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Solar Energy Conservation Using Wireless Sensor Network-Based Street Light Monitoring for Charging Hybrid Electric Vehicles

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Abstract: The demand of the energy sector needs a hybrid energy storage system that will satisfy high energy and power demands for the eV field. As per Ragone's plot lithium-ion battery and supercapacitor, combination can be the best-suited approach to meet this demand reduce the stresses on the battery, and improve the life cycle as a single energy storage device. The short charging and discharging time of the supercapacitor, and the proposed hybridization can lead to failure. Here main theme of the work is to conserve solar and street light energy to store it in suitable energy storage devices located on the street poles so that an ample amount of charging facilities can be made available. The proposed system uses WSNs to monitor and control the performance of the street lights in real time and to reduce the wastage of energy. Combining solar panels with energy storage devices with proper control mechanisms, excess solar energy produced during daylight hours can be used later, especially at night when energy demand is higher. Intelligent monitoring systems adjust the intensity of street lights based on ambient light, traffic availability, and traffic conditions. Additionally, the system provides charging power for electric vehicles, using stored solar energy during off-peak hours. Wireless communication systems facilitate seamless communication between charging stations and WSNs, ensuring efficient resource allocation and preventing power grid overload. The proposed solution offers many advantages such as reduced dependence on conventional energy, lower operating costs, and a sustainable urban environment.

Keywords: *Lithium-ion battery, Supercapacitor, Hybrid electric vehicle, wireless sensor network, solar energy, street light monitoring, Matlab/Simulink.*

1. Introduction

The present work focused on modes of energy conservation that would otherwise decapitate or be lost to the environment. The current automobile sector and many petroleum fuel-based systems are diverting towards electric and hybrid vehicles due to its significant features of zero combustion and developing a green environment, to reduce the hazardous effects of internal combustion engine-based systems. Major limitations for adopting electric vehicles in Asian countries are the high cost and efficient charging mechanism of energy storage devices like batteries and supercapacitors. Proper utilization of non-conventional energy sources like solar and wind energy can reduce these issues at a significant level but with proper infrastructure and grid system, it may take much time for its effective implementations. As per the energy principle, the energy cannot be created nor destroyed, though it can be converted from one energy system to another. The Smart electric vehicles, include identification of the nearest charging station, alarm about any particular part failure of the vehicle, information or signal communication in case of an accident due to foggy situations or urgent unavoidable situations, and many more. Wireless sensor networks and internet connectivity can control all these operations. Street light monitoring not only controls the excess amount of energy wasted but also saves energy that can be stored at charging stations which further can be utilized for charging the vehicle battery or other necessary applications.

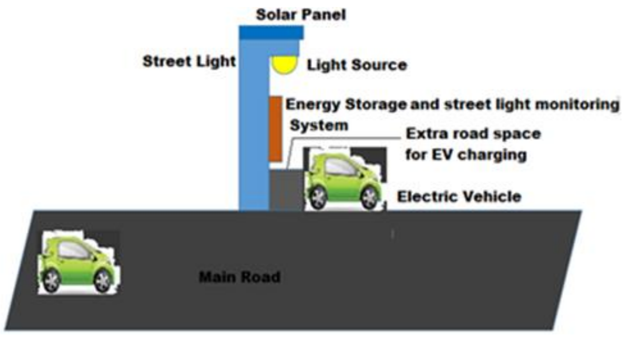

Fig.1. Working methodology of project work

Using the methodology proposed in this work, as shown in Figure 1, a mechanism of variable light intensity of vehicle is proposed so that the street light system will give an

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indication to driver/vehicle about upcoming road conditions, foggy situations, light intensity, etc. and in only necessary conditions the light intensity of vehicle will increase else it will be run in a normal state or OFF. This will conserve the energy that would have been wasted and can be restored in energy storage devices kept at charging stations for further use and can be utilized by charging stations for eV battery charging. Also, non-conventional energy sources like solar energy, and wind energy can be utilized to capture energy storage systems by implementing street lights with solar panels. The sensory smart vehicle detection systems will indicate the presence of a vehicle and indicate a street light to turn ON/OFF. Further, ongoing light-capacity vehicles like two-wheelers or four-wheelers can be charged either in plug-in mode through a socket or using a wireless sensor network.

Fig. 2. Smart city street light monitoring with solar panel and eV charging stations (Image source: Infineon.com)

Intelligent street lights shown in Figure 2, improve the energy network communication by combining related areas into one control system. The smart street light monitoring will perform the lighting operation as per the vehicle detection by which the amount of energy that would have been wasted unnecessarily when there is no vehicle on the road, can be restored in the energy unit as shown in Figure 3.

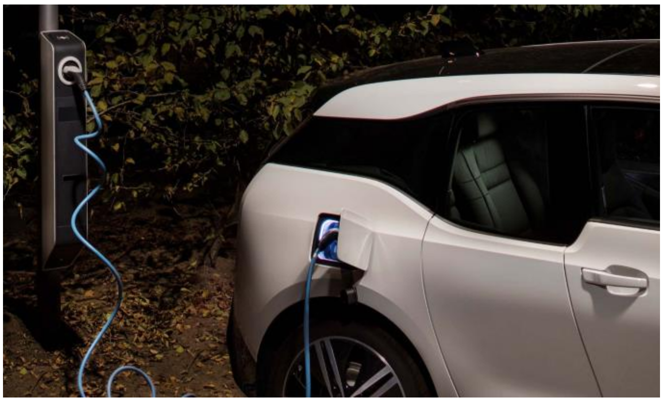

Fig. 3. The integrated charging module,

(Image source: eluminocity, Infineon.com).

This energy unit can be further utilized for EV battery charging for vehicles. And for other necessary applications in nearby areas as well. The energy unit controller monitors the electricity, which runs by LEDs or sodium vapor lamps. Different sensory mechanisms along with an energy controller unit and street light monitoring system will detect the existence of the ongoing vehicles or persons in the region of the streetlight, identify whether or any affecting environmental conditions, foggy or dust situation, etc. vary the light intensity as per the conditions. As shown in Figure 1, these smart street lights are equipped with energy storage units with a wired mechanism for charging electric vehicles. Poor visibility at night time on highways and regular roads is a major issue for the transportation of vehicles. As driving is generally a visual task, therefore low light intensity, and foggy/smoky environment make driving very difficult and many times lead to accidents. In the present situation of energy demands, constant electricity supply to the consumers is not feasible as the rate of electricity production is less than its utilization. Therefore, a better solution is to save electrical energy rather than its consumption and production. The street light monitoring found a novel solution for aforesaid issues. The objective of street light monitoring systems in electric vehicles using wireless sensor networks is to control the use of excessive electricity via remote ON/OFF/DIM of lights that reduce costs and amount of required energy, maintenance, and escalate the life of lamps which directly affects the efficiency of e-vehicle. Compared to conventional modern urbanization and development in automobile industries certain parameters like the safety of drivers, safe driving in foggy situations, and reducing night crime rates need to be considered for the design of an efficient street lighting system. This system can also be used for road accidents to get prompt help for injured people to save their lives. Conventionally street lights were monitored manually, by using high sodium light lamps using optical control circuits. The difficult part for the city is to illuminate the lights on the roads as per the requirements, as it depends upon the climatic conditions in summer day starts at 5 AM but in the winter the day starts after 7 AM, and in the rainy season lights depend upon circumstances. Therefore, seasonal changes are very important for controlling road illuminations. This system also has a feature to help the victims of road accidents using vision sensors and IoT networks. Many times on the streets there are no vehicles at the time of night but the lights are ON, so we can use the vehicle detection sensor for sensing the objects which are passing through the roads. It gives insurance to people who travel mostly at night time. In the beginning, road lights are switched ON in the morning time and switched OFF at night time by manual process, and our proposed system performs this work automatically based on day and night light conditions. An automatic controlling system, controls and monitors energy recovery opportunities on the roads that rich that area range of power stations. In this effort, wireless sensor networks were developed as a technical method to study the viability of monitoring the streetlight control system and charging the EV batteries for lightweight vehicles. IoT system is implemented to get the information and availability of charging point locations, and their capacity in terms of energy and power. The system contains, a modified road with space available for EV charging with the electromagnetic induction mechanism for wireless charging of electric vehicles i.e. the control center, street light equipped with solar panel, energy storage devices, street light monitoring system, Node sensor, and the remote fetal unit. The node sensor is installed at every lamp pole which is used to detect and control the lamp. The microprocessor-controlled electronic device acts as a booster station between the node sensor and the control panel center. The control panel supervises all streetlights in real time. The software is advanced for sensor nodes, servers, and hardware. Figure 2 shows the street light monitoring system. The systems applications can increase the scope of controlling the road lights; and reduce in electricity required for streetlights with a maintenance cost, which tends to increase the availability of streetlights and energy recovery. Entering wireless remote control for the street, roadway, and area lighting makes financial sense, whether switching to LED or retro-fitting fixtures. With the proposed system, one can able to conserve electricity by only using the accurate amount of light you require and by accurately measuring every watt used. Here we can reduce maintenance costs by monitoring real-time faults and by using entire operational intelligence to organize day-to-day planning and effectiveness. In order to replace the conventional combustion engine-based vehicle with an electric vehicle we need to identify it’s affecting parameters like pollutant emission for variable speed limits, temperature monitoring, and structural issues as well. The smart street light equipped with a solar system measures the quality of air under different environmental conditions, detection of nearby vehicles to signal the start and stop of light emissions, and most importantly saves energy. Any unacceptable variation in aforesaid parameters can be informed to the concerned authority for necessary actions for further improvement. Wireless charging will also reduce the chances of accidents and unnecessary traffic at charging stations. The same system can be further used for identifying the availability of parking spaces in heavy traffic zones by use of cloud connection and proper application by connective vehicle system with that of street light monitoring system using IoT.

1.1 Objectives

- Identification and selection of sensor and other components.
- Experimental analysis of the setup for street light monitoring using a wireless sensor network to evaluate technical parameters.
- Implementation of energy recovery and vehicle battery charging mechanism by identifying its working parameters like state of charge, current, and voltage variation.
- Validation of the results with battery and supercapacitor-equipped hybrid electric vehicle.

1.2 Methodology:

As shown in Figure 3, the work starts with the installation of solar panels at selected locations based on sunlight exposure and space availability. Further solar energy harvesting system is designed to capture solar energy and convert it into electrical energy to store it further in battery packs. The wireless sensor network with Zigbee device is deployed for controlling and monitoring street light intensity, fog, and other environmental conditions using sensor and controller arrangements. Development and implementation of a centralized street light monitoring system based on WSN data and dynamically adjusting outdoor lighting intensity based on ambient light levels, traffic, and real-time power generation from solar panels is done. Design and installation of energy storage system of lithium-ion batteries and supercapacitors for efficient energy storage and supply of energy. Next reliable and secure wireless communication protocol to enable the data exchange between solar pane, WSN and charging electric vehicle with proposed hybrid system is implanted ensuring efficient data transfer for optimized energy management. Energy management algorithm is developed for monitoring street lights during peak hours considering energy demands, solar energy availability, traffic and environmental conditions. Finally Simulation and experiential study is performed for validating the results. As an electric vehicle’s battery state of charge reaches a minimum level, the driver will get informed about it on the display screen and search for a nearby charging station having sufficient energy level for charging the vehicle battery. For this purpose, during wired charging mode the driver needs to manually scan the printed QR code on the charging station. Then, the defensive shelter of the socket unlocks spontaneously and the driver can attachment a charging cable so as to rejuvenate the battery of his vehicle. The payment is completed cash-free and appropriately via the smartphone app. Further using the wireless mode, wireless sensor network, and electromagnetic induction working principle the EV gets charged, so, in this case, the driver does need not to get out of the vehicle rather using suitable payment application software payment of battery charging will be done once it gets fully or sufficiently charged. This will also lead to minimizing the traffic and crowd situation at charging stations.

2. Literature Survey

Weibin Liu, et.al. [1] Worked on detection techniques of long-lasting motion for the dissimilarity of illustration which utilizes a histogram of direct inclination using a textured-based context model and Gaussian Mixture Model Algorithm. Outputs of the experiment show the robustness and effectiveness of the commencement in recognizing objects which may be animals, vehicles, human beings, and whatever in different illustration states. Zusheng Zhang, et.al. [2] Worked on a WSN-based street parking system for controlling the parking space condition by implementing a magnetic sensor node using a vehicle diagnosis and adaptive sampling method for accurately detecting a parking car and for energy conservation. Gurkan Tuna et.al. [3] Worked on space and design provocations of WSNs considering current network applications with standard and communication protocols based on field tests in electric power system environments. Pilar Elejoste et.al. [4] Presented an intelligent streetlight management system based on LED lamps, designed to facilitate its deployment in existing facilities using a wireless sensor network to minimize the drawbacks of conventional systems. Jerome Harri, et.al. [5] Worked on a framework based on vehicular mobility for automobile vehicles. Further model evaluation of vehicular mobility and its communication with network simulation was carried out. The experiential analysis was carried out for mobility models for ad hoc networks of vehicles aiming for guidance for supply followers to understand effortless street lights situation compared to the conventional system. Fabio Leccese, et. al. [6] presented automatic process systems that can increase the efficiency and management of road light systems. It uses devices like the Zigbee wireless private network that can be much more robust for the management of road lamp systems, the main part is their moderated infrastructure and controlling system. It utilized a number of sensors to control and to give assurance for the wanted parameters of networks; the data is exchanged from one end to another end using transmitters like Zigbee, and recipients are moved to control room used to clear the conditions of the street light lamps and for getting accurate output in the state of failing the system. Changhai Peng et.al. [7] Proposed an efficient ZigBee-based energy conservation and control system i.e. power sensor nodes which is combination of a gateway, a base station, and sensors to developed and perform both local/remote power parameter measurement and on/off switching for electric appliances. Hongjie Guo, et.al. [8] Worked on a remote sensing system, used for controlling adaptive purpose of metropolitan air quality by deploying various vehicle, as sensor used to measure data including meteorological, traffic status, and environmental data in the city. Zeeshan Kaleem, et.al, [9] proposed electricity-saving outdoor illustration monitoring and control system using Zigbee private wireless network which is able to control and handle outdoor illustrations more effectively than the existing systems. In this system, using ZigBee wireless private network one can control the number of roads with the help of a single model. For proper working of the proposed system, the number of sensors is deployed in the required areas, and after deployment of all sensors. This system can save more than 70% of electricity because electricity saving is more efficient than production. Bushra Rashid et.al. [10] Worked on each application of WSNs in urban areas in detail with all the problems and technical solutions related to it. S. Zahurul et.al. [11] Surveyed advanced agreement for various Wireless Sensor Networks considering the realizing communication infrastructure for DRG in Malaysia using IEEE802.15.4 with ZigBee PRO protocol, sensor, and embedded system. Srishti Banerji et.al. [12] Reviewed sources of energy conservation and as long as their working methodologies, detailed concepts about relevant research, and a present progression of their use in monitoring of structural health for civil engineering structures, considering Solar and mechanical energy cultivators for monitoring structures. Kapileswar Nellore et.al. [13] Presented a survey of current urban traffic management schemes for priority-based signaling and reducing congestion and the AWT of vehicles to provide a taxonomy of different traffic management schemes used for avoiding congestion. The urban traffic management schemes for the avoidance of congestion and providing priority to emergency vehicles are considered and set the foundation for further research. Xiaoli Tang et.al. [14] Worked on a comparative analysis of the number of energy harvesting technologies applicable to industrial machines by investigating the power consumption of WSNs and the potential energy sources in mechanical systems. Chai K. Toh et.al. [15] Worked on the current state, developments, and emerging scope in the area of transportation and mechanisms to improve smart street lights that will make the future smart cities. Ala Khalifeh et.al. [16] Proposed impotent aeriform Vehicles to work as a data carrier for sensor output and transfer the same monitored data cautiously to the center of remote control for further analysis. The next work carried on implementing the issues in the realization of the framework with an experimental evaluation of the design in outdoorsy environments, with various types of environmental obstacles. Jingjing Zhang et.al. [17] Demonstrated the design of a smart street lighting system supported by the combination of NB-IoT and LoRa communication technology by adopting an optimized street lamp control algorithm, to work as the automatic control of street lights according to the real-time traffic flow information. Bhaskar P. et.al. [18] Worked on a cloud-based EV charging framework to overcome issues of high demand for EV charging stations using various IOT-based methodologies like blockchain, behavioral science and economics, artificial and computational intelligence, IoV-based digital twins and software, intelligent EV charging with information-centric networking, parking lot microgrids and EV-based virtual storage, etc. Amjad Omar et.al. [19] Made a comparative analysis of many exploration studies related to smart street light monitoring systems, providing comparative results between various systems that highlight the limitations of every of their Current and future trends.

2.1 Research Gap:

- Smart street light control system for vehicle detection, light intensity, and accident environmental conditions.
- Effective utilization of conserved energy for further applications like EV charging and related novelty.

2.2 The novelty of work:

- Implementation of solar street lights and conservation of energy to charge the EV battery installed on the poles of the street lights.
- Energy preservation by reducing the wastage of energy when it is not required on street lights.
- Accident prevention system by identifying environmental affecting factors like fog, dust, etc.
- Wireless and wired charging of electric vehicles as per the requirement using IoT-based applications and the principle of electromagnetic induction.

3. Simulation and Experimentation

3.1 Simulation

Here simulation is done for the energy circuit designed using Matlab/Simulink software for evaluating and analyzing the results

of solar energy generation during 24 hours as a result of implementing solar panels for street lights to charge the battery and store the extra energy in suitable energy storage device. Figure 4, shows the Simulink circuit for battery charging.

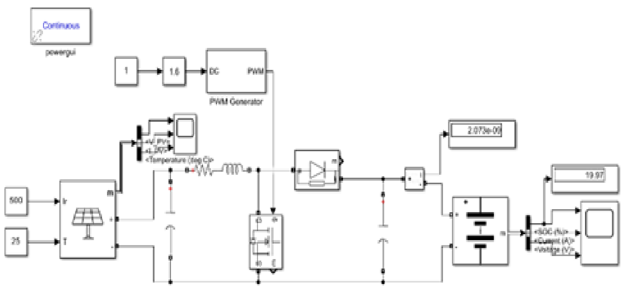

Fig.4. Simulink circuit for battery charging using solar panel

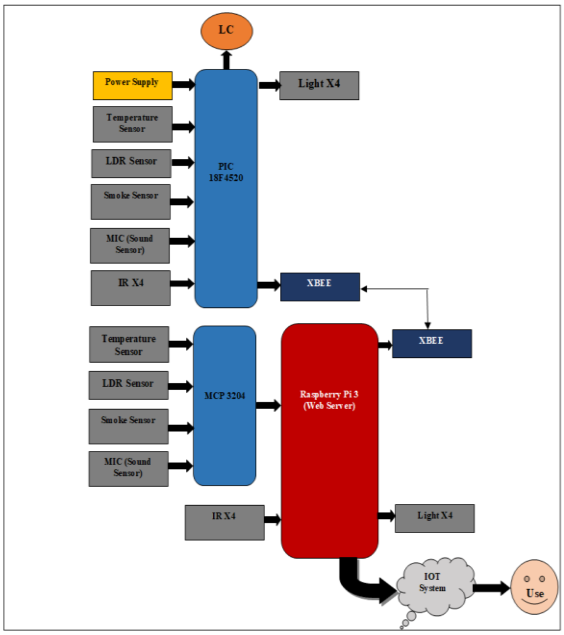

Fig.5. block diagram of the proposed setup

In this system, the role of Zigbee (a wireless private network) is to control the number of roads with the help of a single model. We used a PIC and Raspberry Pi microcontroller for controlling and monitoring all the sensors that were used. Also, we form a network so that we can monitor streets with the help of a single setup of hardware which is more cost-efficient than the existing system. Further for accident detection, we will use sensors like smoke sensors and microphones. After a sufficient literature survey, we develop and propose street light monitoring using WSN as shown in figure 5, for monitoring the temperature, day/night environmental conditions, pollution, accident detection, and rescue system for smart e-vehicles, etc. The existing work consists of split roadside units that will be executed on street lights and a principal server computer. It consists of a microcontroller and XBee network for communication with each system. Android devices are implemented at roadside units preferably for displaying graphic user interfaces, application evolution, and interface with servers via the Xbee grid. Also, after recognition of road accidents, the system will spontaneously propel messages to the salvage system.

Table 1. List of Components Required for Experimental Analysis

Sr. No.	Component	Specifications
1	HESS system	Lithium-ion battery pack of 20A 12 V. supercapacitor pack 13.5V and 100 Faraday
2	Solar panel	5A, 12V, 30W capacity.
4	Microcontroller	6-pin SMD,8-pin DIP chips
5	Raspberry Pi boards	Clock frequency 1.2GHZ, SOC of chipset: Broadcom BCM 2837,

		Processor:32bit, Memory:2GB
6	IR Sensors	2.8V at 15cm to 0.4V at50cm, used for Obstacle detection, Shaft encoder, Fixed frequency detection
7	Light Dependent Resistor	Street Light Control, Night Light Control, 100 LUX Automatic Headlight Dimmer.
8	Gas / Smoke Sensor	1000 ppm Domestic gas leakage Industrial Combustible gas and Portable Gas detector etc.
9	Temperature Sensor	-30^{0}C to 180^0 with Power supplies, BMS, HVAC, Appliances, etc.
10	ZigBee	Standard IEEE: 802.15.4, Frequency 2.4Ghz, range: 10 to 100 light of span, data rate: 20kbps to 250kbps.
11	LCD 16x2	As per requirement
12	Vehicle Model	Small toy car with hybrid energy storage system.

During the experimental setup all related sensors, microcontrollers, and other devices as mentioned in Table 1 are connected as shown in Figure 5. And lithium-ion battery-operated vehicle is used for practical performance of the charging of the vehicle. Energy storage units consist of one another battery pack which will be charged by the street light monitoring system and solar energy. Display devices are used to indicate the variation of performance parameters like state of charge, current, and voltages. The smart system will indicate the working performance parameters of all connected sensors. Figures 6 to 11 show the experimental setup with vehicle detection at different light intensity modes and nodes to reflect street light monitoring. Figure 12 indicates the connections of the street light monitoring system with energy storage units (lithium-ion battery back) to analyze the energy captured and stored for 24 hours.

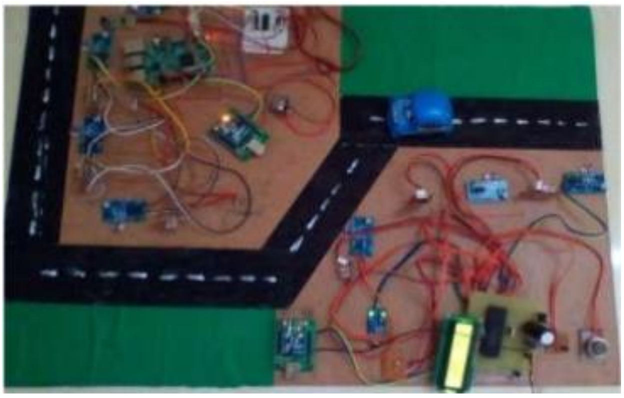

Fig. 6: Experiential Set up

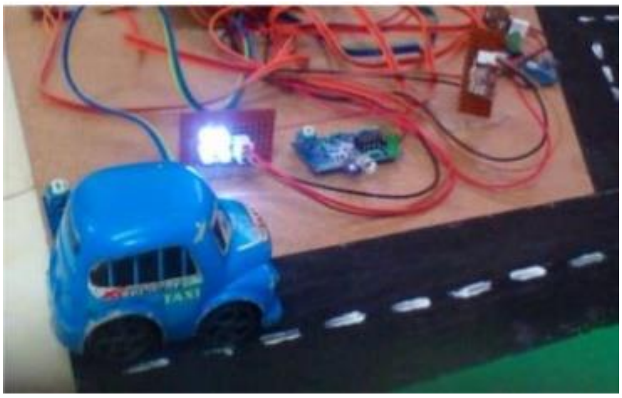

Fig. 7: Vehicle / object detection at high light intensity for node 1

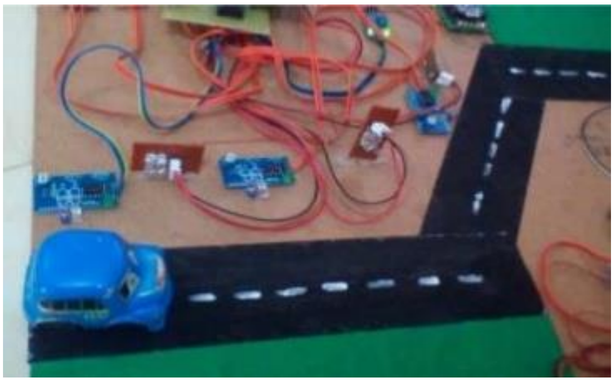

Fig. 8: Vehicle / object detection at lowlight intensity for node 1

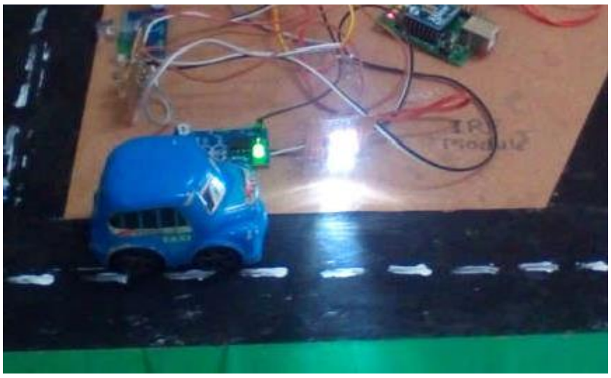

Fig. 9: Turn on the LED when a vehicle or object is detected at low light intensity for node 2.

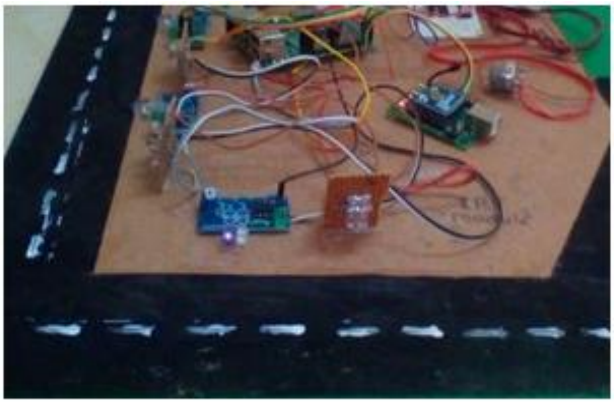

Fig. 10: Turn off the LED in the absence of a vehicle or object at low light intensity for node 2.

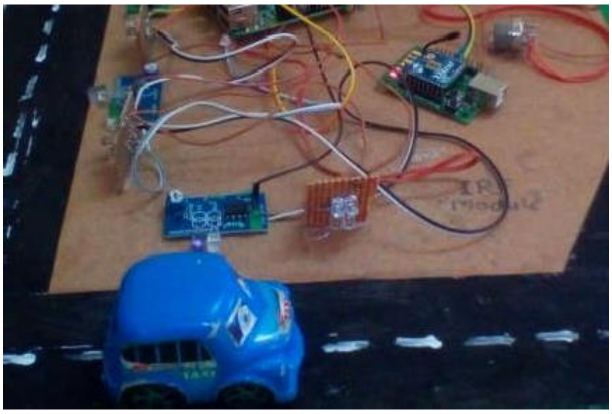

Fig. 11: Turn off the LED when a vehicle or object is detected at low light intensity for node 2.

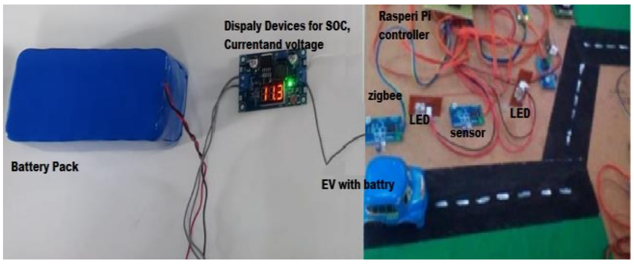

Fig. 12: Street light monitoring system with the battery unit

4. Result and Discussion:

Tables 2 and 3 show experimental results for all sensor data recorded for nodes 1 and 2 respectively. In this table, we consider all sensor readings every 2 hours these readings are for node 1 and 2 for these all sensors are connected to the PIC microcontroller and the PIC microcontroller is sending it to the Raspberry Pi through the Zigbee Network. Here node indicates different street light system equipped with solar panel. Results were taken for sound level, smoke/foggy situation, light intensities, and nodes. Solar energy generation is calculated through simulation for 24 hours and energy generated by solar street light monitoring (scaled to watts) is calculated experimentally as shown in table 4. Lithium-ion battery pack which was initially fully discharged, indicates approx.11% rise to get the state of charge as 11.3% without any measurable variation in current and voltage. With further street light monitoring this energy recovered was found to be sufficient that be utilised for charging the battery packs and storing it at the EV charging stations using wired and wireless sensor modes.

During experiential analysis, time after every interval of 2 hours considering the period of street light requirement is mapped.

Table 2. Experimental results for node 1

Tim	Sou	Smo	Lig	Tem	I1-	I2-	I3-
6A	30.2	22	100.	23.3	DI	DI	DI
8A	33.2	130	120.	24.3	OF	OF	OF
2P	16.2	115.5	239.	32.2	OF	OF	OF
4P	115	115.5	239.	33.2	OF	OF	OF
6P	200	133	145.	27.3	OF	OF	OF
7P	300	200	146.	27.3	DI	DI	OF
9P	123	145	120.	23.3	O	DI	OF
11P	234	145.2	120.	23.3	OF	ON	ON

Table 3. Experimental results for node 2

Tim	Sou	Smo	Lig	Tem	I1-	I2-	I3-
6A	30.2	22	100.	23.3	DI	DI	DI
8A	33.2	130	120.	24.3	OF	OF	OF
2P	102.	288	185	32.2	OF	OF	OF
4P	234.	234	185	33.2	OF	OF	OF
6P	200	133	145.	27.3	OF	OF	OF
PM	300	200	146.	27.3	DI	DI	OF
9P	123	145	120.	23.3	ON	DI	OF
11P	234	145.2	120.	23.3	OF	ON	ON

Table 4. Experimental results for energy generation

Time	Solar energy generated in Kwatts.	Energy captured in battery pack after street light monitoring in watts.
6AM -8AM	1.5	1.1
8AM -10AM	3.0	3.2
10AM -12PM	4.0	4.18
12PM -2PM	4.2	4.28
2PM -4PM	4.5	4.31
4PM -6PM	3.8	4.38
6PM -8PM	1.2	4.42
8PM -10PM	-	3.34
10PM -12PM	-	2.32

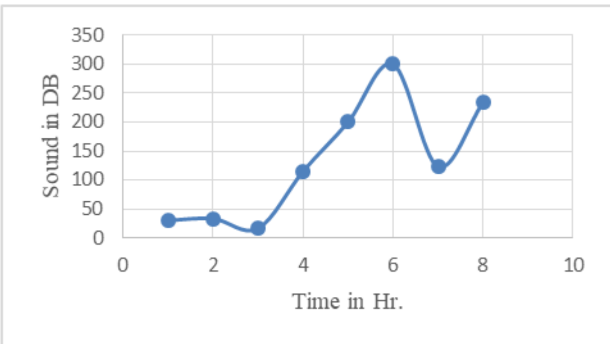

Fig. 13. Sound in DB Vs. time in Hr. for Node-1

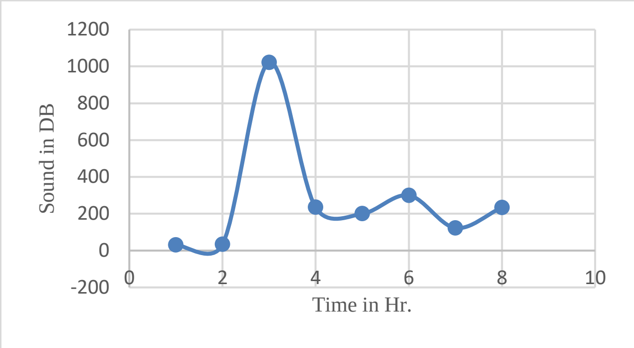

Fig. 14. Sound in DB Vs. Time in Hr. for Node-2

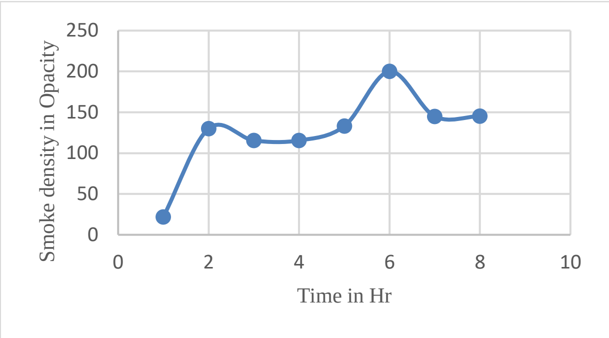

Fig. 15. Smoke density in Opacity Vs. Time in Hr. for Node-1

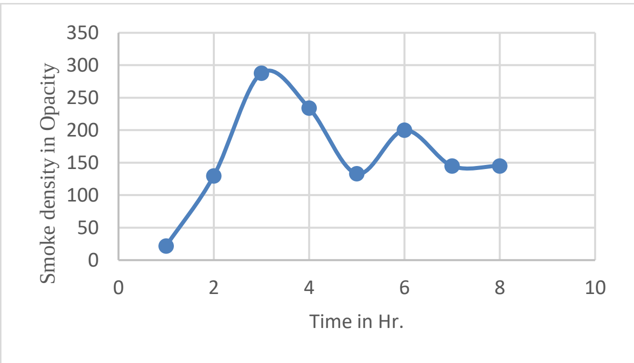

Fig. 16. Smoke density in Opacity Vs. Time in Hr. for Node-2

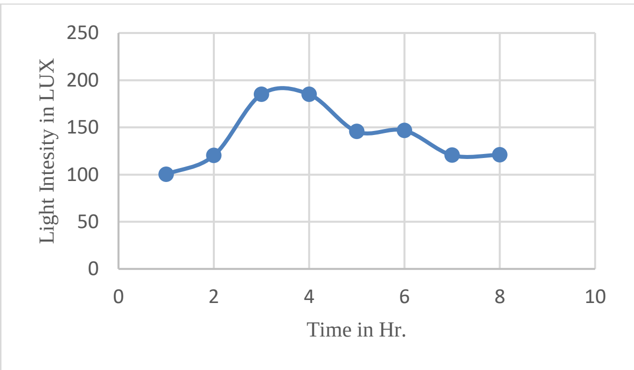

Fig. 17. Light intensity in LUX Vs. Time in Hr. for Node-1

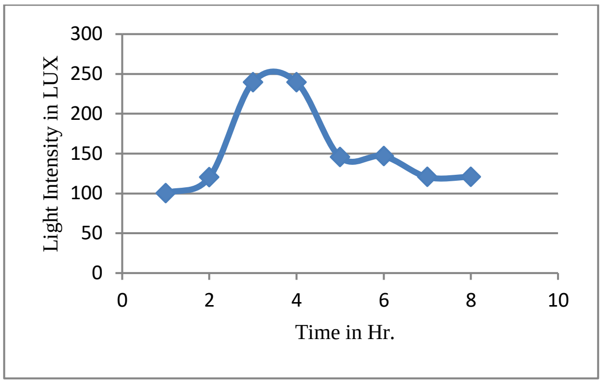

Fig. 18. Light intensity in LUX Vs. Time in Hr. for Node-2

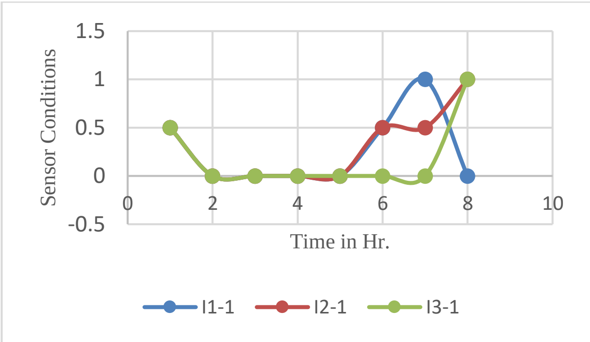

Fig. 19. Sensor conditions Vs. Time in Hr. for Node-1

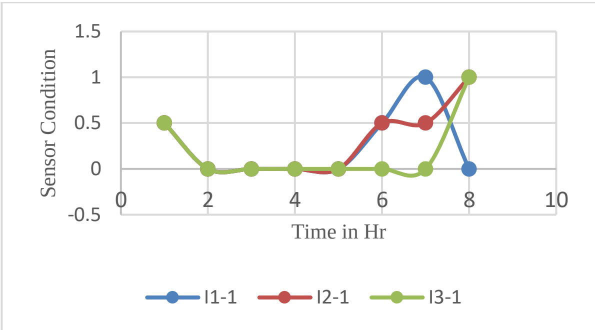

Fig. 20. Sensor conditions Vs. Time in Hr. for Node-2

Figure 13 and 14 show, the measurement of the sound level for node 1and 2 w.r.to, time to indicate the accident detection and control of the sound intensity level to control vehicle noise of moving vehicles and to ensure all category vehicles conform with their specified noise levels.

Figures 15 and 16 indicate smoke density opacity to inspect the level of smoke and proper working conditions and functioning of smoke-generating IC engine-based vehicles. This information is useful for checking the smoke and foggy situation to avoid on-road accidental issues in a cloudy environment.

Figure 17 and 18 shows the different sensor conditions monitoring for effective utilization of all street light control systems and functioning with battery packs.

Figure 19 and 20 indicates the light intensity as per the arrival and occurrence of the vehicle or any moving obstacle in the proximity of light bulb of street lights which is same for both nodes.

5. Conclusion

After experimental analysis of the proposed system following conclusions are put forward,

- The implementation of a wired and wireless sensor network in the street light monitoring model can work automatically without using any physical resources, it can monitor the road lights according to the seasonal variation, reasonable changes, and passing vehicles through the roads.
- The graphical representations show the expected output from the proposed system. The X-axis shows the time every two hours and the Y-axis shows all required sensors experimental results. It shows actual values of sensor changes based on climatic conditions, with the help of a proposed system we can easily monitor the street lights.
- After the deployment of all sensors as proposed and comparison with simulation results, it can be said that this system can save more than 70% of electricity.
- The saved electrical energy can be further utilized for the charging of EV batteries, the proposed HESS system of battery and supercapacitor, and other related applications.
- Wireless mode of EV charging can reduce the physical efforts to move out from the vehicle to recharge the vehicle, crowd situation at the charging point, and, most importantly significant reduction in energy and time as well.
- This type of application for street light monitoring is safe, durable, and with less complexity for smart cities and energy conservation in the green environment.

Author contributions

Ravikant Nanwatkar[1]: Software, Field study, Methodology, fabrication **Deepak Watvisave[2]:** Conceptualization, Data curation, Investigation, **Aparna Bagde[3]:** Software, component selection, Visualization, **Sonali Sable[4]:** Data collection, Software, **Sachin Mutalikdesai[5]:** Experimental analysis and Writing-Reviewing and Editing work. **Chavali Shriramshastri[6]:** component selection, Visualization.

Conflicts of interest

The authors declare no conflicts of interest.

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