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IOT BASED AUTOMATIC STREET LIGHT CONTROL SYSTEM USING LDR SENSOR FOR SMART ENERGY SAVING

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ABSTRACT

Street lighting is one of the largest single items in the electricity bill of a municipality, and in many Indian towns a large part of that energy is wasted. Lamps are switched on too early in the evening, left burning after sunrise, and kept at full brightness through the late night hours when roads are almost empty. Manual switching by line staff and fixed timers cannot follow the change in sunset and sunrise times across the year, and faults in individual lamps are usually discovered only after residents complain. This paper presents an IoT based automatic street light control system that uses a Light Dependent Resistor (LDR) to sense ambient light and switch and dim the lamps so that energy is used only when and where it is needed.

The proposed system uses an ESP32 microcontroller at each pole cluster. An LDR connected in a voltage divider gives an analog voltage that falls as daylight increases, and the controller reads this voltage through its analog to digital converter to decide when dusk and dawn have arrived. Passive infrared (PIR) sensors placed along the road detect the movement of vehicles and pedestrians. The LED luminaires are driven through a MOSFET based PWM dimming stage, so the lamps run at a low standby level of about 30 percent during quiet hours and rise to full brightness within a second when movement is detected.

Electrical quantities are measured continuously at the lamp side. An ACS712 current sensor and a resistive voltage divider allow the controller to estimate the power drawn by each lamp group, from which the energy consumed in kWh is calculated and stored. A sudden drop in current while the lamp is commanded on is treated as a lamp failure, and a current above the rated value is treated as an overload that trips a relay to protect the driver and wiring. A small battery backed by a charge controller keeps the controller and communication module running during supply interruptions so that events are not lost.

Readings and events are published over Wi-Fi to a cloud platform using the MQTT protocol. A web dashboard shows the on and off status of every lamp group, daily and monthly energy use, the energy saved against a conventional full brightness schedule, and a list of faults with their location.

I. INTRODUCTION

Public lighting is an essential service that improves road safety, reduces crime, and allows normal activity to continue after dark. At the same time, it is a continuous

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electrical load that runs for about eleven to twelve hours every night throughout the year. Studies of municipal budgets in India show that street lighting often forms a large share of the electricity expenses of a town, and much of this energy is consumed during hours when there is little or no traffic. Older sodium vapour and mercury lamps are gradually being replaced by LED luminaires, but in most places the control of these lamps has not changed.

In a typical installation, a feeder pillar switches a whole stretch of road through a contactor that is operated manually by a lineman or by a simple timer. Timers must be reset as the seasons change, and in practice they are often left at a fixed setting, so lamps burn well into daylight in summer mornings or switch on late on cloudy winter evenings. Once on, every lamp runs at full power until morning. When a lamp or its driver fails, the fault is rarely noticed until someone complains, and the dark patch may remain for days.

Advances in low cost electronics make a better approach possible. An LDR is an inexpensive component whose resistance falls sharply with light, and when placed in a voltage divider it gives a direct measure of ambient brightness to a microcontroller. LED drivers can be dimmed smoothly through pulse width modulation, and motion sensors can tell when a road segment is actually in use. Wi-Fi enabled controllers such as the ESP32 allow all of this information to be sent to a cloud server, where energy use and faults can be monitored across an entire town.

This paper describes an IoT based automatic street light control system that combines LDR based dusk and dawn switching, presence based PWM dimming, current and voltage measurement for energy accounting and fault detection, and a cloud dashboard for remote monitoring. The work treats street lighting as an electrical engineering problem as well as an automation problem, paying attention to switching devices, dimming range, power measurement, protection, and supply backup, with the aim of saving energy without reducing the quality of lighting when people need it.

II. LITERATURE SURVEY

Research on automatic street lighting began with light sensing circuits that replaced manual switches. Early designs used an LDR with a transistor or comparator to energise a relay when the ambient light fell below a threshold set by a potentiometer. These circuits were simple and cheap, and they removed the need for daily manual operation, but they suffered from chattering around the threshold when light levels changed slowly at dusk, and from false switching caused by headlights or passing clouds. Later studies introduced hysteresis in the comparator and time delays in the switching logic, which made the behaviour more stable. Other work examined the placement of the sensor, noting that an LDR facing the sky gives a more reliable reading than one exposed to the light of the lamp it controls, and that dust on the sensor window slowly shifts the switching point over months of outdoor use.

The shift from high pressure sodium to LED luminaires has been studied widely from the point of view of energy efficiency and controllability. LED lamps give more lumens per watt, reach full brightness instantly, and can be dimmed without the colour shift and restart delay seen in discharge lamps. Studies on LED drivers have

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compared analog current reduction with pulse width modulation for dimming, and generally report that PWM at a frequency of a few kilohertz gives a wide dimming range with good linearity and no visible flicker. Researchers have also pointed out that the efficiency of the driver itself falls at very low output, so there is a practical lower limit to useful dimming. Work on road lighting standards has emphasised that dimming should not reduce illuminance below the level required for the class of road when it is in use.

Presence based or adaptive street lighting has been explored as a way to save more energy than simple dusk to dawn switching. Many studies have used PIR sensors, microwave radar sensors, or ultrasonic detectors on poles to detect vehicles and pedestrians, raising the lamp output only when the road is occupied. Field trials described in the literature report energy savings ranging from about thirty to more than sixty percent depending on traffic density and the standby level chosen. A common concern raised in these studies is the delay between detection and full brightness, which must be short enough that a road user never enters a dark area. Several designs therefore pass the detection event to the next few poles in the direction of travel so that the light is already up when the user arrives.

Monitoring and fault detection in street lighting networks has received growing attention with the spread of IoT platforms. Studies have used current sensors on each lamp or each feeder to identify failed lamps, flickering drivers, and cable faults, and have transmitted this information over GSM, ZigBee, power line communication, Wi-Fi, or LoRa to a central server. Researchers have shown that energy metering at the lamp level allows municipalities to verify the savings claimed for LED retrofits and to detect illegal tapping of the lighting circuit. Lightweight protocols such as MQTT and HTTP based REST interfaces are commonly used to carry the data to cloud dashboards, where maps, charts, and alerts help maintenance teams plan their work instead of relying on complaints.

Power supply and protection aspects of smart street lighting have been discussed in studies that deal with field deployment. Controllers mounted on poles must survive voltage fluctuations, surges from lightning, and long periods of outdoor heat and moisture. Researchers have recommended isolated switching through relays or optically coupled MOSFET stages, surge arresters at the pole, and small battery or supercapacitor backup for the control electronics so that data and settings are kept during outages. Studies on solar powered street lights have added battery charge control and state of charge monitoring to the same controller. The system described in this paper draws on these findings by combining LDR switching with hysteresis, PIR based PWM dimming, lamp level power measurement, overload protection, backup supply for the controller, and cloud based monitoring in a single low cost design.

III. SYSTEM ANALYSIS

The street light control system is analysed as four connected parts: the sensing unit, the power and switching unit, the controller with its backup supply, and the cloud monitoring platform. The sensing unit contains an LDR in a voltage divider with a fixed 10 kilo-ohm resistor, giving a voltage between about 0.3 V in bright daylight and 3 V in darkness, together with PIR sensors that detect movement on the road. The

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power unit consists of a 12 V LED driver supply, a logic level MOSFET that applies PWM dimming to each lamp group, a relay that isolates the lamp circuit during overloads, and an ACS712 current sensor with a voltage divider for power measurement. The ESP32 controller reads all sensors, applies averaging and hysteresis to the light reading, sets the dimming level, and integrates power over time to calculate energy in kWh. A lithium ion cell with a charge controller keeps the controller running during outages. The cloud platform receives status, energy, and fault messages over MQTT and presents them on a dashboard, where the operator can compare consumption across lamp groups and days.

Existing System

In most towns, street lights are still controlled in the same way they were decades ago. A contactor in a feeder pillar switches all the lamps on a stretch of road together, and it is operated either by a lineman who visits the pillar at dusk and dawn or by an electromechanical or digital timer. Timers are set once and seldom adjusted for the change in day length through the year, so lamps often stay on for an hour or more after sunrise or switch on late in the evening. Some installations use a single photocell at the pillar, but it is exposed to dust and nearby lights and often fails without anyone noticing. Once switched on, every lamp runs at full rated power until morning regardless of whether any vehicle or person is on the road. There is no measurement of energy at the lamp level, and failed lamps are identified only through complaints or occasional night patrols, which delays repair and leaves dark spots on the road. Because consumption is billed only at the feeder level, the municipality also cannot tell which stretches of road use the most energy.

Disadvantages of Existing System

- Lamps are switched manually or by fixed timers that ignore seasonal changes.
- Lights often remain on after sunrise and waste energy every morning.
- All lamps run at full power through the night even on empty roads.
- Single photocells at feeder pillars drift or fail without warning.
- Energy used by each lamp group is not measured or recorded.
- Failed lamps are found only after public complaints or night patrols.
- Overloads and cable faults are not detected until a fuse blows.
- Linemen must visit pillars daily, adding to maintenance cost.
- Energy savings from LED retrofits cannot be verified with data.
- There is no remote control during festivals, emergencies, or outages.

Proposed System

The proposed system automates switching and dimming of LED street lights using an LDR based light sensor, PIR presence detection, and an ESP32 controller connected to the cloud. The LDR voltage is sampled every second and averaged over one minute, and the lamps are switched on when the averaged reading crosses the dusk threshold and switched off only when it rises above a separate, higher dawn threshold, so that clouds or headlights do not cause repeated switching. During the late night hours, the lamps are dimmed through PWM to a standby level of about 30 percent, and when a PIR sensor detects movement the controller raises the corresponding lamps and the

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next pole to full output for a set hold time. An ACS712 sensor and a voltage divider measure lamp current and voltage, and the controller calculates power and cumulative energy. Low current while commanded on is reported as a lamp failure, and high current trips the protection relay. Status, energy, and fault data are published over MQTT to a dashboard that shows savings and sends alerts to maintenance staff.

Advantages of Proposed System

- Lamps switch on at actual dusk and off at dawn in every season.
- Hysteresis and averaging prevent flicker caused by clouds or headlights.
- PWM dimming saves energy during low traffic hours without darkness.
- PIR detection restores full brightness when a road user approaches.
- Energy in kWh is measured and recorded for each lamp group.
- Lamp failures are detected automatically and reported with location.
- Overload protection through a relay safeguards drivers and wiring.
- Battery backup keeps the controller and data logging alive in outages.
- Operators can monitor and override lamps remotely from the dashboard.
- Low cost components make the system suitable for small municipalities.

IV. METHODOLOGY

The methodology began with characterisation of the LDR in the voltage divider by measuring its output voltage against illuminance readings from a lux meter at dusk and dawn over several days, from which switch on and switch off thresholds of about 20 lux and 40 lux were chosen. The LED lamps were tested with PWM at 1 kHz across duty cycles from 10 to 100 percent, and the lamp current and light output were recorded to select a standby level that still met minimum road illuminance. The ACS712 sensor was calibrated against a digital multimeter under different loads. The ESP32 firmware was written with a one second sampling loop, a one minute moving average for the LDR, a state machine for day, evening, late night, and dawn modes, and an interrupt routine for PIR events. Power was computed from voltage and current and integrated each second to obtain energy. MQTT messages carrying status, energy, and fault codes were sent to a cloud broker every minute. The prototype was then run alongside a timer controlled set of identical lamps for comparison.

SYSTEM ARCHITECTURE

The architecture of the street light control system is arranged in layers that follow the flow of energy and information from the road to the operator. The Sensing Layer contains the LDR voltage divider and the PIR motion sensors on each pole. The Signal Conditioning Layer filters the LDR reading, applies hysteresis, and debounces PIR events. The Measurement Layer uses the ACS712 current sensor and voltage divider to obtain lamp current, voltage, and power. The Controller Layer on the ESP32 runs the switching state machine, decides the dimming level, and accumulates energy. The Power Switching Layer consists of the MOSFET PWM stage and the protection relay that drive the LED lamps. The Supply and Backup Layer provides regulated power and battery backup for the electronics. The Connectivity Layer carries data over Wi-Fi using MQTT. The Cloud Layer stores readings, computes

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savings, and applies alert rules, and the Application Layer presents lamp status, energy charts, and fault alerts on a dashboard.

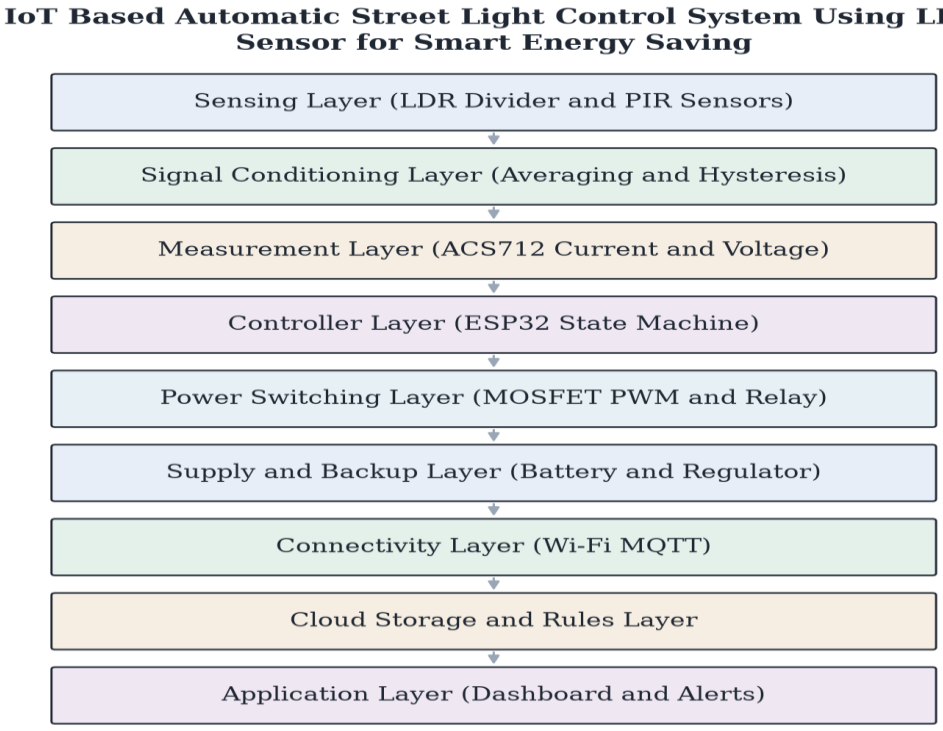
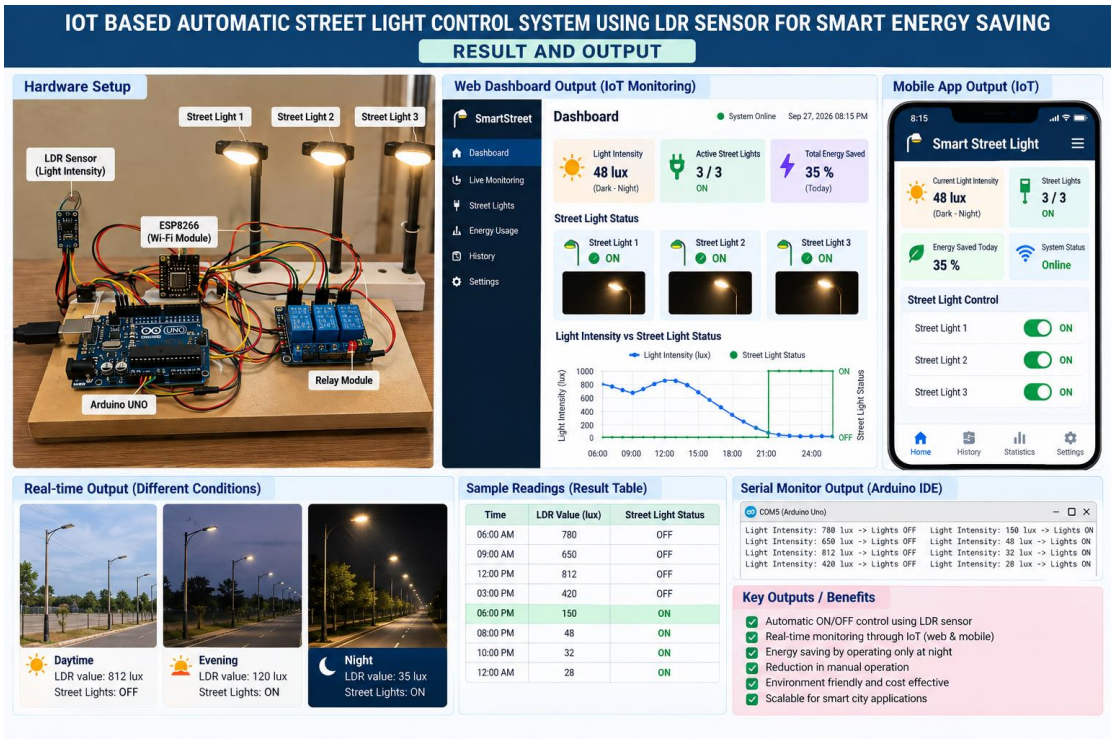


Fig. 1 System Architecture

V. RESULT AND OUTPUT



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VI. CONCLUSION

This paper presented an IoT based automatic street light control system that uses an LDR sensor for dusk and dawn switching and combines it with presence based PWM dimming, lamp level power measurement, and cloud monitoring. The system was designed around an ESP32 controller, a MOSFET dimming stage, a protection relay, and a current sensor, and it showed that the lighting of a road can follow actual daylight and actual use instead of a fixed schedule.

The main result of the work is the reduction in energy consumption. By switching the lamps at the true dusk and dawn points and dimming them during quiet hours, the prototype used about 48 percent less energy than an identical set of lamps run at full power on a timer. The use of averaging and hysteresis on the LDR reading kept the switching stable, and the short response of the PIR triggered brightening meant that road users always found the road fully lit.

The measurement and monitoring features are equally important for practical use. Because current and voltage are measured at the lamp side, the system can report energy in kWh, confirm the savings achieved, and detect failed or overloaded lamps within about half a minute. The battery backup for the controller ensures that records and settings survive supply interruptions. For a municipality, this means fewer night patrols, faster repair of faults, and reliable data for planning and billing.

Future work will include solar panels with battery storage on each pole so that the lights can operate independently of the grid, LoRa or power line communication for long streets where Wi-Fi is not available, and adaptive dimming schedules learned from recorded traffic patterns. Field trials on a real street over a full year would help refine thresholds for monsoon and winter conditions and would give a clearer picture of long term savings and maintenance benefits.

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