Integration of Solar Power and IOT Technology in Smart Street Light with EV Charging Point

[1] Kuldeep Sharma, [2] Dr. Vivek Kumar
[1]Research Scholar, [2] Professor
Department of Electrical & Electronics Engineering
BRCM College of Engineering & Technology
Bahal, Bhiwani, Haryana (India)

***Abstract*-In this era of crisis of diminishing sources of convectional fuels and needs of sustainable energy sources like solar energy are required. To meet the continuing huge requirements of day to day uses, eliminating pollution prone networks, expensive projects, is the necessity and ultimate need of the hour. The suggested framework will have almost all the advanced features can be used in daily life particularly in towns making these smart cities. The evolution of electric and electronics techniques and equipments has made the use of electric vehicles immensely popular and acceptable .Distributive Solar charging stations for charging of EVs are made available nearest to the road using safe and secure solutions Along with street lighting provisions smart network using EEE principles and systems designed. Thus this platform of networking using smart components benefits in different ways like (1) Sustainable Source of Energy (2) Economical project (3) Energy efficient and Eco friendly network (4) Smart, safe and strong multipurpose system for Street lightings and EV charging point. (5) Modern and real time integrated project.**

Keyword: Solar Energy, IoT, Electric Vehicle, Sensors

Introduction

Around the world almost all nations are now days are forwarding towards uses of renewable energy sources in the Power system and encourage the use of plug in electric vehicles. According to “International Energy Agency” (IEA) by 2050 more than 100 million EV or plug in hybrid EV i.e. PEVs sold every year [1]. As a result more and more charging stations will be required. To meet with the required number of charging points the proposed work has been designed to create a smart electric vehicle charging stations designed for residential areas and distributed along the road sides and in streets about 100 m. in every localities of the smart cities. This is based on Time of use Tariff and EV acted as an uninterrupted power supply using Solar Energy. This will decrease the load on power stations and EV charging Stations on Highways. This will also provide perfect, stable, safe and suitable solution with the use of solar energy.

That is why the framework has been designed. As the solar energy is easily available at every place so the idea of street light structures along with EV station structures has been integrated to make it multipurpose usable. With the advent of digital revolution, IoT in particular will serve as asset and resource management and usage to help cities become more efficient and sustainable to cop up with increasing demand. This framework reduces operational costs and this will lead to reduce the burden of huge costs for attaining the equivalent amount of energy arranged from alternate conventional fossil fuels.

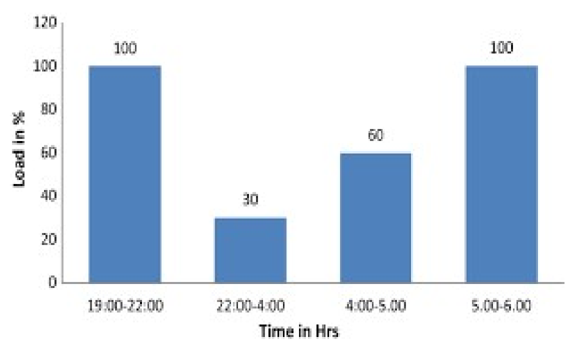

Figure 1: Load Consumption during the day

With the advancement in web based monitoring, real-time analysis of data and connectivity with the system can be supervised from any remote place. The project is suitable for towns where the street lights network is already equipped with solar energy using equipment therefore add -on of EV charging station equipment are co-shared and minimized cost in energy generation surveillance data communication networks

, distributed points. This type of N/W management gives public facilities at door steps, economical and eco friendly services thereby making them smart as well.

This also provides the local government a good amount of savings and gets rid of power consumption bills and maintenance charges and other accidental losses. Alongside the EV stations are available in bulk with almost zero additional charges. This reduces the burden of costly fuels like petrol diesel and gas etc. also risk factors of fire accidents pollution problems thus making the people more healthy and happy. The availability of charging stations in so much quantity and proximity make the people more comfortable and time saver and minimal expense.

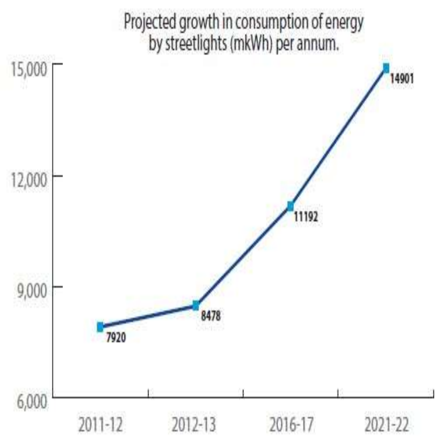

Figure 2- Consumption of energy per year

According to [2], street lighting accounts for anywhere between"20 to 40%" of the energy produced in India. [3] Reports that India has about "35 million" street lights across the country, which consume about "3.4 GW" of electricity and emit about "4.5 million tones" of carbon dioxide annually. These numbers indicate that street lighting is a significant source of electricity demand and greenhouse gas emissions in India, and there is a need for more energy-efficient solutions.

Related work

In Recent year's awareness about the technology and conservation of energy resources is increased among all over the globe. Many researchers from different parts of the world contributed in this field with numerous innovative ideas. It is worth to mention here the relevant work related to proposed system.

Smart Street lights system controlled by network equipped with sensors and actuators, giving a varied range of capabilities and communication interfaces. An alternative control approach for smart street lighting, centralized control with both the short range and long range wireless communication was utilized in this system [4].

It exhibited a solar smart led street light system that provided real-time environmental data as well as allowing live picture streaming in [5]. Configuration deployment and management were integrated in this system.

A Zigbee network was used to transfer the required data from each pole to a linked pole that had a Raspberry pi card to communicate the data to a Wi max modem that was linked to a remote server accessible over the internet. For managing light in a wireless communication system, the DALI protocol was proposed [6].

A vehicle detecting subsystem is included in each node. A lighting subsystem with a wireless communication and control subsystem was designed with a sophisticated predictive monitoring and control system[7].It was also proposed to extract level factors from received signal strength signatures derived from car and pedestrian movement on the road and dim street lights correspondingly [8].

Design of a Proposed System

Solar powered street light generally have 3 methods of installation. 1. Single Sided lights 2. Cross lights on both sides. 3. Symmetric lights on both sides. On the road side of a Highway or locality the height of the pole should be 4.5 -6.0 meters for pedestrian & other vehicles. Height of a pole directly affects the intensity of light. The higher the light pole, the wider the illumination ranges.

All the components are connected as per the circuit/block diagram. The power panel uses the photo electrical conversion properties to convert solar energy to electrical energy in 12V D.C. supply which in turn charges the connected 12V battery during the sunny day. Battery stores the energy which causes the street light from 06:00 p.m. to 06:00 a.m. i.e. night hours and switches off street light with the help of sensor sensing the day light and switches on when day light is off.

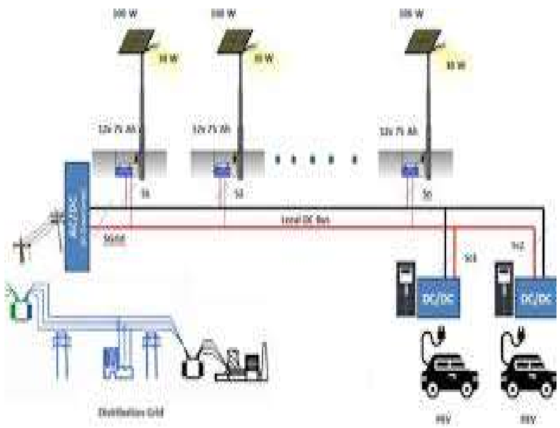

Figure3: Architecture of Integrated system

EV charger connected in parallel with the Battery and is used to charge the PEV taking the output of the same solar panel. The higher current carrying capacity i.e. weight age of Solar Panel and Battery can be used as per requirements at the site. State of Charge and Internet of Things are used to have remote control and communication surveillance to monitor the working of the street lights as well as charging of EV.

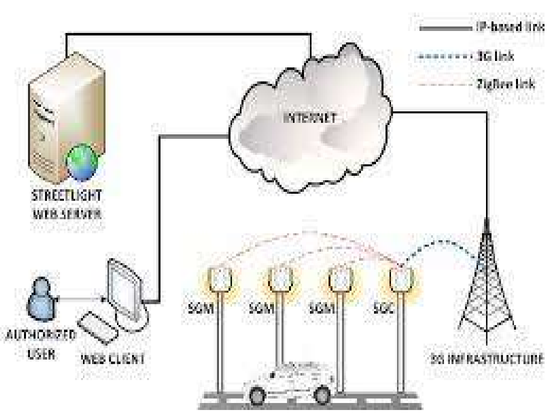

Figure 4: IoT based system

There are three criteria for height of pole and pole to pole distance with rating of light is as follows:-

Criteria 1:- Height of each pole is 6 m. Distance between adjacent poles is 22 m and 64 W foldable all in one solar street light.

Criteria 2:- Height of each pole is 8 m. Distance between adjacent poles is 30 m and 100 W foldable all in one solar street light.

Criteria 3:- Height of each pole is 9 m. Distance between adjacent poles is 35 m and 120 W foldable all in one solar street light.

Parameter of Solar Panel, Battery and Inverter:-

Load Calculation: - Let us consider distance approx. 350m with 8 m height pole and distance between poles is 22 m with 100 Watt LED bulb on each pole.

Load Calculation= V*Ampere

11*100W=220V*Ampere

Ampere = 1100W/220 V

Current = 5 A.

Backup Time: - Usually street lights are used for 12 Hours i.e. 6 p.m. to 6 a.m.

Battery Storage = Total Load * Back up time

= 100 W * 12 hour

= 13200W

Battery Capacity: - Basically there are 2 types of battery technology

a) Lead acid battery

b) Lithium battery

In lead acid type of battery 150 A stores 1300 watt.

Battery capacity = required battery storage / battery storage

= 13200W/1300 W

= 11 batteries.

Generally 11 batteries of 150 Amp comes in 48A

In case of lithium battery, need of 3 batteries with 5 KWh and 48 V.

Inverter capacity:-

Inverter capacity = Load + (Load * 20%)

= 1100 W+ 1100*20/100)

= 1100 W+ 220 W

= 1320 W

Therefore, we need around 1.3 KV inverter capacities.

5) Solar Power capacity:-

Solar Power Capacity = 3 * Battery Capacity

= 3 * (11 * 150 AH)

= 4950 watt

Therefore a need of 5 KW capacity of Solar panel.

	Power	Range added per hour	Charging time	Typical application
Level 1 - single phase (domestic)	2.4-3.7kW	10-20km range / hour	5-16 hours	Home
Level 2 slow - single phase (domestic or public)	7 kW	30-45km range / hour	2-5 hours	Home,work, shopping centres, car parks
Level 2 fast - three-phase (public)	11-22kW	50-130km range / hour	30mins - 2 hours	Urban roadside
Level 3 - fast charge (public)	50kW	250-300km range / hour	20-60 mins	Regional near highways, motorways and key routes
Level 4 - super-fast charge (public)	120kW	400-500km range / hour	20-40 mins	Regional near highways, motorways and key routes
Ultra-fast charge (public)	350kW	1000+ km range / hour	10-15 mins	Highways and motorways

Figure 5: Different levels of charging

The other most useful utilization of the proposed work is that it saves the energy of street lights keeping them off during night hours while not in use. The lights go off as soon as the user is away or with his vehicle what so ever it is. This was provided using shadow sensors.

Hardware Requirements

LDR Input: A light dependent resistor that detects the intensity of sunlight and switches on or off the street light accordingly.

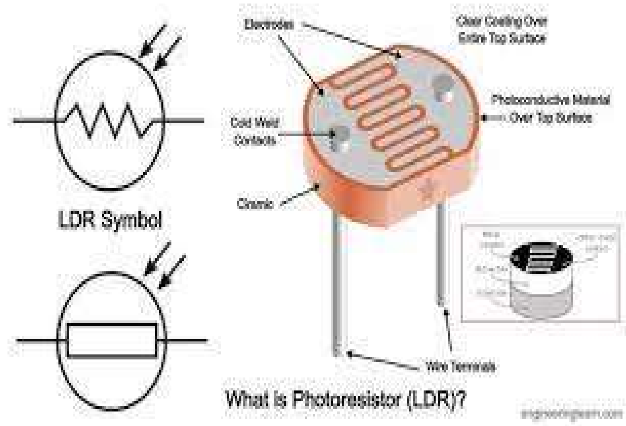

Figure 6 : LDR Circuit

IR Sensor: An infrared sensor will detects the presence and absence of vehicles and pedestrians and according to which it adjusts brightness of the street light accordingly.

LED: It provides illumination for the street light. LED bulbs are more energy-efficient and durable than conventional bulbs.

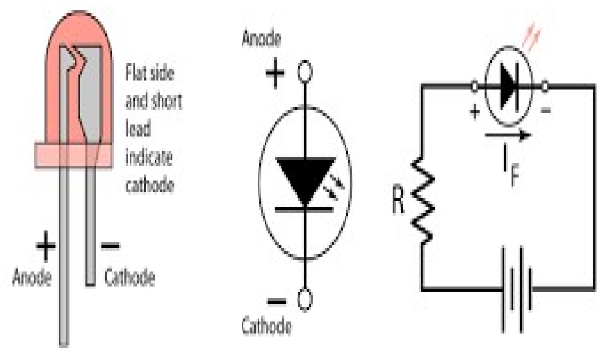

Figure 7: LED Circuit

UART: A universal asynchronous receiver-transmitter that communicates with a central server via wireless network and sends data about the status and performance of the street light system.

Solar Panel: They are also known as photovoltaic (PV) panels that convert sunlight into electricity and charge the battery.

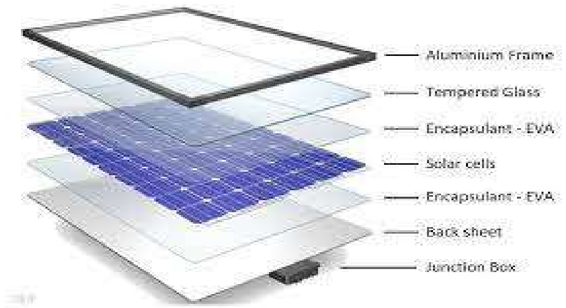

Figure 8 : layers of Solar panel

Battery: A rechargeable device that stores electrical energy and powers the street light system during night or cloudy days.

Charge Controller cum Inverter: A device that regulates the voltage and current from the solar panel and battery and the same is converted from direct current to alternating current for the LED.

The Charging Speed of an Electric Vehicle (EV) can be determined by the amount of kilowatts (KW) a charging station can provide per hour (KW/h). 3 types of EV charging points are described according to levels of charging:-

Level 1:- 12 A and 120 V

Requirement per hour :- 1.44 KW/h

Range per hour : 4 mi

Level 2:- 32 A and 240 V

Requirement per hour :- 7.68 KW/h

Range per hour:- 24 mi

Level 3:- 100 A and 480 V

Requirement per hour : 50 KW/h

Range per hour : 150 mi

Calculation for EV charging time:-

Hour of charging = charge needed (Kwh) / charger power (kw)

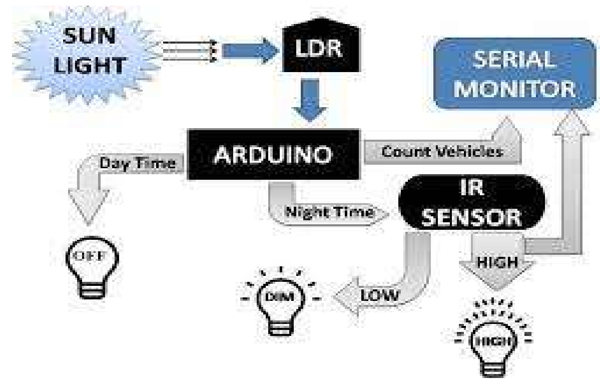

Figure 9 : Flow diagram of system

IoT sensors may detect automobiles, people, sunshine, air quality, and other factors and send data to a central server over a wireless network. The server may then use the data and algorithms to regulate the brightness, colour, timing, and status of the street lights. The server can also send feedback and notifications to authorities or users regarding the street light system's functioning and maintenance. Smart street lighting based on IoT will be more adaptable, efficient, interactive, and intelligent.

The hardware requirements for an IoT system in a smart street light may vary depending on the particular implementation and capabilities needed. However, some common hardware components seen in such systems include:

1. The actual light fixture, which may include LED lights for increased energy efficiency.

2. Microcontroller/Single Board Computer (SBC): A microcontroller or SBC is the brain of the smart street light system, handling data processing, control logic, and communication with other devices. Popular alternatives include Arduino, Raspberry Pi, and specialized IoT boards.

3. Sensors: These devices gather data and monitor the environment. The sensors listed below are often used in smart street light systems.

(a) Light Intensity Sensor: Measures ambient light levels and changes the street light's brightness accordingly. Light sensors are electrical devices that detect and measure light levels. They are also known as photo detectors or photodiodes. They are utilized in a variety of applications, including photography, optical communication systems, industrial automation, and ambient light detection in electronic devices like as smart phones and laptop computers. Light sensors based on the photoelectric phenomenon, in which photon absorption by a substance creates an electric current or voltage.

The basic working principle of a light sensor involves the following steps:

1. Photon Absorption: When light strikes a light sensor's surface, photons (light particles) are absorbed by the material, which might be a semiconductor like silicon.

2. Electron-Hole Generation: When photons are absorbed, their energy is transferred to electrons in the material, causing them to break loose from their atoms. This procedure produces electron-hole pairs.

3. Charge Separation: An electric field in the sensor separates free electrons and positively charged holes. This electric field can be generated either intrinsically inside the material or externally through the use of a bias voltage.

4. Current Flow: When opposing charges create a potential difference across the sensor, electric current flows. The magnitude of the current is proportional to the intensity of the incoming light.

5. Output Signal Processing: Using proper circuitry, the produced current may be transformed into a voltage signal. Following that, the voltage signal can be amplified, filtered, or transformed to a digital signal for further processing or control.

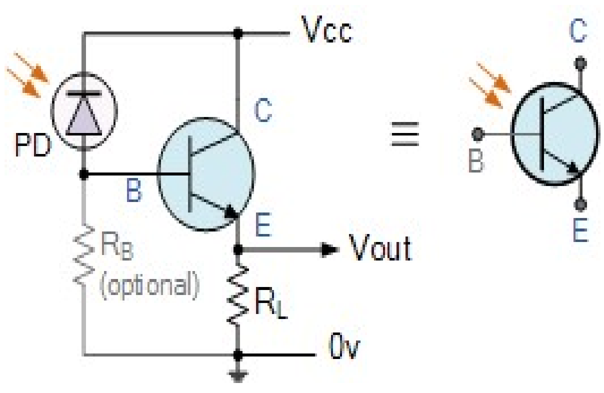

Figure 10: Circuit diagram of Sensors

(b) **Motion Sensor**: Detects movement near the street light and can trigger it to turn on/off or change brightness as needed. Devices that detect movement within their area of vision are known as motion sensors. Motion detectors and motion-activated sensors are other names for them. They are widely used in security systems, automatic lighting systems, smart home devices, and a number of other applications. Motion sensors employ a number of technologies, the most common of which being passive infrared (PIR) sensors and microwave sensors.

PIR sensors can detect changes in the infrared radiation emitted by objects in their vicinity. Any substance having a temperature higher than absolute zero, such as (-273.15°C), emits infrared radiation. These sensors are constructed of numerous infrared-sensitive components arranged in a grid pattern. PIR sensors are made up of a grid-like arrangement of numerous infrared sensitive components.

This change is detected by the PIR sensor, which creates an electrical signal. The signal is analyzed by the sensor's electronics to detect the presence and movement of objects. Heat signature variations are detected by the sensors, which are often utilized in interior applications.

2. Microwave Detectors: Microwave sensors detect movement by producing and receiving microwave signals. They are sometimes known as microwave motion sensors or radar-based motion sensors. In a variety of applications, they are often employed in security systems, automated doors, traffic monitoring, and occupancy detection. The following steps are involved in the operation of microwave sensors:

1. Signal Transmission: The microwave sensor sends out continuous microwave signals at a certain frequency, which is commonly in the gigahertz (GHz) range. The frequency utilized is determined by the sensor design and the application requirements.

2. Signal Reflection: Microwave signals are produced and travel across the environment, encountering things within the sensor's range. When the signals come into contact with an item, they reflect back to the sensor.

3. Doppler Effect: The Doppler Effect happens when an object moves towards or away from the sensor. The reflected microwave signals experience a frequency shift known as the Doppler Effect when they return to the sensor. The frequency of the reflected signal increases as the person or vehicle moves towards the sensor and drops as the object moves away from the sensor.

4. Signal Analysis: The electronics of the sensor analyze the incoming microwave signals and measure the frequency shift induced by the Doppler Effect. The frequency of the reflected signal remains constant if there is no motion in the sensor's field of vision. However, if there is motion, the sensor detects the frequency shift.

5. Motion Detection: To detect if motion is present, the sensor compares the frequency shift of the incoming signals to a predetermined threshold. The sensor detects motion as the frequency shift above the threshold, indicating a substantial change.

6. Action Triggering: When motion is detected, the sensor can perform a variety of actions depending on its application. It can, for example, sound an alarm, switch on lights, open doors, or transmit a signal to a control system.

Microwave sensors provide various benefits, including a large coverage area, the ability to detect through walls and barriers, and resistance to temperature and lighting conditions. However, careful positioning and tuning may be required to eliminate false alarms produced by variables such as ambient interference or minor movements.

(c)**Temperature Sensor**: Examines the temperature to make sure the light is functioning within safe limits. In a variety of applications, from industrial operations to consumer electronics, temperature sensors are electrical devices that detect and monitor temperature fluctuations. The most popular temperature sensors are thermocouples, resistance temperature detectors (RTDs), and thermostats.

2. Resistance Temperature Detectors (RTDs): they are temperature sensors that use the phenomenon of electrical resistance changes with temperature. They are typically made of a pure metal, such as platinum, which exhibits a predictable and repeatable change in electrical resistance with temperature. The resistance increases with rise in temperature and follow the relationship of resistance vs. temperature curve. The resistance of the RTD is measured using a Wheatstone bridge circuit or other suitable circuitry, and the temperature is determined using calibration data specific to the RTD type.

Digital temperature sensors employ integrated circuits to monitor temperature, such as the well-known digital temperature sensors based on the One-Wire or I2C protocols. These sensors generally come in a single package with both an analog-to-digital conversion circuitry and a temperature sensor element.

A microcontroller or other digital device may immediately read and interpret the sensor's digital output, which can be temperature readout in degrees Celsius or Fahrenheit. It's vital to remember that temperature sensors' accuracy, range, reaction time, and other properties might change based on the particular sensor type and its construction. Techniques for calibration and compensation are frequently used to increase precision and account for any errors in the sensor's output.

(d) **Environmental Sensors**: Additional sensors like humidity, air quality, and noise sensors can collect more data for smart city applications. They are also referred to as environmental monitoring sensors since they measure and keep track of a number of environmental characteristics. These sensors are utilized in a wide range of operations, including industrial and agricultural processes, smart homes, weather monitoring, and indoor air quality monitoring. The particular parameter being monitored determines how environmental sensors operate.

1. Temperature sensors: These sensors determine the environment's temperature. As mentioned in the preceding comment on temperature sensors, they can make use of a variety of technologies, including thermocouples, RTDs, thermostats, or digital temperature sensors.

2. Humidity sensors, often called hygrometers, are devices that gauge the relative humidity or moisture content of the air. For measuring humidity, capacitive, resistive, or thermal-based sensors are frequently utilized. Resistive sensors assess changes in electrical resistance, whereas humidity sensors measure changes in a material's dielectric constant. The cooling impact of moisture evaporation on a heated element is measured using thermal-based sensors.

3. Air quality sensors assess several gases and contaminants in the air, including particulate matter (PM), volatile organic compounds (VOCs), carbon dioxide (CO_2), and carbon monoxide (CO). Depending on the precise contaminant being tested, they use various methods. For instance, CO and other gases are detected using electrochemical sensors, whereas particulate matter is detected using optical sensors.

4. **Gas sensors**: They are devices that can identify and gauge the presence of particular gases in the environment. Depending on the gas being targeted, several gas detecting systems are utilized. You may use infrared sensors, metal oxide sensors, or electrochemical sensors as examples. Gas sensors can identify a variety of gases, including ozone, carbon dioxide, ammonia, and methane.

5. **Weather Sensors**: Used in weather stations, these sensors assist measure variables including temperature, humidity, air pressure, wind speed, wind direction, rainfall, and sun radiation. They make use of a variety of sensors and technology, such as anemometers, wind vanes, rain gauges, barometric

pressure sensors, temperature sensors, humidity sensors, and barometric pressure sensors.

An IoT system needs a communication channel in order to send and receive data as well as instructions. The communication module may make use of Wi-Fi, Bluetooth, cellular networks like 3G/4G/5G or Low-Power Wide-Area Networks (LPWAN) like LoRa WAN or NBIoT.

Conclusion and Future trends

Street light control driven by the sun provides a number of benefits, including reduced energy costs, reduced carbon emissions, enhanced energy efficiency, and improved smart city management. It provides a sustainable and eco-friendly replacement for overhead lighting, supporting the development of greener, more sustainable cities.

Increased energy efficiency, cost savings, improved equipment maintenance, and the gathering of important data for urban planning are just a few benefits of using IoT in smart street lighting. Future technology may include artificial intelligence tools, cyber security systems, LDR cameras, as well as widespread usage of renewable energy sources like wind and geothermal energy, depending on the needs of the local environment.

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