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SMART STREET LIGHT SYSTEM INTEGRATED WITH INTERNET OF THINGS BASED SENSORS FOR ENERGY MONITORING

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Abstract. In this proposed work, two prototypes are implemented, one is for smart parking and the other is for monitoring the energy consumption of the same. With the implementation of IoT based Street Light System in the field, nearly 60-70 percent of electricity saving can be achieved as compared to conventional systems. Here, this system is not only controlling the switching of the street lights ON/ OFF but these electricity consumption details can be monitored remotely through another developed prototype. It is demonstrated that for a single pole electricity consumption is nearly 1.2KW load per pole which results in power consumption of 14.4KWh from evening 6:00 PM to morning 6:00AM with conventional system. The implemented system is energy efficient in terms of energy saving which is nearly 9.6KWh can be achieved per day on each pole with same specifications. Moreover, real-time implementation of the proposed system is also demonstrated. IoT is a key technology in healthcare sector for managing, monitoring and controlling the medical devices, services and processes with the basic sensing and actuating components.

Key words: Sensors, Actuators, Arduino Platform, NODEMCU, Internet of Things (IoT), IoT Healthcare, Energy Efficiency, Monitoring and Controlling.

1. Introduction. IoT (Internet of Things) in healthcare sector is transforming the way medical services are delivered, monitored, and managed. It involves the integration of various smart devices, sensors, and systems to collect, transmit, and analyze health-related data in real-time. Applications IoT in healthcare systems are in Remote Patient Health Monitoring, Telemedicine and Telehealth, Chronic Disease Management, Hospital Asset Management, Medication Management, Healthcare Facility Monitoring, Predictive Analytics and Preventive Care, Data Security and Privacy etc. Fundamentally, IoT holds tremendous potential to transform healthcare delivery by enhancing patient engagement, improving clinical outcomes, and optimizing healthcare operations. However, it also presents challenges mainly related to data interoperability, standardization, and regulatory compliance which are needed to be addressed for getting its full benefits in the healthcare industry.IoT facilitates virtual consultations and remote healthcare services, reducing the need for in-person visits and improving access to care, especially in rural or underserved areas. Connected devices enable healthcare providers to conduct remote examinations, diagnose conditions, and prescribe treatments, enhancing patient convenience and reducing healthcare costs.

IoT based street lighting system ensures various metrics of the system like automatic switching of lights from ON state to OFF state or vice versa based on the condition provided for the system. For example, an IoT based system which comprises sensors, actuators, relays, IoT hardware and software with some networking and communication protocols enable the automatic street light monitoring and controlling system to function properly. This IoT based system will be installed on each pole for controlling the lights and monitoring the street lights energy consumption on IoT platforms like web browsers or User Interfaces. In Fig. 1.1, IoT based smart street light monitoring and controlling system is demonstrated in which different components of IoT like IoT devices, Gateways, Cloud, web browser, big data, sensors play essential role. All the smart systems are not intelligent but all the intelligent systems are smart it is because intelligent systems work on larger amount of

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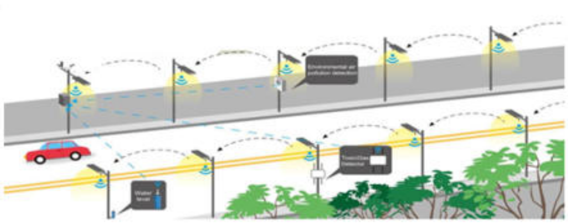

Fig. 1.1: Smart Street Light Monitoring and Controlling System

data means there will be good decisions whereas poor amount of data means there would be wrong predictions. So, for making intelligent systems more and more reliable big data is essential requirement. Street Lights are having very high contribution for providing the safety of transportation system and smart cities development. The existing street lighting system uses old techniques and it is facing so many problems like: Existing Street lighting systems are needed to be Turned ON and OFF manually. It has a high-power consumption and their maintenance is also quite expensive. More manpower is required to handle the functioning of the existing street light system. There is a growing demand of IoT based Smart intelligent systems for street light monitoring and controlling operations. Recently, new technologies evolved for smart city development, smart healthcare, smart agriculture, smart transportation system are also exploring for smart street lighting systems for cities. These technologies can resolve the challenges faced by existing systems such as with the help of IoT, street lights can be switched ON and OFF automatically. Maintenance of street lights using IoT is quite less which leads to cost reduction. Power consumption is quite low in these street lights using IoT which also leads to energy conservation. No large manpower is required to maintain these street lights using IoT technologies. Monitoring the usage of street lights using IoT system is quite easy. Nowadays, it is observed that the sodium lamps are replaced with LED lights in streets of a city because one of the major factors is power consumption which is less and cost is another issue compared to sodium lamps. Further LED lights are eco-friendly and avoids greenhouse gas emission. Our proposed street light monitoring and controlling system can conserve fair amount of energy we can also monitor it on the web browser.

The major contribution of this research work is as follows: Firstly, aprototype is developed for monitoring and controlling of street lights using IoT platforms.Along with this, another prototype is proposed for monitoring electricity consumption at each pole and sending this electricity consumption information to IoT platform, i.e., on web browser. With the first prototype the street lights will TURNED ON/OFF depending on the presence of a moving object. With the implantation of this prototype, nearly 60-70 percent of energy saving can be achieved for a day which is demonstrated in discussion section thoroughly. The developed prototype 2 can be installed at each pole to measure electricity consumption or it could be separately installed for remote monitoring of electricity consumption of home appliances.The integration of both the prototypes can be utilized to collect real-time data of electricity consumption and with large amount of data by applying machine leaning algorithms future electricity consumption demands can be predicted and other controlling actions can be taken with the analysis of the real time data.

This work presents an innovative approach to improving the efficiency and monitoring capabilities of street lighting systems using IoT technology. Quantitative analysis of electricity consumption, demonstrating the energy savings achieved with the IoT-based Street Light System.The main problem addressed is the inefficiency and lack of monitoring capabilities in conventional street lighting systems. By implementing an IoT-based Street Light System along with two proposed prototypes for smart parking and energy consumption monitoring, respectively, the paper aims to tackle the following challenges:

High Electricity Consumption: Conventional street lighting systems often consume significant amounts of electricity, resulting in unnecessary energy expenditure and increased utility costs.

Lack of Monitoring and Control: Traditional systems lack the ability to monitor electricity consumption and control street lights remotely. This limitation hinders efficient resource management and proactive maintenance.

Inefficient Energy Usage: Without real-time monitoring and control, street lights may remain illuminated when not needed, leading to wasted energy and unnecessary environmental impact.

These challenges have been addressed in this research work to demonstrate the potential of IoT-based solutions in achieving substantial energy savings, enhancing monitoring capabilities, and improving overall efficiency in street lighting systems. Further, energy consumption in urban infrastructure,could make a meaningful contribution to global efforts to combat climate change.

In this work, two prototypes have been developed, one for smart parking and the other for monitoring energy consumption. The implementation of an IoT-based street light system can achieve electricity savings of about 60-70 percent compared to conventional systems. This system not only controls the street lights' switching ON and OFF operations but also allows remote monitoring of electricity consumption through another prototype on the web server/UI. It is demonstrated in the result section that a single pole with a conventional system consumes approximately 1.2KW, resulting in 14.4KWh from 6:00 PM to 6:00 AM. Number of results are plotted which directly represents the consumption with the proposed system and existing systems. A comparative analysis is also presented. With the IoT-based system, energy savings of around 9.6KWh per day per pole can be achieved. Additionally, the real-time implementation of the proposed system was demonstrated, highlighting its energy efficiency. Beyond street lighting, IoT is a crucial technology in the healthcare sector for managing, monitoring, and controlling medical devices, services, and processes using basic sensing and actuating components.

As per authors knowledge, the combined approach of controlling the street lights with electricity consumption monitoring is the novelty of the work. The remaining sections of the paper are organized as follows: Section 2 discusses the related work and technical details of the modules needed to implement the proposed system. Next, Proposed system model of Smart street lights monitoring and controlling is discussed in Section 3. Section 4 separately discusses the systems performance and then in Section 5 results are demonstrated. Conclusion and future scopes of the work are presented in Section 6.

2. Related Work and Technical Details. IoT based smart meters study and algorithm designs are presented in [1]. Authors in [5] discussed the LoRaWAN approach for smart street lighting system by using IoT. It is also a communication protocol which is used for IoT based systems to provide longer range of communication. Number of projects which are exploiting this LoRaWAN for its effectiveness to extend range without using the internet. . Lin et al.presented a survey on IoT architecture, enabling technologies, privacy and security and applications in [6]. Further, Smart light monitoring is coupled with ZigBee communication technology which is used in IoT for connecting a greater number of devices to communicate with each other by using this technology. For implementing the IoT system with ZigBee requires a device as a coordinator and other devices as clients. The function of ZigBee coordinator is to collect data from ZigBee client nodes which are generally sensor nodes/motes deployed for specific application [7]. The public safety enhancement and cyber security challenges are proposed by the authors in [8] for IoT based smart grid system for energy efficiency and security and privacy. Further in [9], optimization algorithm is proposed to minimize energy consumption in smart street light system. In [9] authors applied Brute-Force algorithm so there is the scope of proposing other algorithms for the same and minimize the energy consumption to optimize the resource utilization along with this real time data collection which is not taken into consideration is the direction in which a lot of work could be carried out by applying machine learning approaches on real time data to predict future results and reports. Further, in [10] a lot of study is discussed for smart street light system which is intelligent. In [11], Smart Street light systems communication technologies like, Wi-Fi, LoRaWAN, ESP8266, discussed for mesh networking of client nodes still there is scope of Zigbee communication technology for coordinator and client nodes as Zigbee is very popular technology for wireless sensor nodes to communicate with low power and low cost but at the cost of reduced data rates. Work presented in [12] is based on simulation of smart street lights on Fog computing platforms which is totally simulation based and not analytically or experimentally explained and there is also not any product prototype is proposed. In [13] authors discussed the generalized street light system with IoT platforms and cloud platforms. Data Filtering Algorithm is proposed by the authors in [14] This work mainly focused on data storage which is reduced up to some limits. In [15], authors have proposed the IoT based street light system and the IoT platform Blynk is used for remote monitoring and real time data is collected in google spreadsheets. Smart Energy systems research directions are described in [16] with future implementation challenges and limitations of the smart energy systems. Zhonget al.in [17] proposed smart street light system from the optimization aspects and achieved energy saving compared with existing systems but in that work implementation of the hardware is not presented which is highlighted in our proposed system and remote monitoring is also not considered which is considered in our proposed system. In this proposed work, the combined study of Smart Street light system with Smart metering is proposed which is the novel idea of the authors. For each idea there is a prototype developed and installed in the campus of Sithauli Campus of ITM University, Gwalior as presented through some figures in further sections.In recent article of [18], authors reviewed the smart meter as an inter-disciplinary field to support sensing, communication and computing each. Knayer, T., and Kryvinska, N. in [19], demonstrated an analysis of smart meter for household and organizations to achieve efficient energy management. In [20], disruptive technologies such as AI, block chain have been studied to enhance security features for IoT applications in Wearable healthcare systems, stretchable antenna design systems, ambulatory healthcare systems etc.IoT enabled wearable systems are emerging very fast rate and demand of IoT disruptive technologies like AI, Block chain is also increasing due to security and privacy issues in all applications of IoT. Healthcare system contains pulse sensor, Temperature and Humidity sensor i.e., DHT11 which are integrated through IoT platform such as NODEMCU.With the development in the healthcare systems, there is a growing demand of Non-Invasive Techniques for Real-Time measurement of vital signs such as Pulse Rate, Heart Rate (HR), Blood Pressure (BP), SPO2, Respiratory Rate, Blood volume associated to the Cardiac Pulse etc. Thingspeak is a open source cloud platform which is used for monitoring and analysing the PPG signal waveforms in real time related to the humidity and temperature where pulse sensor has been interfaced with ESP8266 NODEMCU development board. Real-time data generated through the IoT device integrated with sensor will be send to the Thingspeak cloud platform and then analysis of waveform will be done by MATLAB analysis tool. Temperature Sensor: It is an electronic device which can be used to measure the temperature of the body and environment. It measures the amount of heat or coldness of the body. It manages the real time monitoring of the data. In [21], Wang et al. have focused on integration approaches of AI with wearable IoT care healthcare systems. IoT solutions optimize hospital operations by tracking the location, condition, and utilization of medical equipment and assets in real-time. RFID tags, sensors, and beacons monitor inventory levels, prevent equipment loss or theft, and streamline maintenance schedules, ensuring efficient resource allocation and cost savings.IoT is specially needed in rural and underserved areas to reduce the in-person visits and improve access to care. Connected devices enable healthcare providers to conduct remote examinations, diagnose conditions, and prescribe treatments, enhancing patient convenience and reducing healthcare costs.IoT technology assists in managing chronic diseases like blood pressure, hypertension, diabetes, and asthma by providing patients with hand-held tools to monitor their health status and adhere to treatment plans. Automated alerts and reminders help patients stay on track with medication schedules and lifestyle modifications. In [22], IoT applications in healthcare are presented with implications in implementing these stat-of art technologies for healthcare sector. Authors in [23] demonstrated real time scenario for integration approaches of IoT with sensor technology.

Technical Specifications. Arduino UNO development board is shown in Fig. 2.1 which is a very popular and extensively used software and hardware platform for developing prototypes. This board contains an ATmega328P microcontroller which is programmed by the user as per their requirements. Mainly, features of this development board are its simple hardware and software which is Arduino IDE is user friendly and a lot of built in functions are available to build prototypes with this development board. Another very important feature is cost which is not much so cost-effective prototypes can be developed with this controller board. Arduino UNO contains 14 digital and 6 analog pins out of 14 digital pins 6 pins are Pulse Width Modulated (PWM) pins. Another microcontroller of this board is ATmega16u2 which is meant to support serial communication and is not user programmable. Basically, ATmega328P is an 8-bit microcontroller in which 32 byte of flash memory is for storing the program code or program memory. In Circuit Serial Programmer (ICSP) headers of the board are used to program the firmware of the ATmega328P and ATmega16u2 microcontrollers.This board is not wi-fi enabled to make it wi-fi enabled ESP8266 wi-fi module is interfaced with Arduino UNO then we can apply it for IoT applications. The SKT500 protocol is used to interface the wi-fi module ESP8266 with Arduino UNO board.

In Fig. 2.2, another IoT development board is demonstrated which is Wi-Fi enabled and the beauty of this piece of hardware is low power requirement and low cost as compared to Arduino UNO. Further, this IoT

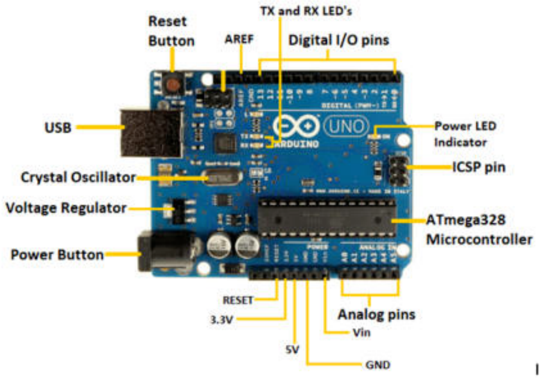

Fig. 2.1: Arduino Uno Development Board

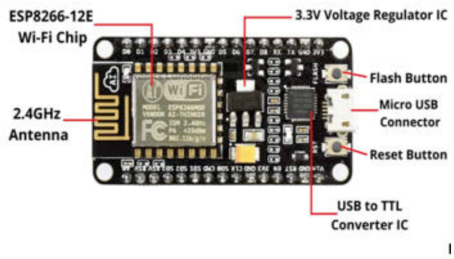

Fig. 2.2: NODE MCU IoT Development Board

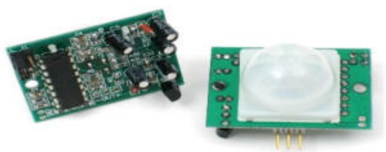

Fig. 2.3: PIR Sensor

Fig. 2.4: PZEM 004T Energy Meter Sensor

Fig. 2.5: Relay 5V

development board has limitation of analog pins which is only one in this whereas in Arduino UNO there are 6 analog pins available for programming the hardware interfaced with this. This NODEMCU contains ESP 8266 Wi-Fi module so it requires a ssid and password to connect to the internet. This board supports 16 digital Input/Output pins, one analog pin, 4MB of Flash memory, SPI and I2C communication interfaces, 64KB of SRAM, clock speed is 80MHz, PCB antenna, 2.4 GHz frequency band for enabling Wi-Fi, CP2102 USB to TTL converter. Next, different sensors and actuators are basic building blocks for any smart system as represented in Fig. 2.3 and 2.4 PIR Sensor and PZEM 004T Energy Meter sensor, respectively are very sensitive components. PIR sensor is basically a motion sensor which is used to detect the physical movement or motion within the range specified by the PIR. This physical parameter, i.e., motion is converted into electrical signal then this signal is analyzed and processed for actuating the output devices or actuators. In an IoT application, sensors are used to measure physical parameters such as temperature, humidity, motion, chemical changes, fire, gas, etc. The working voltage of the Energy meter sensor is 80-260 VAC which is its test voltage also. Rated power is 100A/22000W and working frequency is 45-65Hz. This sensor uses serial communication to communicate with NODEMCU unit by Tx and Rx pins. The energy meter sensor requires 3V power supply which is provided through NODEMCU unit also. To display the readings of each pole LCD display unit can be interfaced.

In Fig. 2.4 Current Sensor CT 013 is shown in which input current range is 0-30A and Voltage Sensor ZMPT1018 AC single phase voltage sensor is also shown it can measure 250 V AC. It is having good consistency for voltage and power measurement. 5 V relay module is used in the proposed system which is having three pins, i.e. VCC, GND and control input pin. The actuating signal output of PIR sensor is provided as the input signal of the relay pin to control the operation of the street lights in the presence of moving object.

3. Proposed System Model of Street Light Monitoring and Controlling System. Fig. 3.1 is illustrating the flowchart of the proposed work excluding the energy monitoring system which is explained separately. In the proposed flow of work, initially it is assumed that all the lights of a street are TURNED

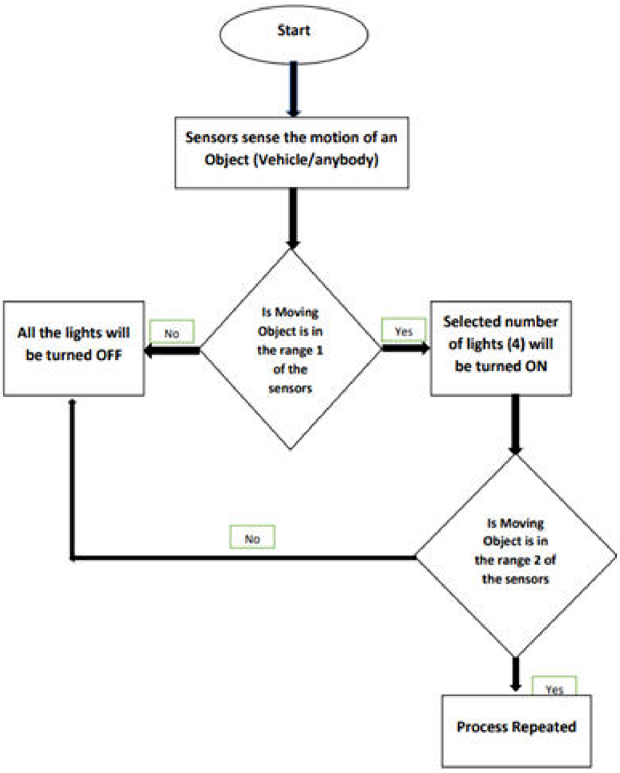

Fig. 3.1: Flow Chart of the Proposed System

OFF. As the moving object comes in the range of sensors corresponding number of lights will be TURNED ON for a specific time period for which it is programmed and then corresponding lights will be TURNED OFF automatically. The same procedure of tuning ON and OFF of the street lights will be continued till motion is detected on the streets and rest of the time lights will remain OFF so this will save huge amount of energy consumption of street lights. As per authors knowledge the work of street lights monitoring is existing but novelty of our proposed approach is to monitor the electricity consumption of each pole with the prototype developed for monitoring and the prototype which is for controlling the street lights. These two prototypes are utilized combinedly and in future a large amount of data could be collected on cloud platform to predict energy demand for residential or industrial infrastructures.

4. Results. In this section, results are demonstrated through figures. One of the protype which is developed using Arduino board, PIR sensor, Relay module is shown in Fig. 4.1, another prototype which is developed using another IoT development platform which is NODEMCU and voltage sensor, current sensor and energy meter is shown in Fig. 4.2, combining features of each other for monitoring and controlling of street lights using IoT. Figure 4.3 monitoring of electricity consumption at each pole and sending this electricity consumption information on web browser is demonstrated. It is observed in Table 4.1 that the real time monitoring of electricity parameters such as voltage, current, power factor, frequency, and power are demonstrated on IoT based applications. Moreover, number of units consumed or the parameters of interest by the application of street light could also be demonstrated on the same platform. Further, Fig. 4.4 presents the IoT based Street Light System Prototype installed at ITM Gwalior Sithauli Campus. As shown in Fig.4.5 the Developed Prototype is installed at this pole of Sithauli Campus at ITM University, Gwalior and initially Street Lights are in the OFF condition and the car which is there is stationary object in this picture. Finally, as shown in Fig. 4.6 and 4.7 initially Street Lights were OFF but with the presence of moving objects (human presence)

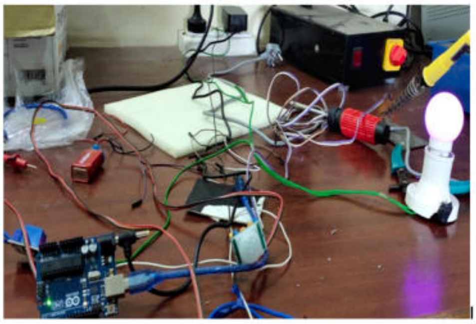

Fig. 4.1: Developed Prototype of Proposed Work

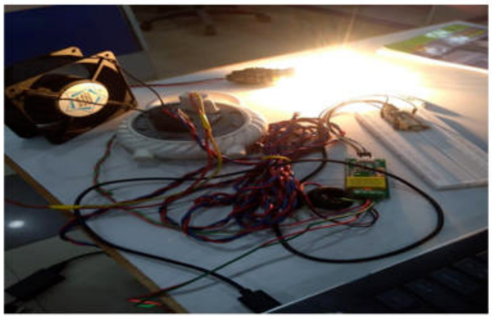

Fig. 4.2: Developed Smart Energy Meter for monitoring Electricity consumption LCD can be interfaced with the same

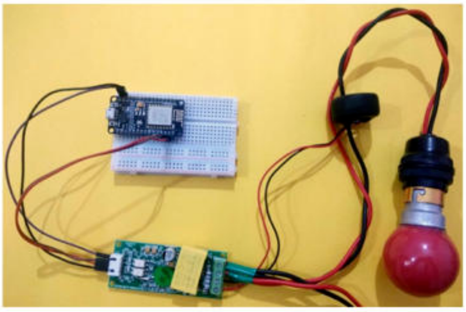

Fig. 4.3: Smart Energy Meter for monitoring Electricity consumption at each pole on breadboard

Table 4.1: Illustration of Electricity Consumption Parameters which could be monitored at Web Server/ User Interface

Parameters	Value	Units
Voltage	225.60	Volts
Current	0.38	Amperes
Power Factor	0.99	-
Power	83.60	Watts
Frequency	49.9	Hz

the lights of this pole is TURNED ON in this picture, Sithauli Campus at ITM Gwalior. In recent article of [18], authors reviewed the smart meter as an inter-disciplinary field to support sensing, communication and computing each.Knayer et al. in [19], demonstrated an analysis of smart meter for household and organizations to achieve efficient energy management.

5. Discussion. In this section, a comparative analysis of the proposed smart street lighting system and the conventional systems such as metal halide street lighting system and high mask LED lighting systems is demonstrated. Further, to analyze the energy consumption of the proposed smart street light system with existing one is demonstrated in the Table 1, based on energy consumption of each system, percentage of energy saving is calculated.It is noticed in the Fig. 5.1 that with the proposed smart street light system considerable amount of energy saving can be achieved during peak and off-peak hours. The same system can be implemented

Fig. 4.4: Street Light System Prototype installed at ITM Gwalior Sithauli Campus

Fig. 4.5: Developed Prototype is installed at this pole of Sithauli Campus at ITM University, Gwalior, India. Initially Street Lights are in OFF Condition as the car is stationary object in this picture.

Fig. 4.6: The process is repeated for another moving objects (human presence) the lights TURNED ON in this picture, Sithauli Campus at ITM Gwalior

Fig. 4.7: Developed Prototype is installed at this pole of Sithauli Campus at ITM University, Gwalior, India. Initially Street Lights are in OFF Condition as the car is stationary object in this picture.

at sub-urban pedestrian areas and residential areas also and large amount of energy saving can be achieved. It is observed in fig. 5.1 that with metal halide lighting system energy consumption per hour for a single pole is 3.3KWh which is 1.2KWh with the high mask LED system and is fixed for each and every hour. Whereas with the proposed high mask LED system the energy consumption is varying during peak and off-peak hours. Fig. 5.2 represent the Comparative Analysis of Energy Consumption between conventional lighting systems and proposed system during peak hours (from 07:00PM to 12:00Noon) and fig 5.3 shows the Comparative Analysis of Energy Consumption between conventional lighting systems and proposed system for 6 hours (from 12:00Noon to 5AM).

Energy Consumed per day is calculated as E (in KWh/day) = P(watt)*T (time in hour per day).

Table 5.1 is demonstrating the energy consumption per day for all three systems. It is noticed that with proposed street light system nearly 69.79 percent of energy saving can be achieved compared to LED lighting system whereas nearly 89 percent of energy saving can be achieved compared to metal halide system.

Along with energy saving, reduction in carbon emission can also be achieved indirectly with the proposed system. Practical demonstration of the proposed system is better explained in the result section by highlighting

Table 5.1: Energy Consumption (in KWh) per day with the proposed and conventional/existing systems

Metal Halide	High Mask LED	Proposed System
39.6KWh	14.4KWh	Nearly 4.35KWh

Table 5.2: Details of Energy Consumptions with existing and proposed systems during off-peak hours with number of hours

Duration in hour	1 hour	2 hours	3 hours	4 hours	5 hours
Metal Halide	3.3KWh	6.6KWh	9.9KWh	13.2KWh	16.5KWh
High Mask LED	1.2KWh	2.4KWh	3.6KWh	4.8KWh	6.0KWh
Proposed System	0.40KWh	0.35KWh	0.24KWh	0.18KWh	0.08KWh

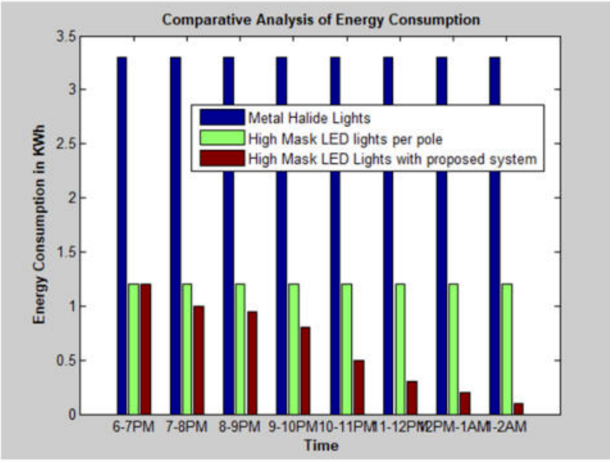

Fig. 5.1: Comparative Analysis of Energy Consumption between conventional lighting systems and proposed system for 8 hours (from 6PM to 2AM)

the installed system in the field.Quantitative analysis, of the electricity consumption of street lights, highlighting the inefficiencies of conventional systems and the significant energy savings achieved with the implemented IoT-based solution is demonstrated. This quantitative analysis contributes to the impact of IoT technology on energy consumption in urban environments. Challenges related to data security, privacy and battery life are very important for real time implementation.

6. Conclusion and Future Work. In this work, an integration approach of monitoring and controlling of the devices is proposed though two prototypes implemented in the field and real time system demonstration is presented in the result section and the energy consumption is analyzed in the discussion section and comparative analysis is also demonstrated which shows percentage of energy saving achieved is nearly 60-70 percent with the proposed system. In the proposed system, one prototype is for controlling the switching of the IoT based smart street lights and other is for real-time monitoring of the electricity consumption of the system and sends this electricity consumption information to IoT platform, i.e., on web browser. The proposed system could be extended for a smart city and can be connected with smart grids to provide solutions to many problems related to the electricity sector. In future, data could be collected from these prototypes and percentage of saving could be calculated and it would be patented and commercialized. Another scope of this work is combining the resultant data of these prototypes at large scale and applying machine learning approaches to predict future

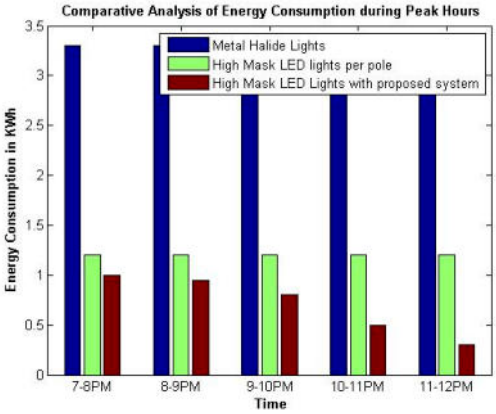

Fig. 5.2: Comparative Analysis of Energy Consumption between conventional lighting systems and proposed system during peak hours (from 07:00PM to 12:00Noon)

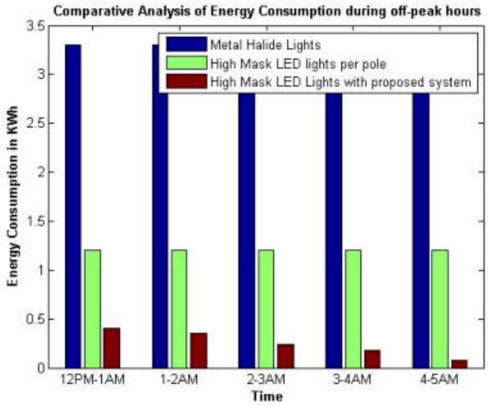

Fig. 5.3: Comparative Analysis of Energy Consumption between conventional lighting systems and proposed system for 6 hours (from 12:00Noon to 5AM)

demand of electricity at residential or industrial infrastructure.Proposed work can be extended by incorporating solar panels and Real-Time-Clock (RTC)modules to achieve more energy efficiency and conserving the energy and supply this energy to power grid. In future, the proposed system can be extended to provide IoT solutions by applying Artificial Intelligence disruptive models with enhanced machine learning approaches for autonomous systems which can take self-decision without human intervention to detect and predict faulty lights, electricity consumption etc. Integration approaches of IoT with cloud are another direction to extend the work.

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