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Amit Bhandari, Mukesh Kumar Ojha, Monika Dixit

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IoT Based Highway light powering system using wind and monitoring system.

Amit Bhandari[1], Mukesh Kumar Ojha [1], Monika Dixit[1]

[1]Department of Electronics and communication, Greater Noida Institute of Technology, Gr.Noida

ABSTRACT

This document contains information about the highway streetlight powering system and how to maintain it so that continuous power supply can be provided to highways using renewable energy sources. Renewable power sources are not only solar power, which is currently used in the power system in such applications. Instead of solar power, we are using wind as a potential source to generate electricity for highways. Highways in villages or roads in sub-urban areas are not electrified yet, and those which are electrified use electricity from the local power stations. Hence, no renewable power source is used in such applications. As a result, a large portion of central and state government revenue is wasted in powering such systems. Due to the upcoming shortage of coal in India, it's very important to optimize every unit that could be transformed into renewable power using an optimization unit. An IoT (Internet of Things) system is used to detect and locate the nits which are used to generate electricity using wind, and it can also be used to monitor the output power, electrical loads, faults and status of streetlights on highways. Implementation of IoT in our unit can help us to detect the output and working state of streetlights and hence help us to electrify each and every road in our rural and sub-urban areas.

KEYWORDS

Internet of Things (IOT); Micro-controller; Global service for mobile (GSM); Wi-Fi; UART; Micro-controller; Database.

1. INTRODUCTION

One of the major responsibilities of state and federal governments is street and highway lighting. Street and highway lighting not only creates a safe scenario for the people but also strengthens and empowers the country's development graph.

Inefficient lighting dilutes much of the financial resources every year and hence has a huge impact on the central and state government balance sheets. An efficient lighting system can reduce up to 25–60% of the daily revenue allotted by the government. Aside from the revenue benefits, a better lighting system can also make the climate and nature pure and serene. The revenue saved by adopting the renewable lighting system could be used to expand the reach of the government and also allow the government to install the system in underdeveloped areas of the cities. As a result, the entire infrastructure of the city could be enhanced. It will benefit not only vehicle owners or drivers, but also pedestrians who wish to commute safely.

The government of India is transforming street lighting in India through the UJALA scheme, as well as the smart cities and street lighting national programme (SLNP).has decided to replace conventional light bulbs with leds to save electricity and adopt climate change with Energy Efficient Services Limited (EESL). The government hoped that by taking this step, it would reduce power consumption by about 1500MW and CO2 emissions by about 62 lakh tons.

A good lighting system allows travelers and commuters to commute easily at nighttime and reduces the chances of accidents due to stray animals on roads. These accidents are not only life-threatening but also cause huge roadblocks in some areas. In hilly areas, street lighting is also very important because of supply chain maintenance. The power used in streetlights in hilly areas is not available. Hence, chances of accidents are very high in these areas.

IoT [16] implementation in street lighting can also make this system robust and efficient because the operator can monitor the status, faults, and power consumption remotely and work on the necessary steps. IoT [16] can also be used to monitor renewable energy generation and to detect device faults or power outages.

Common renewable energy sources are solar and wind. Due to the limitations of solar panels, power generation using wind could be very easy and effective. We all know that highways are built in open areas where there is plenty of wind. using small turbines and a dynamo, we can generate electricity which can charge the battery pack and be used at night. This turbine dynamo setup removes the dependency on sunlight used by the solar panel to charge the battery. Hence, this setup could be used in each geographical location.

Using IoT [16], operators can monitor the power generated by the turbine and dynamo and they can also check the level of battery charge percentage. Apart from battery percentage, light on time, light status, and faults can also be monitored. Individual Wi-Fi or GSM [12] [14] could be part of the system to provide connectivity to the IoT server. More than that, different sensors could also be used to detect voltage percentage, current, and faults in the system. Using unique identification of all the highway lights, monitoring and servicing would be a hassle.

An IOT [16] system consists of various sensors, actuators to improve signal strength, a micro-controller for better computation and logical operations, and a network device for providing connectivity. A suitable regulated power supply is also needed in the system for undisrupted power.

This research paper contributes to the enhancement of existing highway lighting systems with renewable power source lightning systems. The aim of the research paper is to replace the existing power system with a renewable power system to save electricity, reduce government expenditure, and monitor highway light.

1.1. LITRETURE SURVEY

Work done by Marufa Yeasmin Mukta a, Md Arafatur Rahmana, b, A.Taufiq Asyhari c, and Md Zakirul Alam Bhuiyan in a research paper titled IoT for energy efficient green highway lighting systems: Challenges and issues [1] is very important because they were focusing on challenges and issues in energy efficient highway lighting.

They have discussed the ways of generating green energy, which is sustainable for the long term. This green energy is used by smart cities, which would be beneficial for the environment and may also lessen the burden on the government budget. They also discussed the poor facilities provided in street lighting and the issues arising from poor lighting or no streetlights. The huge amount of electricity generation is also responsible for the higher concentration of greenhouse gases in urban areas. They discussed renewable and non-renewable power sources for the generation of electricity used in streetlights in their research paper. As a renewable power source, vertical axis wind turbines (VAWT) are a promising device for the generation of electricity. Power generated from these wind turbines is efficient enough to drive the streetlights for more than 10 hours, which would be sufficient in the Indian region.

E.A.D. Kumara, N.K. Hettiarachchi, K.G.R.M. Jayatilleke , in their research paper titled Overview of Vertical Axis Wind Turbines [2], they briefly discussed the renewable energy source for streetlights and many other applications in their system.They discussed VAWT and HAWT, which are currently being used in Sri Lanka for green power generation. They have talked about the benefits and limitations of both types of turbines and also discussed the power requirements of the current streetlight industry. Wind power, the growth of wind power, and harvesting electricity using turbines were discussed in their article.

Mohammad Khan, Mohammed Alavi, Nithin Mohan, AbidAzeez, Abdul Shanif, and Bilal Javed in their research work titled "Wind Turbine Design and Fabrication to Power Streetlights [3] have discussed the design of wind turbines to generate maximum electricity. Their main focus is to design wind turbines in such a way that small streets can also be used as power generation for streetlights. They have taken the use case of Abu Dhabi, where streets are usually smaller than normal streets in urban areas of developed countries. They have used 12v batteries for storing power generated from turbines. They have also discussed the turbine blade material and angle of the blades. They are not updating the data from the controller to the webserver so that other operators can also see the power generation.

Renato Ricci, Daniele Vitali, Sergio Montelpare, they discussed the wind-solar joint power generation unit in their research paper titled "An innovative wind-solar hybrid streetlight: development and early testing of a prototype" [4].They have discussed the benefits of a joint power supply unit, citing the windless nights and no sunlit days. They have also opted for the grid connection feature so that in case of a power outage, an uninterrupted supply could be provided. Streetlight design for both solar and wind was also discussed in their research paper. LED lights were used to minimize power consumption and improve output.

Mohammad Shariz Ansari, Sagar Garg, Sagar Kaushik, Shivam Sachdeva, they also discussed the joint integration of wind and solar units for the generation of power for street lighting in their research paper titled "Solar and Wind Hybrid Energy System for Street Lighting [5]."have an integrated sensor for detecting lights using LDR and a 12v battery to store power. Power generation is done using dynamos and turbines, and for solar power, a separate solar panel is used. They have also not used IoT as a platform to put the data on the cloud so that local municipal operators can see the status and fault any of the solar lights.

Samrudhi Vaidya , V. P. Rajderkar [6] in their research paper also discussed wind and solar integration for power generation. In their title, titled "Design of Hybrid Streetlight System using Solar and Wind Turbine," they have discussed the variations and methods to generate power for the lighting units. Their hybrid system is useful in both scenarios, in full sun light days and in speedy wind days.

After reading all the research papers, we concluded that 10 or 15 years from now we have to shift from non-renewable power sources to renewable power sources of energy as fossil fuels are about to be finished. Other than that, we must find multiple ways to store power and minimise power consumption by modifying various electrical equipment. Power efficient devices are developed using power electronics, which is a different field for us now. Power saving could also be done using continuous monitoring of devices using IOT. Faulty units can send

alarms so that they can be replaced or serviced on time to

save power.

Now, to enhance the working and reach of all reviewed research papers, our research paper has touched a few more hidden points. In our research work, we are not focusing on hybrid models of streetlights. We are working on wind power only and the turbines were installed on the divider area so that whenever a vehicle passes through, due to its aerodynamics, winds are generated. These winds can propel our turbine blades, which efficiently generate power using a dynamo. Power generated by the dynamo is stored in a battery all day long, and at night, streetlights are turned on using an LDR sensor and a relay setup.

Every step of our streetlight operation, such as energy generation, turbine rpm, voltage and current values, and street light status, is captured by a controller, which then sends the entire detail to the cloud server so that the local municipal operator can see and operate appropriately in the event of a power outage.

2. PROPOSED WORK

This module in the research paper is based on a Wi-Fi based micro-controller having the capability to read analogue signals using SAR ADC [11]. The module contains a dynamo, which generates electricity whenever wind passes through the turbine. A turbine is arranged in such a way that it uses the wind which is generated by the movement of a vehicle. The aerodynamics of the vehicle are used here for wind generation. Once the turbine rotates, it rotates the shaft of the dynamo and, as a result, electricity is produced.

Using the help of sensors and actuators along with ADC [11], electricity generated is measured by the controller and, as an output controller, now has an electricity value. This value will now be sent to the cloud for the monitoring purpose of highway lights. If there is now electricity generation noted for a particular light tower after a fixed buffer time, it would raise an alarm, informing the local authority to deal with the issue. This alarm would be in the form of a SMS or web page notification.

The cloud server plays an important role here because for every city there would be a proper database having tables as per the location, and in the table, tower ID, location, working status, latitude, longitude etc. would be saved. Once the alarm for the fault is received from the controller end via HTTP request, the webpage will be loaded with the proper details of the faulty light tower.

The ESP8266 [11] would be used for the above system unit for ease of use. It has the capability to handle and send HTTP requests for the cloud setup. It also has 1 ADC pin to read voltage generated and, using an additional ADC ic, we can also measure battery DC voltage. Along with that, to save power in the daytime and use the system at night, an LDR sensor would be placed so that automation could also be provided.

Figure1 depicts the architectural diagram of the setup.

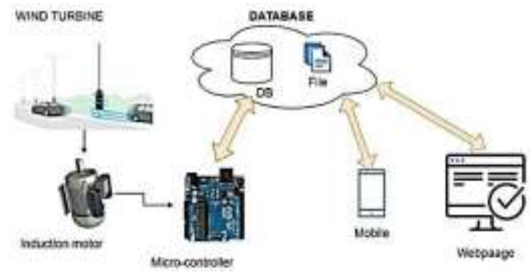

Fig. 1 Architectural diagram of proposed setup.

2.1. WORKING OF SYSTEM

The working system starts with the wind turbine. Wind turbines are placed on the divider areas on the highways where wind speed is very good. Now when any vehicle passes through, due to its aerodynamics, wind is generated, and it rotates the turbine. The turbine is connected to the dynamo, which is generally known as an induction motor. Once the motor shaft is rotated, electricity is generated by the dynamo, which is sensed and used by the controller.

The controller will now amplify the input current provided by the dynamo and use it for reading and sensing. This input voltage is given to the battery for charging purposes, and the status of charging is noted by the controller. The controller will now update the cloud using an HTTP [11] request with proper details of the light tower. The data sent to the cloud also has an error status bit in that whenever detected high, details of streetlight such as location, latitude, longitude, and tower id.

The circuit diagram SAR ADC is depicted in Figure 2. The SAR ADC [11] includes two inputs; the analogue input from the turbine is the first input with a sampling capacitor, and the second is the test value with DAC. Both the inputs are compared using a comparator and the output is derived using a formula depending on the values of the inverting and non-inverting input values.

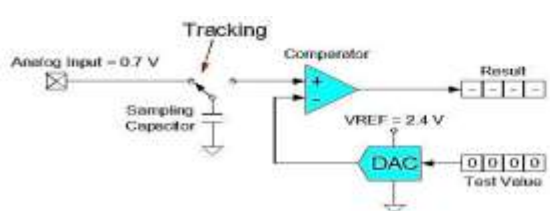

Fig. 2 SAR ADC working.

Value from the ADC is stored and measured, and it gets updated to the cloud using Wi-Fi. To provide Wi-Fi, local city authorities have to setup routers for proper Wi-Fi availability. Another way to put the data into the cloud is using GSM [11]. As we are growing with the number of smart cities, local municipal authorities are providing public Wi-Fi, which could be used in this system to avoid extra node costs.

Continuous monitoring of the system will lead to a huge amount of data which can also cause excess cloud server cost. So to ease out the system and its working, a time-based trigger is used to update the value to the cloud. In this method, data is uploaded to the cloud at a particular time. Hence, time should also be an important part of the monitoring. Additionally, event-based updating is also placed in this setup so that when a fault is detected, at that particular moment, data is uploaded to the cloud.

Wi-Fi communication is based on the UART [10-11] protocol where TX-RX are used with the Wi-Fi chip to communicate. The Wi-Fi chip works on the AT command, which needs to be sent via controller to Wi-Fi. Now, based on AT commands, Wi-Fi will behave and get connected to the cloud. The cloud would be an AWS or HTTP cloud. For better reach, HTTP cloud would be better because of the easier access. The Pin diagram of ESP01 is depicted in Figure 3 and 4 depicts the connection of ESP01 with Arduino.

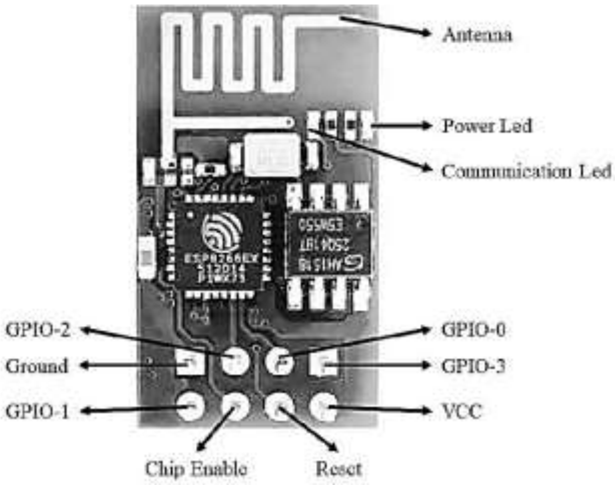

Fig. 3 ESP01 Pin Diagram

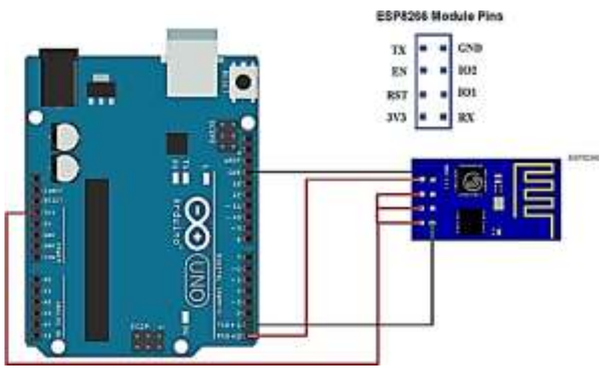

Fig. 4 Connection Diagram of ESP01 and Arduino

Once the interfacing is done, data sending using AT commands would begin. On time-based and event-based triggers, both would initiate the data upload process with separate commands sets. Values with AT commands would send the data to the cloud using an API request. Once an API request is hit, data is received by the cloud PHP files, which further saves the data to database tables. Data saved to tables will be updated after every time trigger or every event trigger.

On the cloud side, two sections are there. The first one is the database section, and the second is the file system section. In the first section, a database is created based on the city name, and inside the database, there are tables based on the area names. These tables contain data for every light post where the unit is deployed. These tables have columns named such as location, lamp id, error status, voltage value, battery charge percentage.

To insert values into the database, the second section of cloud setup file handling is used. The file system generally contains PHP and HTML codes for insertion, updating, and fetching of data from and to the database. It is also used in displaying the data from the database. HTML, CSS, and JavaScript are used for this process.

Data storage is a very critical point here because there would be a lot of data from light posts. Hence, deletion of old data is very crucial at this point.Data available in the database is used to display on the web-based gui or mobile apps. Data of faulty light post is visible and proper notification is given to the local authority. Hence as a result, detailed information about highway light can be visualized and decision making could be done.

3. RESULT

After assembling the unit with the light post, we remove the dependency of city power stations to power up the highway lights. This would let the authority to use this saved budget for other development work within city. This setup also easy out the sunlight dependency which is not available in the nighttime. Hence as a result, we would a system to view the working status of highway lights and error if any one light unit has.

Fig. 5 Result of Location details

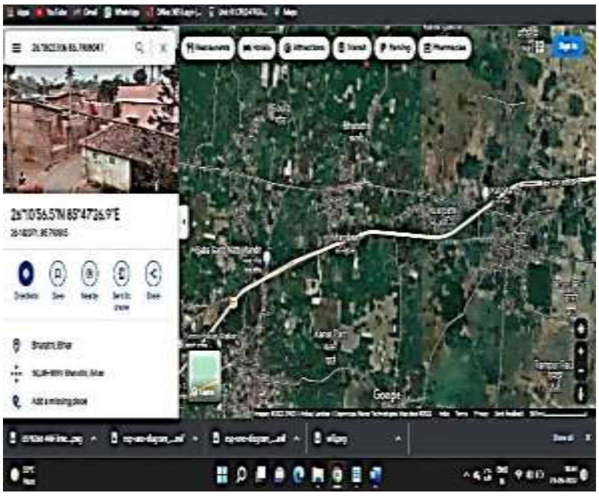

Fig. 6 Result Location on Google Map

In case of error, there would be option to view the location of the light post so that proper and timely solution would be provided. Figure 5 shows the results of location details and Figure 6 depicts the result location on Google Map.

4. CONCLUSION

Our research paper details the existing system and also explains what issues the current highway light systems are dealing with. The local city municipal authority spends a lot of money on streetlights on highways and still the infrastructure is not developing well. After installing our proposed system, not only would expenses be minimized but also it would allow us to monitor the light towers' working and faults.

This proposed modification would help operators to easily detect and rectify the faults and take necessary steps to handle such issues in future in advance. These prior steps not only make municipal infrastructure strong but also help local public and daily commuters to commute easily. With the implementation of such wind turbines, state government would have electricity surplus, which they could sell to the other state or state electricity bill could be normalized.
Addition to this, we also know, we are planning to adopt electric vehicles as our primary vehicle in coming decade. Hence, this setup would also create a roadmap for the charging infrastructure of the electric vehicle in the state.

Road accidents on highways could also be monitored seamlessly because of the un-interrupted power and lighting. This could also be a plus point of the proposed model. Using IoT, various other solutions would be implemented with better features, which would help local authorities to work efficiently.

5. FUTURE WORK

While working on the system, we have analysed that more advanced features could be adopted here for smoother working of units. Connected light posts would also be a part of the proposed setup where multiple light posts relate to each other and share the information within each other.

Another modification is to use AWS or Azure clouds instead of HTTP servers. It would be an important step if a cloud service provider came into the picture. These service providers have various services that would automate the system and enhance the working of the entire project. These would also have the option to use the MQTT communication protocol, which is a light-weight communication protocol.

Here, the network is very important because the entire IoT system is based on the internet. Hence, to provide continuous internet connectivity, local authorities have to maintain a proper internet setup. Instead of using Wi-Fi, the system could also use GSM for cloud connectivity.

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AUTHORS

Amit bhandari received his B. Tech degree in electronics and communication engineering from Maharishi Markandeshwar University Mullana, Ambala, India in 2014 and MTech degree in VLSI design from Greater Noida institute of Technology, Gr. Noida, India in 2022. He is currently working in automobile industry as a cloud architect in Pune, Maharashtra. His areas of interest are VLSI Design,

embedded system, IoT, machine learning and cloud architecture.
E-mail: amit.bhandari55@gmail.com

Mukesh Kumar Ojha is currently working as Associate Professor & Head of Department of Electronics & Communication Engineering at Greater Noida Institute of Technology, Gr. Noida. He is having more than 17 years of experience in academics in various Engineering college and University. He received the Ph.D in Signal Processing from Birla Institute of Technology , MESRA, Ranchi, main campus in the year 2021. He did M.E in communication System from the department of Electronics & Communication Engineering, Anna University, Chennai in year 2007. Mukesh Kumar Ojha obtained B.E degree in Electronics & Communication Engineering from the Institution of Engineers, India in year 2003. His Research Interest includes Signal Processing, Machine Learning, Blind Source Separation, Pattern recognition and its application towards Brain Computer Interface and Internet of Things. He has published several reputed national/International papers in SCI/Scopus journal and attended various reputed conference. He has also chaired in many National and International Conferences. He is also an active member of various technical communities such as IEEE, Institution of Engineers, India, and IETE, India.
E-mail: mukeshbit12@gmail.com

Monika Dixit, is currently working as Assistant Professor in the department of Electronics & communication Engineering, Greater Noida Institute of Technology, Gr. Noida. She received her Ph.D degree in VLSI Design from Amity University, Noida.
She has got 11 years of experience in the teaching profession. Her Research area includes VLSI and Internet of Things. She has filled many patents and Research paper in various reputed Journal and conferences. She has also organized many conferences, workshop and FDPs in the past.
Email: monika.ec@gniot.net.in