Smart Solar Energy System: Application for Traffic in Saudi Arabia

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Abstract - *The purpose of this study is to encourage the usage of solar Energy in Saudi's remote, off-grid rural areas to power traffic light installations. It takes a photovoltaic system to continually consume this energy. In the study, the components, methodology, design investigations, and findings are presented. The primary power source for the system's operation is provided by solar cells, which absorb light and produce electricity. To provide electricity to the system when there is no sunlight, lead-acid batteries are adopted as the PV system's electric energy storage. To charge the storage battery, a charger circuit was constructed.*

***Key Words*: solar energy, power source, photovoltaic system, sunlight, traffic light**

1. INTRODUCTION

As the world continues to face the challenges of climate change and energy scarcity, there is an increased need for sustainable and renewable energy sources. One such source is solar power, which has been gaining popularity in recent years due to its numerous benefits. Smart solar energy systems have been developed for use in various applications, including traffic management. Solar-powered traffic systems have several advantages over traditional grid-powered systems. First and foremost, they are environmentally friendly since they do not emit harmful gases into the atmosphere. Additionally, they are cost-effective since they rely on a free source of energy – sunlight – that requires minimal maintenance costs. Another benefit of smart solar-powered traffic systems is their reliability [1]. They can function during power outages or when there is a disruption in the power grid, ensuring uninterrupted traffic flow. Furthermore, these systems can be designed to include sensors that detect changes in weather conditions or traffic density, allowing them to adjust their operations accordingly. Smart solar energy systems for transportation have several advantages over typical grid-powered systems. These include environmental friendliness, cost-effectiveness, reliability, and adaptability. As such, it is important to continue exploring ways in which solar power can be harnessed for various applications as we strive toward a more sustainable future [2,3].

Solar-powered traffic systems have become increasingly popular in recent years due to their numerous advantages. One of the most significant benefits of these systems is that they rely on a clean and renewable source of energy, which reduces carbon emissions and helps to mitigate climate change. In addition, solar power is much cheaper than traditional electricity sources, which makes it an economically viable option for cities and municipalities looking to reduce their energy costs. The use of solar power also ensures that traffic lights and other infrastructure remain operational even during power outages or other emergencies, which can improve safety on the roads. Another advantage of solar-powered traffic systems is that they are highly efficient and reliable. Unlike traditional electrical grid systems, which can experience frequent interruptions or failures due to weather events or equipment malfunctions, solar-powered systems are designed to be self-sufficient and require minimal maintenance. This means that traffic signals can operate continuously without interruption, ensuring smooth traffic flow and reducing the risk of accidents caused by malfunctioning lights [4]. Moreover, solar-powered traffic systems offer greater flexibility in terms of placement and installation compared to traditional electrical grid systems. Because they do not require a connection to the electrical grid, these systems can be installed in remote locations where access to electricity may be limited or non-existent. This makes them an ideal solution for rural areas or developing countries where access to reliable electricity is often scarce. In addition, solar-powered traffic systems are much safer than traditional electrical grid systems since there is no risk of electrocution from exposed wires or faulty equipment. Furthermore, because solar panels are usually mounted high above ground level on poles or other structures, they are less susceptible to damage from vehicle collisions or vandalism than traditional streetlights. Solar-powered traffic systems help reduce reliance on fossil fuels by providing a sustainable alternative source of energy that does not contribute to greenhouse gas emissions [5]. This helps promote environmental sustainability while also reducing dependence on foreign oil supplies. The advantages offered by smart solar energy systems for traffic are numerous and significant. From reducing carbon emissions and improving safety to increasing efficiency and reliability, solar-powered traffic systems offer a range of benefits that make them an attractive option for cities and municipalities around the world. As we continue to work towards a more sustainable future, it is clear that solar power will play an increasingly important role in powering our transportation infrastructure [6,7].

Smart solar energy systems for traffic are the future of sustainable transportation. Solar-powered traffic systems come with numerous advantages that make them a viable alternative to traditional electricity-powered systems. Firstly, they are cost-effective, as they do not require any additional costs in terms of energy bills or maintenance costs. This makes them an ideal solution for countries and cities struggling with limited budgets. Secondly, solar-powered traffic systems are environmentally friendly and contribute to reduced carbon emissions. This is critical in the fight against global warming and climate change. Additionally, these systems can function effectively even during power outages or natural disasters when traditional electrical grids may be down. Another advantage of smart solar energy systems for traffic is their reliability and durability. These systems can withstand harsh weather conditions such as extreme temperatures, rain, hailstorms, and snowfall without affecting their performance. Furthermore, the use of solar-powered traffic lights can reduce accidents on roads by providing adequate visibility at all times. This helps to ensure that drivers follow road safety rules and regulations. Overall, the benefits of smart solar energy systems for traffic cannot be overstated. These innovative solutions offer a more sustainable and reliable alternative to traditional electricity-powered systems while also contributing to environmental conservation efforts globally [8,9].

In Saudi Arabia's isolated, off-grid rural areas, this study promotes the adoption of solar energy to power traffic light installations. This energy must be continuously consumed, which requires a photovoltaic system. The study presents the results of the component, methodology, and design studies. Solar cells, which absorb light and generate energy, are the main source of power for the system's operation. Lead acid batteries are used as the PV system's electric energy storage to utilize electricity when there is no sunlight. The construction of a charger circuit was built to charge the storage battery. Infrared (IR) sensors have been employed primarily to control the traffic signal sequence based on the crowd of traffic. In other words, the smart energy system uses sensors to detect the flow of traffic and adjust the timing of the traffic lights accordingly. This system also incorporates a renewable energy source, which is a solar panel, to power the traffic lights. By using renewable energy sources, this system reduces carbon emissions and helps to mitigate climate change. The smart energy system can be integrated with other transportation systems, such as public transport networks, to optimize traffic flow and reduce congestion. The development of a smart energy system for traffic lights is a significant step towards creating sustainable transportation systems that are environmentally friendly while ensuring safety on our roads.

2. METHODOLOGY AND DISCUSSION

Arduino is an open-source electronics platform that has revolutionized the world of technology. It is a microcontroller-based kit, as shown in FIG. 1, that allows users to create a wide range of electronic projects, from simple LED blinkers to complex robots [10,11]. One such project that can be created using Arduino is a traffic light system with smart energy management. Traffic lights are an important part of our daily lives and play an important role in road safety. However, traditional traffic lights consume a lot of energy and are not very efficient. With the help of Arduino, we can create a smart traffic light system that uses renewable energy sources and reduces energy consumption.

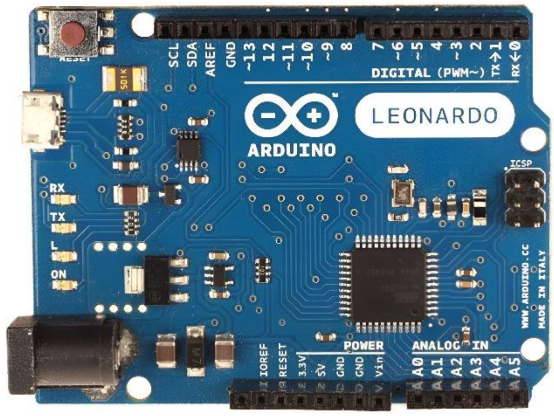

Fig -1: Arduino Uno Board

The Arduino-based traffic light system consists of two LEDs (red and green) connected to the microcontroller board. The system also includes sensors that detect the presence of vehicles and pedestrians at the intersection. The sensors send signals to the microcontroller board, which then controls the LEDs accordingly.

2.1 Smart Traffic Control System

One of the key features of the smart traffic control system is its ability to adapt to changing traffic conditions in real-time. For example, if there is an accident or road closure on a particular route, the system can quickly reroute traffic to alternative routes to minimize delays and congestion. Another advantage of this technology is that it can be integrated with other transportation systems, such as public transit. By coordinating traffic schedules with traffic signals, the smart traffic control system can help reduce wait times for commuters and improve overall travel times. The mechanism of action of the system includes three different stages, as illustrated in FIG. 2. These stages are:

Fig -2: Process flow of the smart traffic control system

- **Sense traffic:** Smart traffic control systems must incorporate sense traffic technology if they are to truly revolutionize urban transportation. Sense traffic is a vital component of any smart traffic control system. Its absence limits the potential benefits of such systems and hinders efforts to improve urban mobility. Therefore, city planners must prioritize the implementation of sense traffic technology when designing smart transportation solutions.
  The sense traffic stage involves using IR sensors to detect the number of vehicles on the road, their speed, and their direction of travel. This information is then used to adjust traffic signals and optimize traffic flow.

- **Control traffic:** One key feature of the system is the ability to control traffic stages, which involves using real-time data to modify the timing of traffic lights. There are several benefits to controlling traffic stages in a smart traffic control system. Firstly, it can help to reduce congestion by ensuring that vehicles are moving smoothly through intersections. This can also lead to a reduction in emissions from idling vehicles, contributing to improved air quality. In addition, controlling traffic stages can improve road safety by reducing the likelihood of accidents at intersections. By adjusting the timing of lights based on factors such as pedestrian crossings and turning vehicles, the risk of collisions can be significantly reduced.

- **Traffic signals:** One of the key benefits of incorporating traffic signals into a smart traffic control system is that they can be programmed to respond dynamically to changing traffic conditions. This means that they can adjust their timing based on real-time data about traffic volume, congestion, and accidents. In the system, LEDs are interfaced with the Arduino Uno. Red and green signals have been adopted for each lane.

2.2 Programming Logic and Arduino Port Manipulation

Arduino programming logic and port manipulation are two essential concepts that every Arduino programmer must understand. The Arduino board is a microcontroller-based platform that uses a simplified version of the C++ programming language. The programming logic in Arduino involves using conditional statements, loops, and functions to control the behavior of the microcontroller.

Port manipulation is another critical concept in Arduino programming, which involves controlling the input/output (I/O) pins on the microcontroller. These pins can be used to connect sensors, actuators, and other electronic components to the Arduino board. Port manipulation allows programmers to control these pins directly by setting their values to high or low.

By combining these two concepts, complex projects, which involve multiple sensors and actuators, can be created. Overall, understanding Arduino programming logic and port manipulation is crucial for anyone looking to create innovative projects using this powerful microcontroller platform. The programming logic of the system can be summarized as follows:

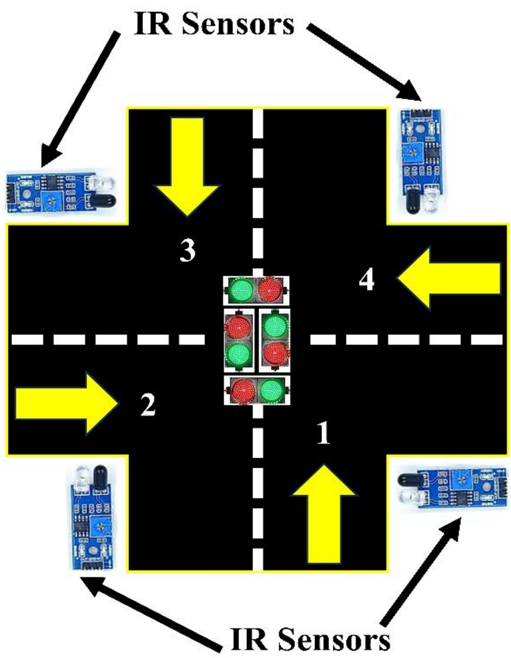

Fig -3: Schematic diagram of the smart traffic control system

- As shown in Figure 3, there are four distinct roads labeled 1, 2, 3, and 4.

- Generally, the system will start clearing traffic from roads 1, 2, 3, and 4 in the end.

- Traffic preference is given to the busiest lane. In other words, the green LED will be high, and the red LED will be low in the busiest lane. Green LEDs of other traffic lines will be low, and red LEDs will be high.

Controlling traffic lights, sensors, and other components of a traffic system with precision and accuracy is feasible by controlling the ports on an Arduino board. Port manipulation of the system is adopted as follows:

- Digital pins 0 to 7 represent port D in Arduino
- Multiple pins can be controlled at the same time by using registers
- Values of the pins are stored in ports by starting initialization from right to left, i.e., pin7, pin6, pin5, pin4, pin3, pin2, pin1, pin0.
- The direction register for port D is represented by DDRD.
- DDRD is written in the void setup () part of the Arduino code.
- Setting pins to HIGH or Low values is accomplished by using the command PORTD, which stands for register for the state of the outputs.
- PORTD is written void loop () part of the Arduino code.
- The final traffic code is as follows:

```
int sensor1;
int sensor2;  int sensor3;
int sensor4;
void setup()
DDRD = B11111111;
PORTD = B00000000;
void loop()
sensor1 = digitalRead(8);
sensor2 = digitalRead(9);
sensor3 = digitalRead(10);
sensor4 = digitalRead(11);
if(sensor1 == 1)
PORTD = B11100001;
delay(2000);
else if(sensor2 == 1)
PORTD = B11010010;
delay(2000);
else if(sensor3 == 1)
PORTD = B10110100;
delay(2000);
else if(sensor4 == 1)
PORTD = B01111000;
delay(2000);
else
PORTD = B11100001;
delay(1000);
PORTD = B11010010;
delay(1000);
PORTD = B10110100;
delay(1000);
PORTD = B01111000;
delay(1000);
```

3. PROTOTYPE OF THE SMART SOLAR ENERGY SYSTEM

This system uses solar energy to power traffic lights and other road signs, reducing our reliance on nonrenewable energy sources and aiding in climate change mitigation. Some may argue that implementing this system would be prohibitively expensive or impractical. While the initial costs of installing the necessary infrastructure may be high, the long-term benefits of reduced energy consumption and improved traffic flow make it a worthwhile investment.

3.1 Battery charger with voltage regulator

Solar battery chargers have revolutionized the world of portable electronic devices. With the increasing reliance on smartphones, tablets, and other gadgets, the need for a dependable and long-lasting power source is more important than ever. Solar battery chargers, which use the power of the sun to charge our devices, provide a practical solution to this problem.

One of the primary benefits of solar battery chargers is that they are environmentally friendly. Solar chargers use clean and renewable energy, as opposed to traditional chargers that use electricity derived from fossil fuels. This not only reduces our carbon footprint but also aids in the fight against climate change.

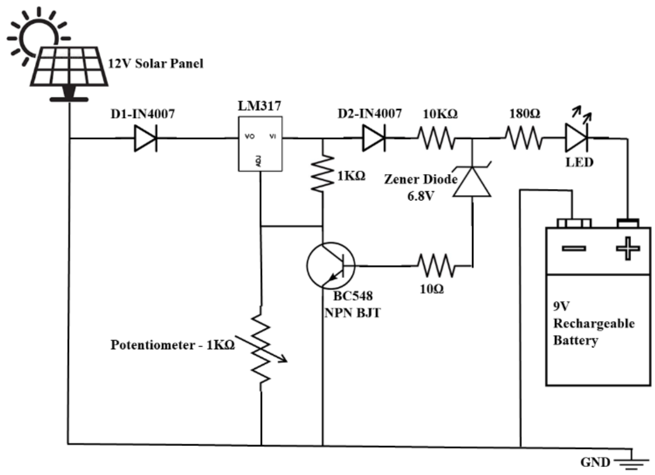

Fig -4: Schematic diagram of the solar battery charger

Furthermore, solar battery chargers are portable and convenient. They are perfect for outdoor activities because they are lightweight and compact. Therefore, a solar battery charger has been modified to charge the system's main battery, as seen in Fig. 4. A Solar panel, diodes, LEDs, a transistor, resistances, and an LM317 voltage regulator are among the components used.

The LM317 is a voltage regulator with three terminals for voltage regulation. It regulates the positive voltage from 1.25 to 37 volts depending on the output requirements. Two exterior resistances are required for output voltage adjustment. It provided line regulation of 0.01 percent and load regulation of 0.1 percent. It has various features such as overload current limiting and saving operating function requirements.

This circuit works on the premise that a charger-regulated circuit will generate a constant voltage. The charging current is routed to the voltage regulator via the first diode in this configuration. The regulator's regulation pinout controls the output voltage and current—the regulated current used by the battery. The circuit presented in Fig. 4 shows a 12-volt solar panel powering a 9-volt battery. The LM317 acts as a regulator, and the transistor acts as a switch to control the operation and charging of the battery.
When assessing the viability and effectiveness of renewable energy sources, the efficiency of solar panels is critical. Temperature is a critical factor that has a significant impact on solar panel efficiency. The relationship between temperature and solar panel efficiency has long been a source of contention among scientists and experts. As shown in Fig. 5, the maximum output voltage of the solar panel was about 9 volts.

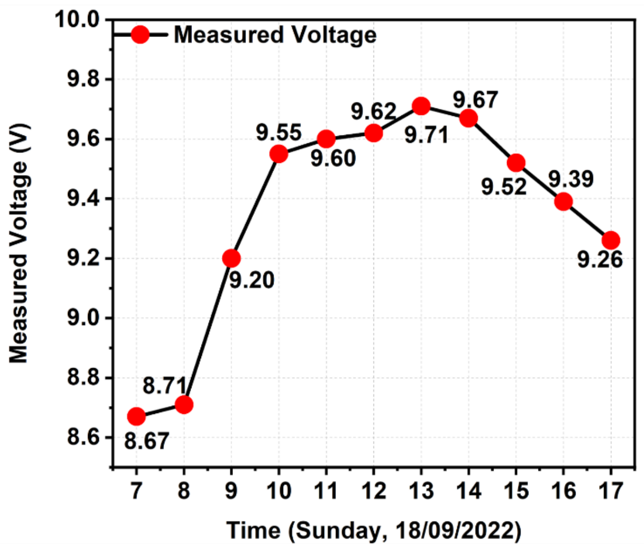

Fig -5: Measurements of the solar panel

High temperatures are widely acknowledged to decrease the performance of solar panels. As the temperature rises, so does the electrical output, resulting in lower overall efficiency. Because of the nature of the semiconductors used in solar cells, this phenomenon occurs. Because high temperatures increase electron mobility, there are more recombination losses and lower energy conversion rates. Furthermore, high temperatures can cause thermal stress on the materials used in solar panels, resulting in degradation over time. This can lead to a shorter lifespan and higher maintenance costs for solar installations.

3.2 Prototype of the system

Using Arduino to combine IR sensors with a battery charger and voltage regulator is a game-changing innovation with numerous advantages. For starters, the incorporation of infrared sensors allows for the efficient and accurate detection of objects or obstacles in the vicinity, thereby improving safety measures. Furthermore, the inclusion of a battery charger ensures that the device receives a continuous power supply. This reduces the need for frequent battery replacements while also reducing environmental waste. Furthermore, by incorporating a voltage regulator, voltage fluctuations are regulated, preventing damage to sensitive components. The Arduino platform provides an open-source programming and customization environment, making it accessible to both professionals and hobbyists. Additionally, this combination offers affordable solutions because it does not require additional devices. Fig. 6 depicts the smart solar energy system's final prototype.

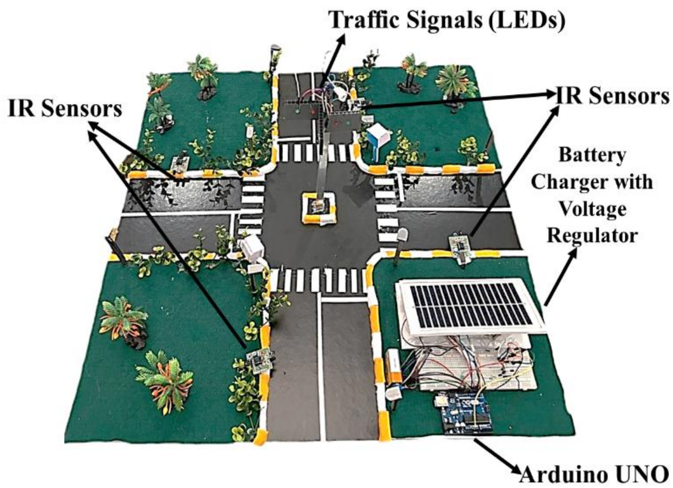

Fig -6: Smart solar energy system's final prototype

4. CONCLUSIONS

This study promotes the use of solar energy to power traffic light installations in Saudi Arabia's remote, off-grid rural areas. A photovoltaic system is required to continuously consume this energy. The components, methodology, design investigations, and findings are presented in the study. Solar cells, which absorb light and produce electricity, are the primary power source for the system's operation. Lead acid batteries are used as the PV system's electric energy storage to use electricity when there is no sunlight. A charger circuit was built to charge the storage battery. LED stoplights are energy efficient, have a long life span, and require little maintenance. The manipulated stop light used in this project was useful because the microcontroller could be programmed at any time if a phase change was needed.

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