cloud computing technologies, it accelerates the speed by data analysis [2].In this paper a Home Energy Management System has been developed using PIR sensors, Zigbee module and IR remote controller. The PIR sensors will notice the presence of a person in a room and according to IR remote controllers attached to the appliances in the room, they will work. It will save the wastage of unnecessary energy. The PIR sensors will communicate to the server via Zigbee module, which will transfer the data. A LCD display is also used for monitoring the PIR sensors value and for the end user interface. Thus this prototype is useful for avoiding the wastage of energy and for an intelligent home automation system [3]. The paper presents an intelligent energy safety and management systems to autonomously shut down power outlets instantly to prevent electrical circuit overload. The presented billing module is used to identify user, activate smart power outlet (SPO) module, deduct payable for electricity, and cut off power supply to the outlets by taking away the RFID card. In addition, the WSN transfers the power parameters of each SPO module to central energy monitoring platform, and the monitoring platform with graphical user interface (GUI) displays the power charge of the electricity real-time information [4]. The paper proposes implementation of sensor web node as a part of IoT using a Raspberry Pi. Using this technology, in an example of monitoring and determining the confidence of fire in building, a full system, based on Sensor Web elements, is created and developed starting from a scratch. The primary advantages of this concept include how each device forms a small part of the Internet, by which the advanced system is able to interact and communicate, maximizes safety, security, convenience and energy-savings [5]. The proposed system makes use of modern concepts and technologies like RFID identification, Wiegand protocol, ARM 11 controller, Cloud etc.to make the management task easier and efficient compared to systems being implemented today. The system is designed to remove the costlier counterparts being employed which are not only adding to costs but also in terms of space required to perform their tasks and reduce the unnecessary manual work being carried out at libraries, to have a simple and transparent access to the library data to both beneficiaries and authorities [6].There are two major components in this system which includes: a wireless sensor network and an intelligent home gateway. Wireless sensors are used for sensing and transmitting electricity data. The control and remote monitoring of home appliances are provided to users through the intelligent home gateway. The actual power consumption is measured by the sensors and this information, with the on/off status of electronic products, is transmitted via ZigBee, which is used as a communication protocol. [7]. The project presents a low cost and flexible home control and monitoring system using an embedded microprocessor and microcontroller, with IP connectivity for accessing and controlling devices and appliances remotely using smart phone application. The proposed system does not require a dedicated server PC with respect to similar systems and offers a novel communication protocol to monitor and control the home environment with more than just the switching functionality [8]. The system allows the measurement of the electric energy parameters of within a building, where the main power source has been divided into several sections for individual analysis. Measuring electric energy in sections allows the identification of higher consumption areas, the detection of abnormal conditions in voltage and current of the building. The consumption of electric energy parameters are displayed by means of an easily understood graphic interface which can be consulted via the Internet [9]. This system is based on a three-layer structure. In the server layer, the meters installed in the campus buildings acquire the data. In the middle layer, storing and processing of data is done. In the client layer, monitoring interfaces, are accessible remotely through the Internet, based on statistical and data mining techniques and provide both traditional and advanced monitoring tools. These techniques exploit data in order to find electrical patterns, predict future power consumption, optimize peak power, detect faults and deviations, etc. [10].

4. PROPOSED SYSTEM

The proposed system is divided into following three different modules in order to measure the power consumed by different appliances. These are explained as follows:

4.1 Data Collection

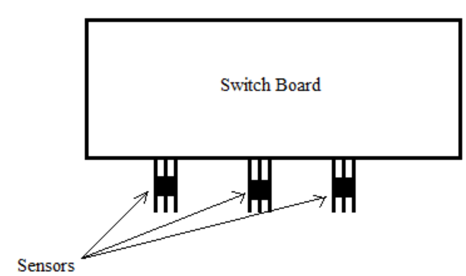

Fig 6. Data Collection

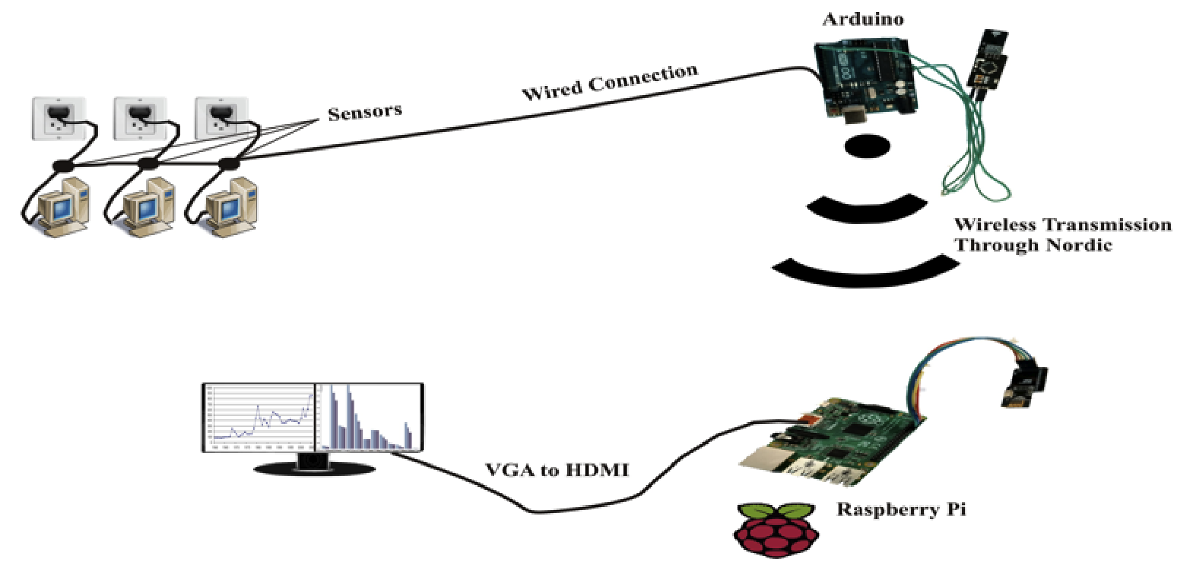

Fig 7. System Architecture

The test bed comprises of three computing devices. Initially, the real-time electric current values of the appliances are to be gathered. This is done with the help of CT (current transformer) sensors, one each clamped on every test device. The sensors are each of 5A capacity to withstand all the variations in the devices and give the electric current values in analogue form. This data is further passed on to the Arduino board through a wired connection.

4.2. Data Digitisation

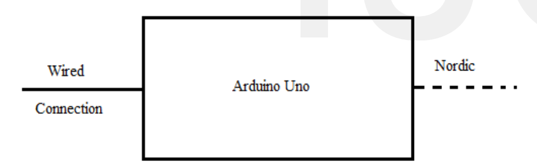

Fig 8. Data Digitisation

The sensor data coming from the wired connection is taken as input into the separate channels of the Arduino UNO board. Here, A to D conversion is performed on the analogue data received from the CT sensors. Now, the digitised values are taken up by module mounted on the Arduino board. Nordic will transfer this data over to the Raspberry pi. Transmission over the wireless module also ensures the security of the data.

4.3. Data Presentation

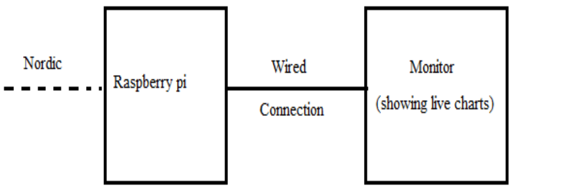

Fig 9. Data Presentation

The digitised electric current values from the sensors are fed to the Raspberry pi through its UART pins. LAMP stack installed on the Raspberry pi provides MySQL as the database. Python programming on these pins calculates the power consumption values and send them to the database. Now, the data being real-time, time stamping is a matter of concern. Since our processor lacks a real-time clock, we use a separate RTC attached to Raspberry pi. The RTC will give the universal clock timings at the GPIO pins of the Raspberry pi. The database, therefore, has records of consumption data in tuples of time and power consumed. All this data after being stored have to be displayed on a screen as live charts and graphs.

5. COMPARISON WITH EXISTING SYSTEM

Aiding for the controlled usage of electricity, there are many alternatives that have been designed. Numerous efficient energy alternatives in light fixtures, windows, insulators, building controls, and appliances, as well as whole building design and construction have been developed in the recent years. Even the utilisation of such alternatives cannot lead to conservation of energy if used on an uncontrolled scale.

Smart meters introduced help in reducing power outages and tripping of electrical systems, and also economize to receive lower energy bills. But shifting from the old traditional meters to smart meters adds to extra costs for the new smart meters and disposal of the old analogue meters. Some people also doubt the accuracy of the device and the security of the data too.

The system being proposed in this paper provides an interactive way of viewing the electrical consumption data to the user. An interactive form of data means a better understanding and interpretation by the user which ultimately leads to more accurate decisions. This system also ensures security of the usage data through a proper user-authentication module. We are using Raspberry pi as the processing device which is cost-effective and light-weight in comparison to contemporary processors.

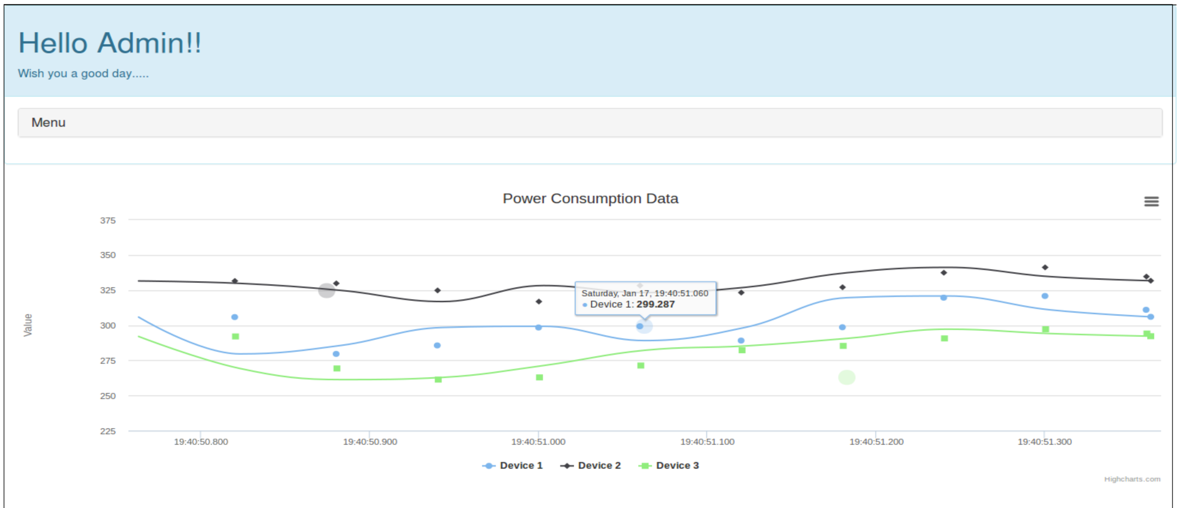

Fig 10. Graph showing real-time power consumption of different appliances

6. RESULTS

The dynamic graphs shown on the screen represent individual line plots for each appliance. This will enable the user to observe the power consumption patterns of the appliances separately. Any unusual pattern in the plot tells about the deviation from the normal usage pattern of the appliance. For example, when peaks in the graph cross the threshold value, it indicates that the electric consumption is more than normal. This informs the user to limit the usage of that appliance. Also when the line plot abruptly goes down and constantly remains in the same level, it suggests the appliance is damaged. In this situation, the observer might have to either replace or reject the appliance.

7. CONCLUSION

The automated power measurement system can provide information on the working of electrical appliances and their power consumption patterns.It is possible to do the pertinent changes in order to have a significant impact on energy savings using the information provided by the dynamic graphs,. In addition, it successfully makes monitoring easy for its user with the intuitive user interface showing various live graphs and charts.

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