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Smart Tariff Controller Based Energy Bill Optimization for Industrial applications

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Abstract: This Electricity tariff setting is a primary instrument of economic regulation. Tariff provides economic signals, which determine the volume and nature of the demand and supply of power. It is not surprising therefore that a considerable portion of the power sector reform effort is expended on rationalizing tariffs. Through this paper we aim to discuss the potential for alternative ways of charging for electricity and providing concessions to improve the affordability of essential electricity use, facilitate the equitable, efficient and full recovery of the cost of supplying electricity and provide clear information to consumers regarding the impact of their electricity use. Many of the existing tariff elements have been formulated over the years as a result of available technology. In reviewing the electricity tariff structures it is therefore important to consider some of the developments in technology particularly with respect to metering which may facilitate a greater variety in tariff structures now or in the future. In this project we are implementing a smart automatic tariff based load controller to optimize and reduce the energy bills of the industries. This controller will be programmed to operate the non priority loads such as water storage tank pumps, water heaters, Air compressors specially during the off peak periods when electrical tariffs are less costly. And turn this loads automatically off whenever the energy costs are higher. This automatic control of non priority loads in industries will be preset by the user / Energy auditor after the site study. User needs an automatic tariff controller because energy electrical rates kept varying each hour of the day and cannot be operated manually.

***Index Terms* - Demand side management, Smart grid, Microgrid, Smart industry Optimization**

I. INTRODUCTION

Whenever the electricity supply companies make an announcement about its intention to approach the Electricity Regulatory Commission to hike electricity tariff, there is a hue and cry among the public. Hundreds of letters and articles pour into the press opposing the hike. Organizations representing the interests of their members hold meetings, conferences and even protest marches opposing any increase in electricity tariffs. This is understandable. Nobody would like to pay more for a service without corresponding improving either in quality or quantity. With increasing power cuts and poor service, any increase in the price of electricity is bound to result in stiff opposition. Power systems are among the most critical infrastructure over decades, where the supplied power from large central power plants is delivered to consumers through transmission and distribution networks. To provide high power quality, network operators have been using services from generation units such as frequency and voltage control and black start. However, increase in the electricity demand as well as the social and political movements towards using renewable energy resources to reduce greenhouse gas emissions have made the optimization of power grid a hot topic again in both academia and industry. To address the demand rise using the traditional paradigm, significant capital investments and operational costs are required to upgrade the infrastructure, which will be reflected in higher electricity bills of consumers. On the other hand, renewable resources are uncertain and intermittent in nature and are not as reliable as traditional generation units to support the grid with services such as frequency and voltage control. The challenges have become more serious in the recent decade due to significant penetration of renewable based generation units into power distribution grids. Solar rooftop panels have been cheap enough to be installed in each household, converting traditional consumers to prosumers, i.e., entities which can both generate and consume electricity. With a high penetration level, these distributed generators (DGs) may deliver the whole demand locally at specific times of a day, causing negative demand in the area.
This phenomenon has never been experienced in traditional power grids. These challenges, combined with the lack of visibility and situational awareness associated with the obsolete infrastructures push the power grid to be more vulnerable to frequent disturbances, which often lead to cascade failures or even blackouts. Optimal design and operation of smart grids require real-time information from smart meters. These new entities in the power system have both measurement and communication facilities to measure important parameters, such as power import and export from/to the grid, and communicate it with appropriate data centers. Using these data and advanced data-driven algorithms, the data center can perform decision making algorithms and

control the grid. For instance, the demand response (DR) is achieved by merging prosumers and intelligent devices using smart meter functionality. Smart meters may contain extra capabilities such as protection, phase measurements and automation to provide higher flexibility.

II. RESEARCH METHODOLOGY

The process of managing the energy consumption in intensive energy sectors such as industrial and commercial sectors involves a very expensive and complex monitoring of individual equipment to help the operator understanding the energy usage. Energy monitoring at the end-use equipment level allows the consumer to have deep insight into his energy usage and hence enable the operator to make informed decisions to reduce operational costs while improving the system ecological profiles. With the continuing evolution towards the smart grid and government incentives, there is a need for smarter energy management that are cost effective, promote the ability to save energy and are actively providing feedback to operators to them reducing their energy consumption. The existing energy monitoring system in industrial sector usually take a single power reading from one panel board, but rarely emphasize the importance of feedback to industrial and commercial operators. To measure the energy consumption at individual end-use equipment level within an industrial or commercial facility, one would need to retrieve data from the mains that indicates the total amount of power consumed at the facility, and be able to analyze the contributing factors to its total power consumption. If the machine specifications within the facility are provided within a database, it is possible to disaggregate the data retrieved from the mains, and accurately predict which machine in the facility is contributing to how much of the overall energy consumption. The Energy Monitoring and Management System (EMMS) consist of the following three modules; 1) In-operation Machine Detection (IMD), 2) Disaggregation and Time-ofUse Calculator (DTOUC), and 3) Graphical User Interface and Operation Scheduler (GUIOS) module. Fig. 1 shows the architecture of the EMMS and its three modules. The IMD module is responsible for identifying the enabled machines (i.e., consuming energy) within the process by taking the measured total active and reactive power as input and output whichever combination of active machines is present within the system as an array to be sent to the DTOUC module. The DTOUC has two embedded functions; the first function estimates the energy consumed by individual machine while the second function calculates the costs of the energy consumed by each machine according to the TOU prices over one full day operation window and displays them to the operator. Within the GUIOS, the operator has the ability to create a timetable with their system's machines. The GUI provides the operator with useful cost-savings feedback based upon the user input while the fuzzy inference system (FIS) provides useful energy consumption feedback to the operator. The EMMS described above has the ability to facilitate cost savings and provide the operator of the product with relevant cost-improvement feedback [1].

In the coming decades, electrical power control grids, confronted with decentralization, liberalization of energy, and increasing requests for high-quality and reliable electricity, will come under stress in trying to provide energy according to these needs [1]. The use of a Smart Grid (SG) is considered a promising approach to coordinate these upcoming needs. Energy management has been investigated as one of the foremost and most complicated optimization problems in power control systems. In practitioners proposed different approaches for efficiently managing the energy by using a smart grid with optimal power dispatch, scheduling of efficient home electrical appliances, and using metaheuristic approaches to solve energy resource-management-related problems in an SG to attain better performance, respectively. SGs provide bidirectional or two-way communication to manage electricity demand and provide communication between the utility and consumer, and this communication is used for energy optimization which permits more productive energy generation and distribution through better communication and information. Energy management in SGs focuses on reducing Peak-to-Average Ratio (PAR), minimization of electricity cost, minimization of power consumption, and maximization of user comfort. This paper considered a residential area containing multiple homes with multiple appliances, aiming to reduce electricity costs while maintaining user comfort and optimizing energy consumption. The relationship of demand and supply in Demand-Side Management (DSM) is reflected by dynamic pricing rates rather than flat pricing. DSM manages the load efficiently to shift from on-peak to off-peak hours. With the help of DSM, load management is handled by the Demand Response (DR) and Load Response (LR) features. There is communication between DR and LR in order to control the high peaks. In our work, we considered Real-Time Pricing (RTP), i.e., dynamic pricing rates which encourage users to shift load between peak hours. RTP works more efficiently for electricity markets as compared to other schemes. To achieve the goal of reducing Peak-to-Average Ratio (PAR) and electricity cost while increasing user comfort level, we used metaheuristic approaches. In this paper, the metaheuristic approaches Earth Worm Algorithm (EWA) and Harmony Search Algorithm (HSA), and hybrid EHSA (EWA and HSA) metaheuristic algorithms are examined to see how effectively we were able to control and monitor smart appliances for multiple and single homes. An Energy Management System (EMS) is a collection of computer-aided tools used by electric utility grid operators to monitor, control, and optimize the performance of a generation or transmission system. Energy management is the process of tracking and optimizing energy consumption to reduce energy consumption in a building. Energy management is regarded as a critical component of an SG to improve renewable energy consumption and energy efficiency Electricity consumption is rising in tandem with the world's population. Conventional power grids are incapable of meeting today's electricity demand. The concept of the SG has been introduced to meet this demand. SGs have been is introduced to meet today's electricity demand, which is increasing because of the increase in population and electricity usage. An SG is an electricity network that allows for the bidirectional flow of electricity and data, as well as the use of digital communications technology to detect and respond to changes in usage and other issues. By using an SG, it is possible to manage power quality, energy efficiency, generation, and storage while fulfilling the market need, Some essential components of SGs used to meet energy optimization challenges are Smart Meters (SM), Renewable Energy Sources (RES), and Smart Appliances. SGs are designed to improve the reliability of the electrical power supply and reduce overall energy consumption. Using this information, Demand-Side Management (DSM) strategies are applied to optimize the usage of electricity and maintain a balance between demand and supply, which ultimately results in reduced electricity costs. These DSM strategies help users to manage the load during peak hours [2].

A smart energy monitoring system is an electronic device or software that allows users to monitor and manage their energy consumption. The system typically consists of sensors, data loggers, and software applications that work together to collect and analyze energy data in realtime. With this information, users can make informed decisions about their energy usage, identify areas of waste, and optimize their energy consumption to reduce costs and environmental impact. The primary components of a smart energy monitoring system are sensors, data loggers, and software applications. The sensors are responsible for collecting data on energy usage, such as the amount of electricity, gas, or water consumed. These sensors can be installed on various devices, including appliances, meters, or outlets. Data loggers are devices that store data collected from the sensors and send it to the software applications for analysis. Finally, the software applications analyze the data and provide users with real-time feedback on their energy consumption. A smart energy monitoring system offers several benefits to users, including: Improved Energy Efficiency: By monitoring energy consumption in real-time, users can identify areas of waste and take steps to reduce their energy usage. This leads to improved energy efficiency and lower energy bills. Environmental Sustainability: A smart energy monitoring system promotes sustainable practices by reducing energy waste and greenhouse gas emissions. This helps to protect the environment and promote a greener future Cost Savings: By optimizing energy consumption, users can save money on their energy bills. This makes a smart energy monitoring system a cost-effective solution for homeowners and businesses. Increased Awareness: A smart energy monitoring system raises awareness about energy consumption and encourages users to adopt sustainable practices. This leads to a more informed and engaged community that is committed to reducing its environmental impact. While a smart energy monitoring system offers numerous benefits, it also presents several challenges, including: Cost: The cost of implementing a smart energy monitoring system can be prohibitive for some homeowners and businesses. The initial investment in sensors, data loggers, and software applications can be expensive, making it difficult for some users to adopt this technology. Data Privacy: A smart energy monitoring system collects sensitive data about a user's energy consumption. This data must be protected from unauthorized access, which can be challenging in a world where cyber threats are on the rise. Technical Expertise: Implementing and maintaining a smart energy monitoring system requires technical expertise. This can be a challenge for users who lack the skills and knowledge to install and maintain the system. Integration: Integrating a smart energy monitoring system with existing home automation systems can be challenging. This requires coordination between different systems and technologies, which can be time-consuming and complex. Smart energy monitoring systems incorporate a range of technologies to enable their functionality. These technologies include: Internet of Things (IoT) - IoT refers to the interconnectivity of devices through the internet. Smart energy monitoring systems use IoT to connect energy monitoring devices to a central system. This enables real-time monitoring of energy consumption. Sensors - Smart energy monitoring systems use sensors to detect energy consumption levels. These sensors are installed in various points throughout the home or building, allowing for accurate and real-time monitoring of energy consumption. Artificial Intelligence (AI) - AI is used to analyze energy consumption data and provide insights into energy usage patterns. This enables consumers to make informed decisions about how to reduce their energy consumption. Cloud Computing - Smart energy monitoring systems use cloud computing to store and analyze energy consumption data. This enables real-time monitoring of energy consumption, even when the user is not on the premises. Smart energy monitoring systems have a wide range of benefits. They can help to reduce energy consumption and save money on energy bills. They can also help to reduce carbon emissions and promote sustainable living. Overall, a smart energy monitoring system is an excellent investment for homeowners and businesses looking to reduce their energy consumption and save money on energy bills. With the ability to track energy usage and make informed decisions, users can take control of their energy consumption and contribute to a more sustainable future. Smart Energy Monitoring System (SEMS) is an emerging technology that uses advanced sensors and data analytics to monitor energy consumption in real-time. SEMS can play an important role in reducing energy consumption, minimizing energy waste, and promoting sustainable energy practices. In this literature review, we will examine ten papers published between 2010 and 2017 that explore different aspects of SEMS [3].

With the increased use of modern technologies and smart appliances in every field of life, energy consumption is rapidly increasing. The rising electricity demand cannot be fulfilled by the traditional electric power grid. That is why the smart grid is becoming more popular to fulfill daily electricity demand. The smart grid (SG) is supposed to be the incorporation of information technologies (IT) in the existing power grids to increase their robustness and consistency. Smart meters (SM) are used for communication and energy monitoring purposes in SG. To schedule smart appliances in residential, commercial and industrial sectors, an energy management controller (EMC) is installed at the consumer premises. Demand side management (DSM) has many strategies that help to solve the energy optimization problem by peak clipping, load shifting, strategic conservation, flexible load shifting, strategic load growth and valley filling. By using these strategies, the load is shifted from high demand timings to low demand timings [1]. The two main functionalities of DSM are proper management of the load and demand response (DR) [2]. Consumer load management is also known as DSM. It is the process of shifting electricity demand from high-demand (on-peak) hours to low-demand(off-peak) hours to decrease the energy cost. DR is the consumer’s response to variable pricing signals. There are two shapes of DR: in the form of energy price reduction or some incentives to consumers. The main objectives of the energy management system (EMS) are the reduction of the energy bill, PAR and consumer discomfort. Many algorithms have been deigned to accomplish the aforementioned objectives. For cost and energy consumption minimization, mixed integer linear programming (MILP), mixed integer nonlinear programming (MINLP), non-integer linear programming (NILP) and convex programming were used . However, these techniques are used for fewer appliances and have a large convergence time. In order to overcome these deficiencies, researchers use meta-heuristic techniques to resolve the issue of energy optimization. For cost minimization, the genetic algorithm (GA) was proposed by the authors. For cost minimization and aggregated power consumption, differential evolution (DE) and ant colony optimization (ACO) were used.

In SG, numerous algorithms have been proposed by researches, for energy-efficient optimization in residential, commercial and industrial areas, for the benefits of both consumers and the utility. The main targets of researchers have been balancing the load and decreasing electricity cost. Different parameters such as pricing mechanisms, types of appliances and different user demands are considered. Hybrid bacterial foraging and genetic (HBG) algorithm-based DSM for smart homes was proposed by the authors in [3]. They focused on peak load reduction, cost minimization, user comfort maximization and load shifting. Through HBG cost, PAR and waiting time were reduced compared to GA and BFA. A smart community-based energy optimization technique was discussed in [4]. The authors focused on the end-user’s high comfort level and less energy usage with integration of renewable energy sources using particle swarm optimization (PSO). A time-constrained nature-inspired algorithm-based home energy management (HEM) system was proposed by the authors. GA, moth-flame optimization algorithm (MFO) and their hybridization were proposed for energy bill reduction and achieving end-users' high comfort level [4].

III. PROPOSED SYSTEM

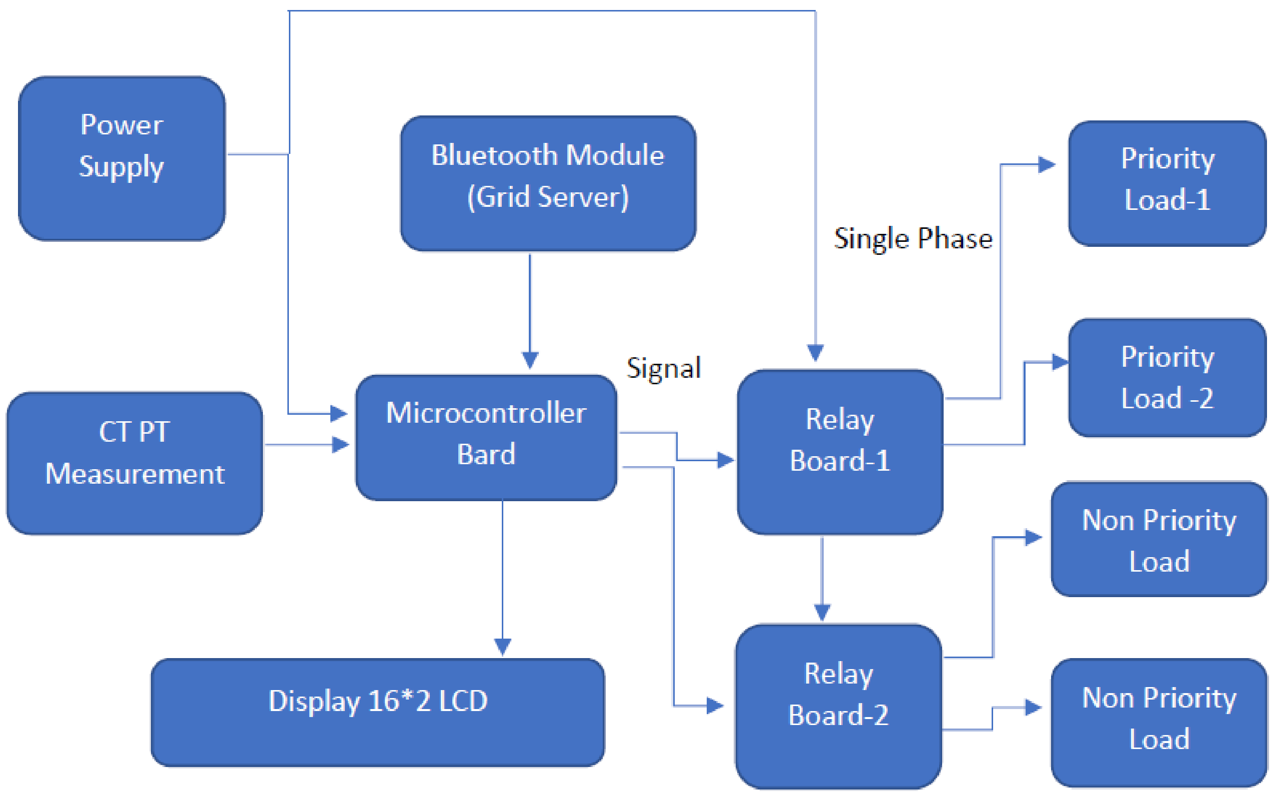

Fig 1: System Architecture

3.1 Power Supply

A power supply is an electrical device that supplies electric power to an electrical load. The main purpose of a power supply is to convert electric current from a source to the correct voltage, current, and frequency to power the load. As a result, power supplies are sometimes referred to as electric power converters. Some power supplies are separate standalone pieces of equipment, while others are built into the load appliances that they power. Examples of the latter include power supplies found in desktop computers and consumer electronics devices. Other functions that power supplies may perform include limiting the current drawn by the load to safe levels, shutting off the current in the event of an electrical fault, power conditioning to prevent electronic noise or voltage surges on the input from reaching the load, power-factor correction, and storing energy so it can continue to power the load in the event of a temporary interruption in the source power (uninterruptible power supply).

3.2 Bluetooth

Bluetooth module is a PCBA board which integrated Bluetooth functions. Bluetooth module can be used in short-distance wireless communication, which can be divided into the Bluetooth module and Bluetooth voice module according to its usage.
Bluetooth module is a basic circuit set of chip which integrated Bluetooth functions and which can be used in wireless network transmission. Generally, the Bluetooth module can be divided into the following types: data transmission module, remote control module, etc. Usually, modules are the semi-finished products, which are processed on the basis of chips to make the next application easier.

3.3 CT/PT Measurement

There are many reasons why you might want to use a microcontroller to measure DC voltage and current. You might be monitoring the output of a generator or solar array, you could be measuring the current consumption of your project or you might want to observe the charging and discharging of a battery. Measuring DC Voltage with a microcontroller (or any digital data device) requires the use of an Analog to Digital Converter (ADC). Many modern microcontrollers, including the Arduino Uno, have a built-in ADC, making DC voltage measurement the simplest of our four tasks.

As stated earlier one of the factors that determine the accuracy of our ADC is its reference voltage. By default, the Arduino Uno uses its power supply voltage as the reference. This is supposed to be 5-volts and can be derived either from its USB port or from its internal linear voltage regulator, which is used when the Uno is powered using the barrel connector. These voltages are not always precise; the USB voltage is dependent upon your computer's power supply and the length and gauge of the USB cable itself. When using the linear regulator with an external supply the accuracy is determined by that regulator,, which can also vary from exactly 5-volts.

3.3 Microcontroller

A single-board microcontroller is a microcontroller built onto a single printed circuit board. This board provides all of the circuitry necessary for a useful control task: a microprocessor, I/O circuits, a clock generator, RAM, stored program memory and any necessary support ICs. The intention is that the board is immediately useful to an application developer, without requiring them to spend time and effort to develop controller hardware.

As they are usually low-cost, and have an especially low capital cost for development, single-board microcontrollers have long been popular in education. They are also a popular means for developers to gain hands-on experience with a new processor family.

3.4 Display

16×2 LCD is an alphanumeric display that can show up to 32 characters on single screen. You can display more characters by scrolling the texts one by one. It can be used with all Microcontroller boards like 8051, AVR, Arduino, PIC, and ARM Microcontrollers. Most projects require an LCD display to communicate with the user in a better way. Most projects requires to display warnings, errors, Sensor values, State of the input and output device, Selecting different modes of operations, Time and date display, Alert message and many more. This will give the project a better view and its operation in a more visual way.

A 16×2 LCD means it can display 16 characters per line and there are 2 such lines. In this LCD each character is displayed in 5×7 pixel matrix. This LCD has two registers, namely, Command and Data.

The command register stores the command instructions given to the LCD. A command is an instruction given to LCD to do a predefined task like initializing it, clearing its screen, setting the cursor position, controlling display etc.The data register stores the data to be displayed on the LCD. The data is the ASCII value of the character to be displayed on the LCD.

3.5 Relay

Relays are electrically operated switches that open and close the circuits by receiving electrical signals from outside sources. Some people may associate "relay" with a racing competition where members of the team take turns passing batons to complete the race. The "relays" embedded in electrical products work in a similar way; they receive an electrical signal and send the signal to other equipment by turning the switch on and off. For example, when you push the button on a TV remote to watch TV, it sends an electrical signal to the "relay" inside the TV, turning the main power ON. Relays are electric switches activated by electrical signals, akin to passing batons in a relay race. They control circuits by opening and closing in response to external signals. Various types exist for different applications, with differing capacities for current and circuits. Typically, relays are electromagnetically operated switches, with two sides: one connected to high voltage devices and the other to the control system (e.g., Arduino). They feature pins for common, normally open, and normally closed connections, and come in models with different channel counts.

There are various types of relays used in many applications to control different amounts of currents and number of circuits. A relay is a switch which is electrically operated by an electromagnet. This relay has two channels. This means it can control two high voltage devices. There are other models with 1, 4, and 8 channels. The relay has two sides. One connects to the high voltage device and the other side connects to the Arduino. The side that controls the high voltage device has 3 pins. The common pin (COM), normally open pin (NO), and normally closed pin (NC).

IV. RESULTS AND DISCUSSION

Sr no	parameter	Value1	Value2
1	Units of energy before tariff	5(before)	3.5(after)
2	Load factor	0.8	
4	Cost Per KW Installation	20000-/	20000-/

Table 1: Result Comparison

V. CONCLUSION

In conclusion, the implementation of a Smart Tariff Controller for energy bill optimization in industrial applications offers significant benefits in terms of cost reduction and efficiency improvement. By leveraging advanced algorithms and real-time data analysis, businesses can strategically manage their energy consumption, capitalize on favorable tariff rates, and minimize peak demand charges. This not only leads to substantial savings on energy bills but also enhances operational sustainability and competitiveness. Furthermore, the adoption of such technology aligns with broader objectives of energy conservation and environmental responsibility, making it a compelling solution for modern industrial enterprises seeking to optimize their energy usage while maximizing profitability. Additionally, the integration of smart technologies fosters greater operational agility, allowing companies to adapt swiftly to changing market conditions and regulatory requirements. Ultimately, by prioritizing energy efficiency and cost-effectiveness, organizations can enhance their bottom line while concurrently contributing to a more sustainable future.

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