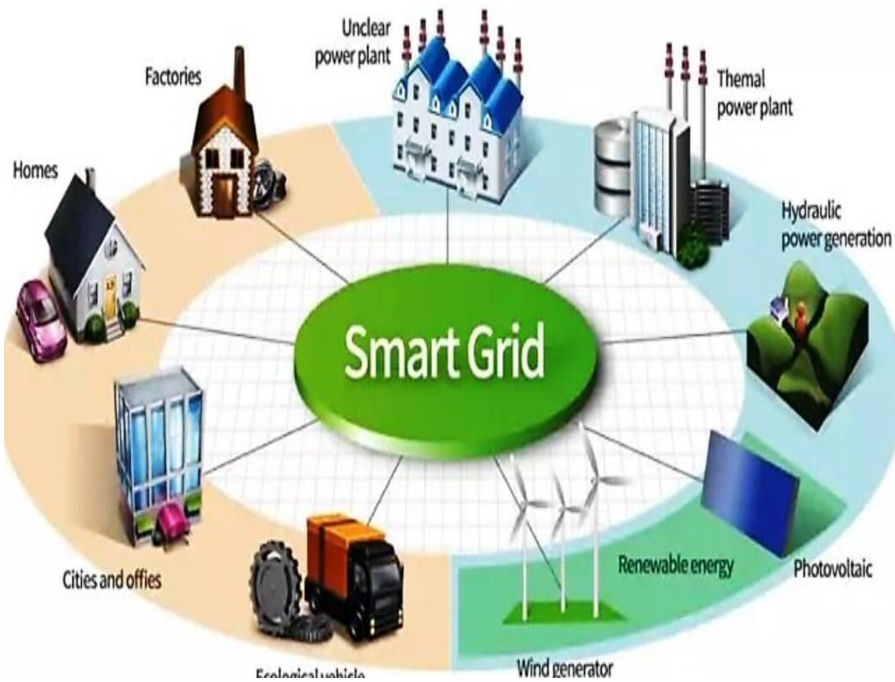
Nile Higher Institute for Engineering & Technology
Communication & Electronics Department
2022 - 2023



IoT-Enabled Smart Grid using PV Panel

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2022-2023

Contents

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Smart Grid Team

2023

List of Publications

- Ibrahim, H., & Abdelmawla, N. (2022). IoT-Enabled Smart Grid using PV panel. Nile Journal of Communication and Computer Science, 4(1), 31-47.

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List of Abbreviations

Index	Description
PV	Photovoltaic
IoT	Internet of Things
PCB	Printed circuit board
LDR	Light Dependent Resistor

Abstract

This project summarizes the implementation of smart grid that uses a Wi-Fi network (**IEEE 802.11**) to communicate with sensors (**IEEE 802.15.4**) and actuators from multiple nodes. It addresses the issue of ordinary energy consumption, which consume large amount of power. The system can be easily configured to automatically control the supply of energy, and light requirements for various electrical plant types through a mobile application enabled Interface (**IEEE 802.15.2**). The mobile application (**IEEE P 2301**) dashboard can further provide a complex analysis of the whole system by collecting values from different sensors. The designed smart grid system is power efficient, self-sustained, and can be set up easily by the user as each rack acts as a single node or module according to the pre-designed circuit simulation (**IEEE 1074**) and implementation phase. Due to the modular approach, the system is also scalable without the requirement of more complicated materials or wiring.

Keywords: *Wi-Fi, IoT, Sustainable, Energy, Smart Grid.*

Problem Statement

- **Egypt currently produces 58 GW of power per year, and the maximum consumption that occurs will be 32 GW of power, and therefore I have a surplus of wasted electricity that we need to store and benefit from, and problems such as not knowing the cause of power outages and maintenance costs that take time and effort due to reliance on old technologies, so we You need to resort to smart grids, because they provide the ability to store electricity, monitor consumption, reduce losses, and many advantages that we will talk about later.**

- **Thus, we propose an innovative solution to increase Energy production to cater to the growing population and power consumptions.**

CHAPTER 1

Introduction

Chapter 1: Introduction

Smart grid systems integrate renewable energy sources such as wind, solar, and storage into the grid system. These new power generation technologies are smaller, more widespread, greener, and able to maintain grid resilience and spread congestion points [1-2]. A smart grid uses an extensive sensor network supported by a two-way communication system to constantly monitor grid conditions. A bi-directional communication network enables the exchange of measurement data and control signals between network units, improving monitoring and management of network**(IEEE 802.1x)** and user assets [3]. Additionally, the smart grid must be supported by sufficient computing resources to ensure that the collected data can be processed within the required timeframe. Control and monitoring are more distributed because the amount of data collected is enormous and sensors (**IEEE 802.15.4**) are distributed throughout the network [4]. Egypt has 58 GW of generating capacity, but summer peak consumption ranges from 30 to 32 GW [5]. The problem turns out to be that the investment in generating capacity far exceeds the rate of adding (and enhancing) grid capacity that makes up the national grid. Figure 1 shows how the smart grid works.

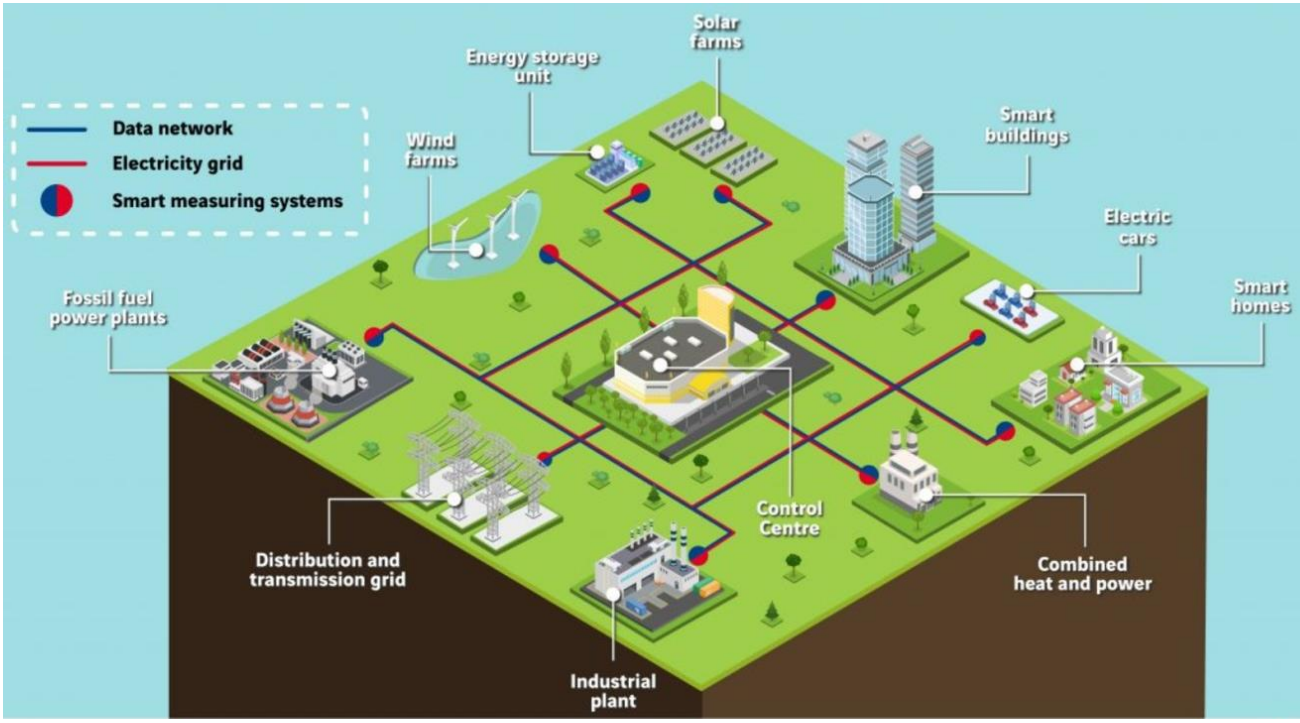
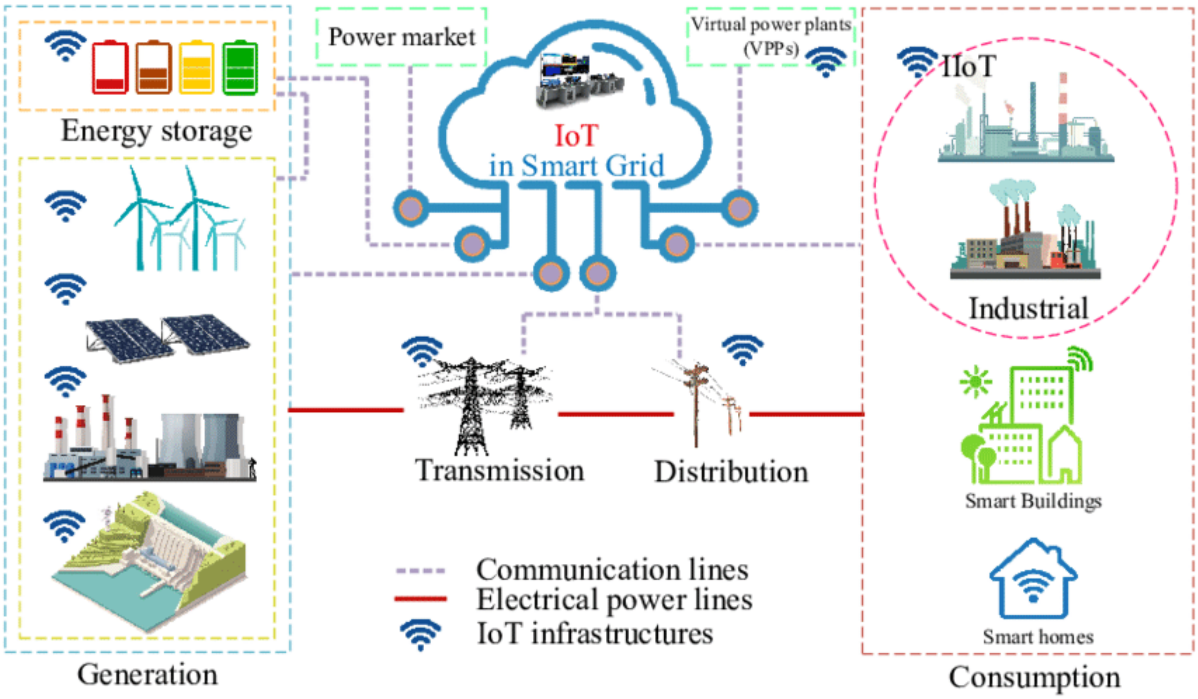


Fig.1. How Smart Grid Works, [Source: vinci.com].

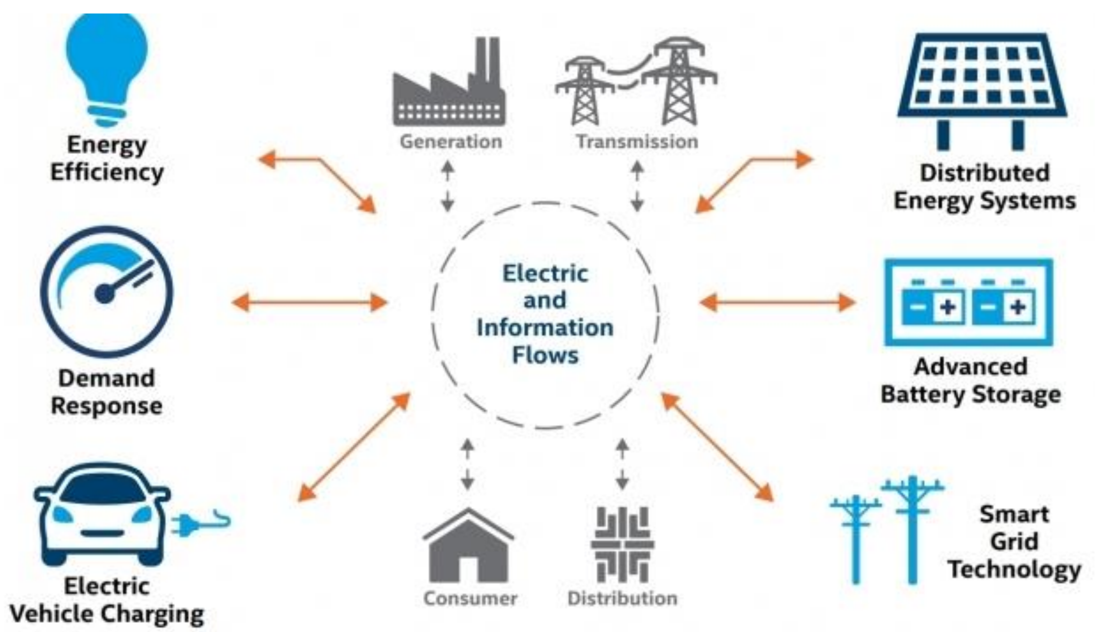
A smart grid allows electricity distribution companies to analyze big data on the consumption of electricity using sophisticated servers and IT infrastructure embedded into control centers, former head of the New and Renewable Energy Authority (NREA) [6-7]. This also allows companies to anticipate problems with the grid or malfunctions in different parts, making the electrical system more reliable and efficient. The grid also helps to cut back on lost electricity, as engineers are able to keep a close eye on the performance, anticipate problems before they occur, and quickly maneuver to avoid interruptions. The new grid would also come with smart control units for street lights, which the ministry is piloting in Port Said before rolling them out to the rest of the country. Control centers are the main ingredient in a smart grid as the plan includes the establishment of 47 smart control centers nationwide, some of which are already under construction [8]. These centers will replace Egypt's current six control centers and more will be built to better manage and monitor Egypt's energy use [9].

One of the future-oriented solutions in the telecommunications sector is IoT**(IEEE 1451-99)**.It is generally viewed as a network of embedded devices. Electronics, software, sensors and actuators that can exchange information Communication networks such as the Internet. Because IoT supports two-way communication and distributed computing capabilities, it can be seen as a potential solution to address the inevitable problems of transitioning traditional energy grids to upgraded smart grid systems [10-11]. Additionally, IoT-enabled smart grids **(IEEE P2301)** can improve grid operations and management. It is efficient because it seamlessly integrates with other smart entities such as smart appliances, smart homes, smart buildings and smart cities to access and control more devices over the internet. However, this requires the use of more sophisticated computational capabilities and resource allocation mechanisms. Although energy systems are becoming more efficient to monitor and operate, there are many obstacles to IoT-enabled smart grid **(IEEE P2301)** implementation.

Furthermore, IoT-Enabled Smart grid designs consider energy storage to maximize efficiency and make better use of renewable energy. The electricity produced is not always consumed due to varying and often unpredictable consumer behavior. In a conventional grid, that energy is simply wasted. One reason for this is that traditional grids were not designed to store electricity that will not be used immediately [12]. On the other hand, renewable energy sources such as solar and wind are not always reliable. Clouds can block the sun for days, and wind farms can stop spinning without strong winds. As Egypt seeks to increase its reliance on renewable energy, storage has become a priority to meet the days when the weather is not on our side, but the investment required to store just 1kWh of power in a battery is "massive" and simply not viable, so you can forget to go the battery route. Storing power in lithium-ion batteries costs about $1,000 per kWh, according to Vox [13]. Figure 2 shows the complete system of Smart-His grid using PV.



(a)



(b)

Fig.2. Smart Grid using PV System [14-15].

Finally, this study proposes a solution in the form of an IoT-enabled smart grid using PV to address these issues (**IEEE P2301**). The study offers a unique, fully self-contained and energy efficient smart grid that can be deployed anywhere. Solar power **(IEEE 1562)** is the direct conversion of solar radiation into direct current. Solar radiation is captured by semiconductor devices called solar cells that can absorb photons of light and release electrons. If their free electrons are lead, an electric current, also called electricity, is produced. Therefore, photovoltaic **(IEEE1562)** power is a renewable energy source as it is derived from an inexhaustible source of energy, the sun. The sun is also a clean, sustainable and free resource. Our solar power system **(IEEE 1562)** is directly connected to the main power grid and is also isolated from the power grid. The term isolation is used because these isolated power generation systems do not need to be connected to the mains power grid to generate energy from the sun. They are usually located in areas with limited access to electricity. Figure 3 shows a complete photovoltaic system.

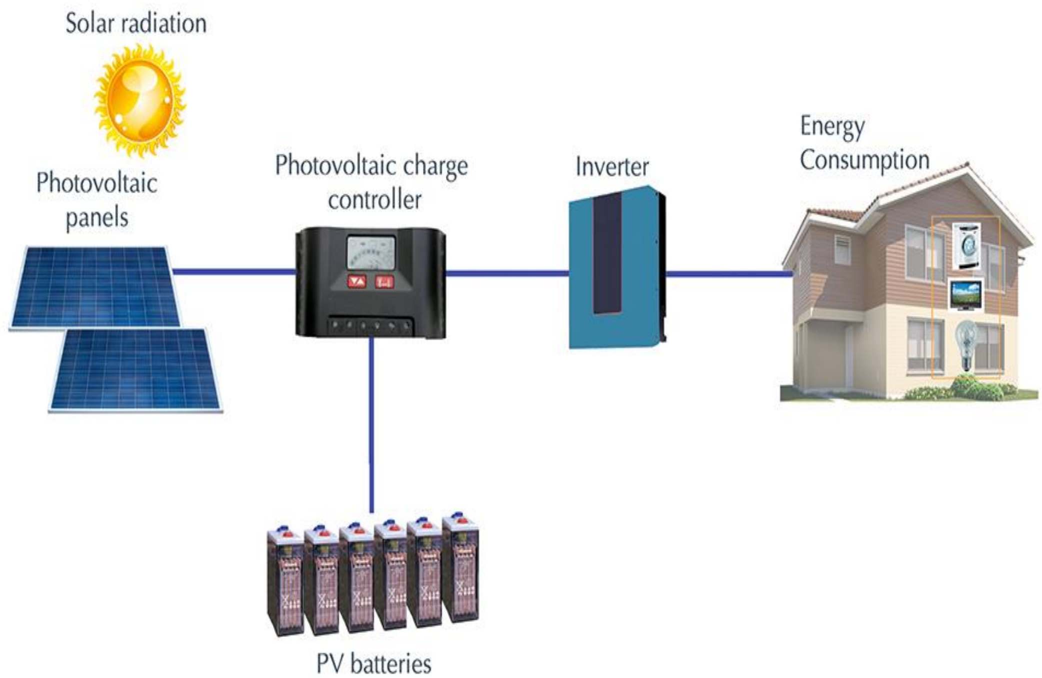


Fig.3. Photovoltaic System **(IEEE 1562)**, [Source: Bester Energy].

1.1. How is a smart grid different from the current (traditional) one?

A smart grid allows electricity distribution companies to analyze big data on the consumption of electricity using sophisticated servers and IT infrastructure embedded into control centers, former head of the New and Renewable Energy Authority (NREA) Mohamed El Sobky tells Enterprise. This also allows companies to anticipate problems with the grid or malfunctions in different parts, making the electrical system more reliable and efficient. The grid also helps to cut back on lost electricity, as engineers are able to keep a close eye on the performance, anticipate problems before they occur, and quickly maneuver to avoid interruptions, Mohamed El Hefnawy, power systems marketing director at Schneider Electric North-East Africa and the Levant told Enterprise. The new grid would also come with smart control units for street lights, which the ministry is piloting in Port Said before rolling them out to the rest of the country, sources have told Al Mal.

Control centers are the main ingredient in a smart grid: The plan includes the establishment of 47 smart control centers nationwide, some of which are already under construction. These centers will replace Egypt's current six control centers and build some more to better control and oversee energy consumption in Egypt, Al Mal reported previously.

Smart grid design comes with energy storage in mind to maximize efficiency and allow us to better use renewables: Electricity that is produced isn't always consumed due to the varying and often unpredictable behavior of consumers. In traditional grids, that energy would simply go to waste — partially because traditional grids are not designed to store electricity that is not used immediately. Meanwhile, renewable energy sources**(IEEE 1547),** such as solar and wind, aren't always reliable, since clouds may block the sun for days or wind farms can stop spinning in the absence of strong wind, El Sobky tells us. As Egypt looks to increase its reliance on renewable energy, storage has become a priority to account for the days when the weather is not on our side, he added. But you can forget about opting for the battery route, as the investment required to allow for the storage of just 1 kWh of electricity in a battery is "major" and simply not feasible, El Sobky says. Storing electricity in a lithium-ion battery costs around USD 1k per 1 kWh, according to Vox. Figure 2 shows the full system of Smart Grid using PV.

1.2. What is Solar PV?

Solar PV cells or solar cells convert solar energy into electrical energy. The PV cells are clubbed together in a system to be called as solar PV systems & they behave similar to any other power generation systems. Solar PV systems **(IEEE 1562)** make use of solar energy which is convenient & easy to store. The PV Systems **(IEEE 1562)** consist of proper conduction of electrical energy, controls the flow of energy, facilitates electrical conversion, distribution & provides the necessary storage of the energy produced by the array.

1.3. Elements of a PV system

Diverse applications have diverse system requirements with different set of components which work in synchronization. Following are the elements of a PV system.

- Solar PV modules.
- Solar Inverter with Anti-islanding mode feature.
- Battery Bank.
- System and Battery Controller.
- Assortment of balance of system (BOS) hardware, including wiring, over-current, surge protection and disconnect devices.
- Power conversion unit (PCU).

1.4. What makes it different from the conventional system?

The basic operation of the system is similar to that of the conventional system only that the source of energy in the PV system is solar radiation. Other important elements of systems discussed above are used in synchronization for the appropriate power distribution, storage etc.

Following Diagram explains the PV system functioning:-

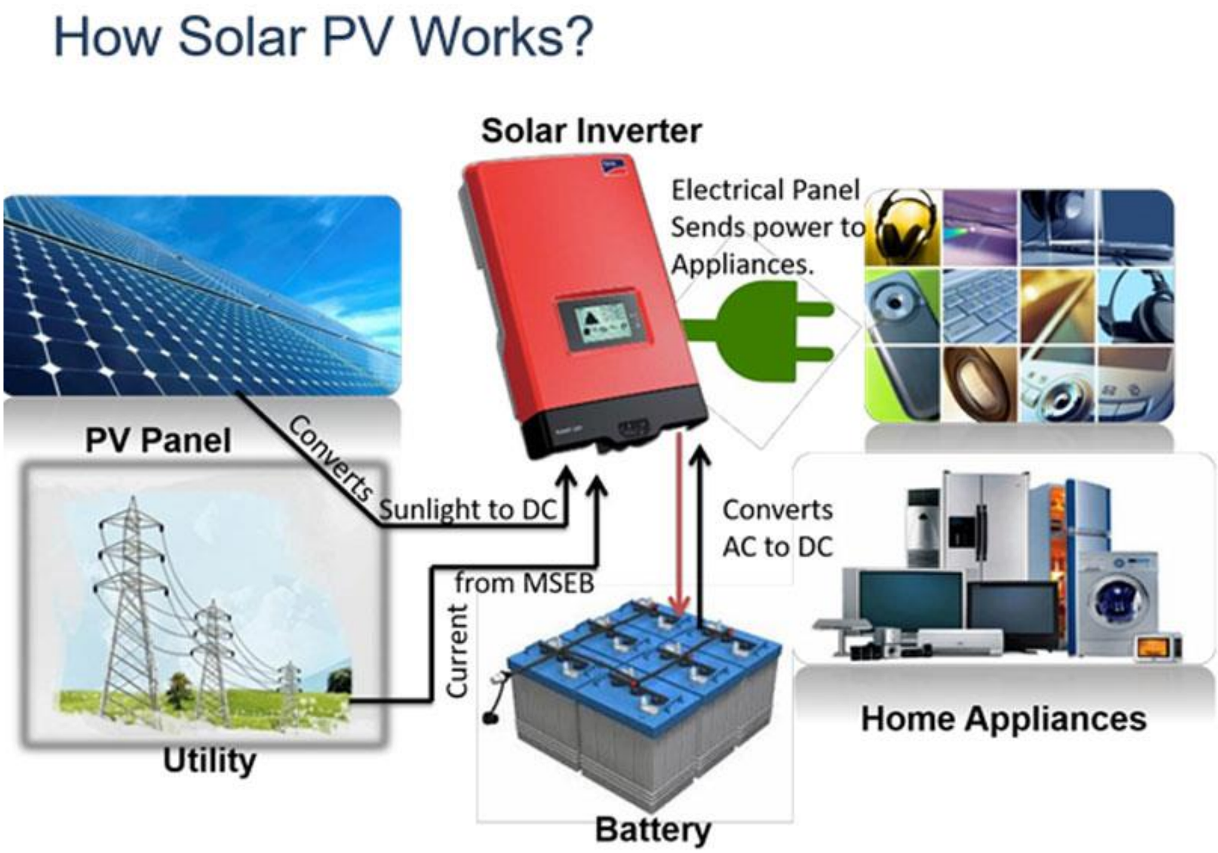


Fig.4. How Solar PV Works.

Figure 3 shows the important elements of the Solar PV system, As we can infer from the image, the systems are similar to those of the conventional systems with the difference of the PV panels. PV panels play the role of converting sun rays to DC electrical energy which are connected with dedicated system and thus result in the generation of electricity. Batteries are often used in PV systems to store the additional energy & this power can be utilized during non-sunlight hours i.e. during the night time or during odd weathers etc.

1.5. Why Install Solar PV Systems (IEEE 1562)?

Until recently solar system installation was perceived as a matter of luxury and not a necessity. With rising temperatures & a significant climate change it has become crucial for organizations & individuals to know the importance of using the renewable resources as the conventional ones are on the verge of extinction.

Not only do we need to think about the extinction of the conventional resources but also about the highly harmful emissions that go out as a by-product harming environment globally. Following are few of the many important points that throw light on the significance of Solar PV systems.

1.6. Importance of Solar PV Systems

- Convenient – Solid state and self-contained process of energy conversion.
- Clean – No consumption and emission of matter.
- Robust – The system can withstand severe weather conditions.
- Sustainable – System fuel i.e. solar energy is abundantly available.
- Scalable – Can be installed with capacity of Watts to Mega Watts.
- High Savings – Solar PV system is a one-time investment; we can reap the benefits for next 25 years.
- Safe – It is one of the most secure energy conversion process.
- Popular – Solar PV technology is becoming popular & the governments are subsidies & tax credits.

Finally, This research proposes a solution in the form of an IoT-enabled smart grid using PV to address these issues (**IEEE P2301**). In this study, we offer a one-of-a-kind, totally self-contained, and energy-efficient smart grid that can be placed anywhere. Photovoltaic energy is the direct transformation of solar radiation into direct current electricity. Solar radiation is captured by semiconductor devices called photovoltaic cells, which have the ability of absorbing light photons and emitting electrons. When these free electrons are lead, the result is an electric current, otherwise known as electricity. Therefore, photovoltaic energy is a renewable energy because it comes from an inexhaustible source of energy, the Sun, a source that is also a clean, sustainable and free resource.

We have photovoltaic systems that are directly connected to the main electric network and also that are isolated from the network. These isolated systems of current generation do not need to be connected a main electric network in order to produce energy from the Sun, hence the term “isolated”. They are usually located in areas where access to electricity is restricted. Figure 4 presents a full Photovoltaic System, [Source: Bester Energy].

1.7. Project Motivations

The motivation for this project in the smart grid area is Due to resource limitations in such as (i) Energy; (ii) Power; (iii) Wires; so it is essential to implement and develop smart grid system over IoT. Egypt currently produces 58 GW of power per year, and the maximum consumption that occurs will be 32 GW of power, and therefore I have a surplus of wasted electricity that we need to store and benefit from, and problems such as not knowing the cause of power outages and maintenance costs that take time and effort due to reliance on old technologies, so we You need to (i) resort to smart grids, because they provide the ability to store electricity, (ii) monitor consumption, (iii) reduce losses.

1.8. Project Aims

This project aims to achieve the following (i) Provide a renewable energy source. (ii) Storage of surplus electricity. (iii) Eliminate the problem of power outages. (iv) Reduce pollution from the use of non-renewable energy in electricity generation.

1.9. Project Contributions

This Project is a smart solution over IoT **(IEEE P2510)** using PV Smart Grid **(IEEE 1547)**. The project performs the following enhancements: (i) increase Power Savings: This project will contribute to the storage of existing surplus electricity, the treatment of power outage problems, and the provision of a reliable renewable power source. (ii) Achieving Sustainability: Using primarily renewable energy sources smart grid support grid independence and help to reduce carbon emissions. (iii) Resiliency: Smart grid provides uninterrupted 24/7 power and balance load demand for your changing power needs. (iv) Increase Power Systems

Efficiency: With sophisticated control, useoptimize power usage based on demand, energy prices, and other factors.

CHAPTER 2

Economically Feasibility Study and Engineering

Chapter 2: Economically Feasibility Study and Engineering Standards

2.1. Relation with Environment and Economic Benefits

Overcoming financial obstacles to a greener future of Energy. All these factors will save millions on the country as well as provide excellent service to the consumer. These Factors are:

I) Reduce power Losses.

II) Reliability against sudden faults.

III) Reducing carbon emissions.

IV) Reducing the use of long transmission lines.

V) Control the flow of power.

2.2. Economically Feasibility Study

Overcoming financial obstacles to a greener future of Energy. All these factors will save millions on the country as well as provide excellent service to the consumer. These Factors are presented in

Fig. 4.

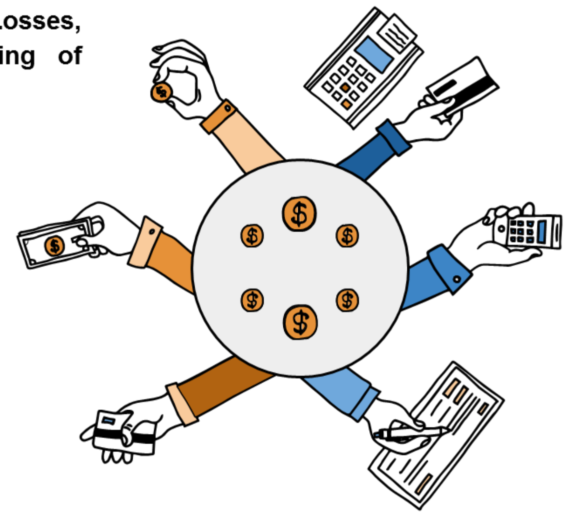


Fig.5. Economic and Environmental Benefits.

Smart Energy Grid is an electricity network that consists of a system of infrastructural, hardware and software solutions that enable two-way communication between all system parts and participants and provide efficient power generation and distribution in the supply chain [16-17].

It allows electricity distribution companies to analyze the consumption of electricity using IT infrastructure embedded into control centers, former head of the New and Renewable Energy Authority [18]. By 2025, it is expected that there will be 30.9 billion IoT devices installed worldwide, of which 19% will be used in the energy industry, increasing the emphasis of cyberattacks on this industry by 54% [19-20]. Figure 5 presents the used technologies in smart energy grids. It is often characterized as a self-sufficient distributed system. It can provide energy from different power sources, including renewables and storage [21]. Table 2 classifies and compares the widely used communication network technology in smart grid systems [22-25].

Fig.6. Technologies in Smart Energy Grids.

Table 1. Traditional Grid vs. Smart Grid.

Index	Metric	Traditional Grid	Smart Grid
1	Topology	Radial	Network
2	Generation	Centralized	Centralized and Distributed Generation
3	Operation and Maintenance	Manually Check Equipment	Remote Monitoring
4	Restoration	Manual	Self-Healing
5	Power Flow Control	Limited Protection	Adaptive Protection
6	Monitoring	Blind	Self-Monitoring
7	Reliability	Estimated based on Failures and Cascading Outages	Predictive with Real Time Protection and Islanding
8	Customer Interaction	Limited	Extensive

Table 2. Communication Network Technology in Smart Grids.

Index	Metric	ZigBee	Wi-Fi	WiMax	Satellite	4G/LTE	5G
1	Coverage	Up to 100 m	Up to 100 m	Up to 50 km	-	Up to 16 km	Up to 500 m
2	Data Rate	20-250 Kbps	2Mpbs-1.7 Gbps	75 Mbps	50 Mbps	979 Mbps	20Gbps
3	Network Type	NAN, FAN and Premise Network	NAN, FAN and Premise Network	WAN, NAN, and FAN	WAN	WAN, NAN, and FAN	WAN, NAN, and FAN
4	Prospects	Mesh Capabilities, Ease of Use, Portability, Affordability, and Low Energy	Excellent For Short Distances	Low Cost and Energy	Good When There Are No Other Choices	Existing Network, Affordable Cost, Strong Security, and Extensive Coverage	Low Energy, Fast Response Times, Fast Data Rates, And Scalability
5	Considerations	Limited Range, Low Interference, and Low Data Rate	Low Security	Not widespread, coverage drastically decreased if line of sight is lost	High Cost	Congestion may occur if consumers share the network.	-

2.3. Engineering Standards

The Institute of Electrical and Electronics Engineers Standards Association (IEEE SA) is an operating unit within IEEE that develops global standards in a broad range of industries, including: power and energy, artificial intelligence systems, internet of things, consumer technology and consumer electronics, biomedical and health care, learning technology, information technology and robotics, telecommunication and home automation, automotive, transportation, home automation, nanotechnology, information assurance, emerging technologies, and many more. IEEE SA has developed standards for over a century, through a program that offers balance, openness, fair procedures, and consensus. Technical experts from all over the world participate in the development of IEEE standards.

This project follow the criteria of many sub-standards based on IEEE standardization policy such as:

- Common Gateway based Wi-Fi (IEEE 802.1)
- Sensors (IEEE 802.15.4)
- Bluetooth (IEEE 802.15.2)
- Cloud Computing (IEEE P2301)
- Software Life Cycle (IEEE 1074)

2.3.1. Common Gateway based Wi-Fi (IEEE 802.1)

IEEE 802.11 is part of the IEEE 802 set of local area network (LAN) technical standards, and specifies the set of media access control (MAC) and physical layer (PHY) protocols for implementing wireless local area network (WLAN) computer communication. The standard and amendments provide the basis for wireless network products using the Wi-Fi brand and are the world's most widely used 143 wireless computer networking standards. IEEE 802.11 is used in most home and office networks to allow laptops, printers, smartphones, and other devices to communicate with each other and access the Internet without connecting wires. IEEE 802.11 uses various frequencies including, but not limited to, 2.4 GHz, 5 GHz, 6 GHz, and 60 GHz frequency bands. Although IEEE 802.11 specifications list channels that might be used, the radio frequency spectrum availability allowed varies significantly by regulatory domain. The protocols are typically used in conjunction with IEEE 802.2, and are designed to interwork seamlessly with Ethernet, and are very often used to carry Internet Protocol traffic.

2.3.2. Sensors (IEEE 802.15.4)

IEEE standard 802.15.4 intends to offer the fundamental lower network layers of a type of wireless personal area network (WPAN) which focuses on low-cost, low-speed ubiquitous communication between devices. It can be contrasted with other approaches, such as Wi-Fi, which offer more bandwidth and requires more power. The emphasis is on very low cost communication of nearby devices with little to no underlying infrastructure, intending to exploit this to 141 lower power consumption even more. The basic framework conceives a 10-meter communications range with a transfer rate of 250Kbps. Tradeoffs are possible to favor more radically embedded devices with even lower power requirements, through the definition of not one, but several physical layers. Lower transfer rates of 20 and 40Kbps were initially defined, with the 100Kbps rate being added in the current revision. IEEE 802.15.4 has been widely accepted as the de facto standard for wireless sensor networks (WSNs). However, as in their current solutions for medium access control (MAC) sub-layer protocols, channel efficiency has a margin for improvement. Key 802.15.4 features include: (i) real-time suitability by reservation of Guaranteed Time Slots (GTS), (ii) collision avoidance through CSMA/CA, (iii) integrated support for secure communications, (iv) power management functions such as link speed/quality and energy detection, (v) Support for time and data rate sensitive applications because of its ability to operate either as 142 CSMA/CA or TDMA access modes. The TDMA mode of operation is supported via the GTS feature of the standard, and (vi) IEEE 802.15.4-conformant devices may use one of three possible frequency bands for operation (868/915/2450 MHz).

2.3.3. Bluetooth (IEEE 802.15.2)

Task group two addresses the coexistence of wireless personal area networks (WPAN) with other wireless devices operating in unlicensed frequency bands such as wireless local area networks (WLAN). The IEEE 802.15.2-2003 standard was published in 2003 and task group two went into "hibernation".

2.3.4. Cloud Computing (IEEE P2301)

IEEE P2301 defines essential topology, protocols, functionality, and governance required for reliable cloud-to-cloud interoperability and federation. The standard will help build an economy of scale among cloud product and service providers that remains transparent to users and applications.

With a dynamic infrastructure that supports evolving cloud business models, IEEE P2302 is an ideal platform for fostering growth and improving competitiveness. It will also address fundamental, transparent interoperability and federation much in the way SS7/IN did for the global telephony system, and naming and routing protocols did for the Internet.

2.3.5. Software Life Cycle (IEEE 1074)

IEEE 1074 provides a process for creating a software life cycle process (SLCP). The SLCP is defined as the project-specific description of the process that is based on a project's software life cycle (SLC) and the integral and project management processes used by the organization. These integral processes include configuration management, metrics, quality assurance, risk reduction, and the acts of estimating, planning, and training. It is primarily the responsibility of the project manager and the process architect for a given software project to create the SLCP. This methodology begins with the selection of an appropriate software life cycle model (SLCM) for use on the specific project. It continues through the creation of the SLC. The methodology concludes with the augmentation of the SLC with an organization's support processes to create the SLCP. The activities described in the 1074 mapping table cover the entire life cycle of a software project, 141 from concept exploration through the eventual retirement of the software system. 1074 does not address no software activities, such as contracting, purchasing, or hardware development. It also does not mandate the use of a specific SLCM. 1074 presumes that the project manager and process architect are already familiar with a variety of SLCMs, with the criteria for choosing among them, and with the criteria for determining the attributes and constraints of the desired end system and the development environment that affects this selection.

CHAPTER 3

Related Work

Many researchers and developers have worked on many systems that aim to develop smart solutions for optimal energy utilization. The following are the most prominent posts in this field. Germany has integrated IoT infrastructure and technology solutions to implement a smart grid project in Mannheim [26]. The project has enabled the widespread adoption of renewable energy and the coordination of energy consumption and production in the city.

The Lumin Energy Management Platform is a prime example of IoT applications in smart grids, reducing costs, reducing emissions, and facilitating the adoption of green energy. The company provides intelligent panels and data analysis tools to optimize storage, manage power consumption, and facilitate PV system integration at home [27].

Schneider Electric offers a range of connected solutions for bringing solar energy into your home. The company can equip homes with photovoltaic systems, monitoring and management tools to go completely off-grid, or generate and convert solar energy to partially meet home needs [28].

Cisco [29] is one of the leading providers of smart grids for the Internet of Things. The company, along with several partners, helps a variety of upstream and downstream players adopt connected technology and improve network operations. Their success story includes modernizing BC Hydro. Cisco uses smart metering and advanced analytics technology to improve utility efficiency and reliability.

Siemens has a large share of smart grid solutions in its IoT portfolio. The company offers a variety of software and infrastructure solutions for energy intelligence [30]. One of his customers, German electrical wholesaler Rexel, undertook a major retrofit project and for energy measurement and analysis he integrated a Siemens energy monitoring system. Finally, all previous systems lack a user-friendly application that facilitates waste collection and recycling while having a small, easy-to-use home device for the general public.

Many researchers and developers have worked on many systems that aim to develop smart solutions for optimal energy utilization. The following are the most prominent posts in this field. Germany has integrated IoT infrastructure and technology solutions to implement a smart grid project in Mannheim. The project has enabled the widespread adoption of renewable energy and the coordination of energy consumption and production in the city.

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CHAPTER 4

System Design and Analysis

Chapter 4: System Design and Analysis

4.1. System Design and Analysis

We've been working to build a Smart Grid Energy System using IoT and PV panel. The basic operation of the system is similar to that of the conventional system only that the source of energy in the PV system is solar radiation. Other important elements of the system are used in synchronization for the appropriate power distribution, storage etc. Figures 5 and 6 shows proposed system use case and sequence Diagrams, while figure 7 presents system flowchart.

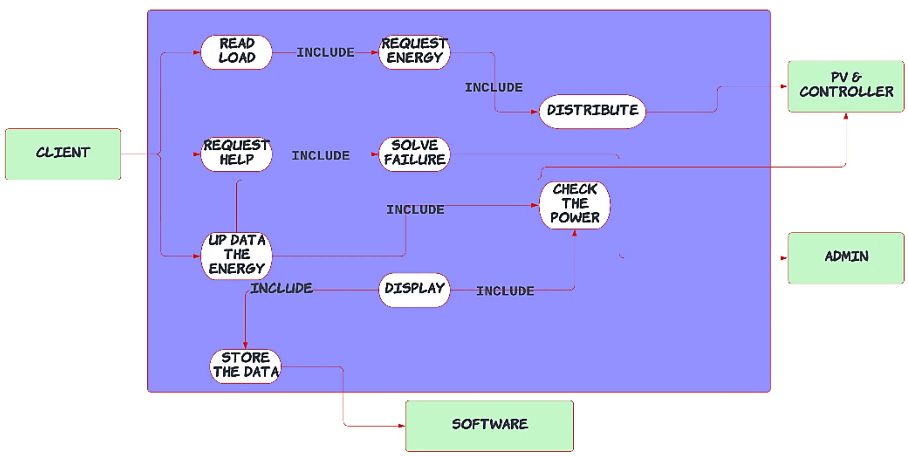


Fig.7. Proposed System Use Case Diagram.

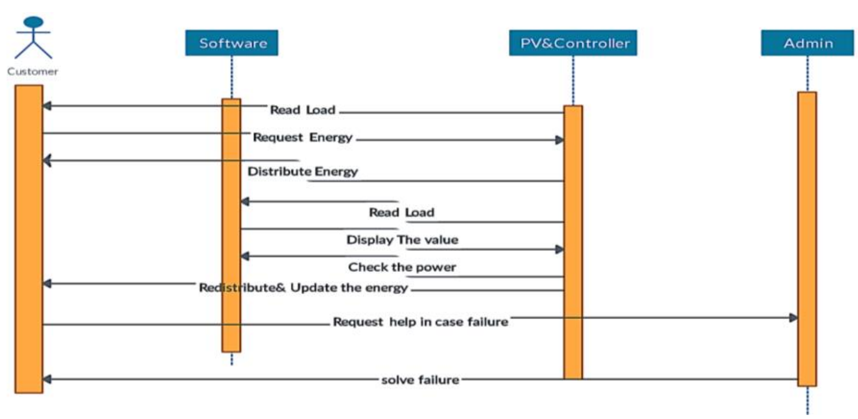


Fig.8. Proposed System Sequence Diagram.

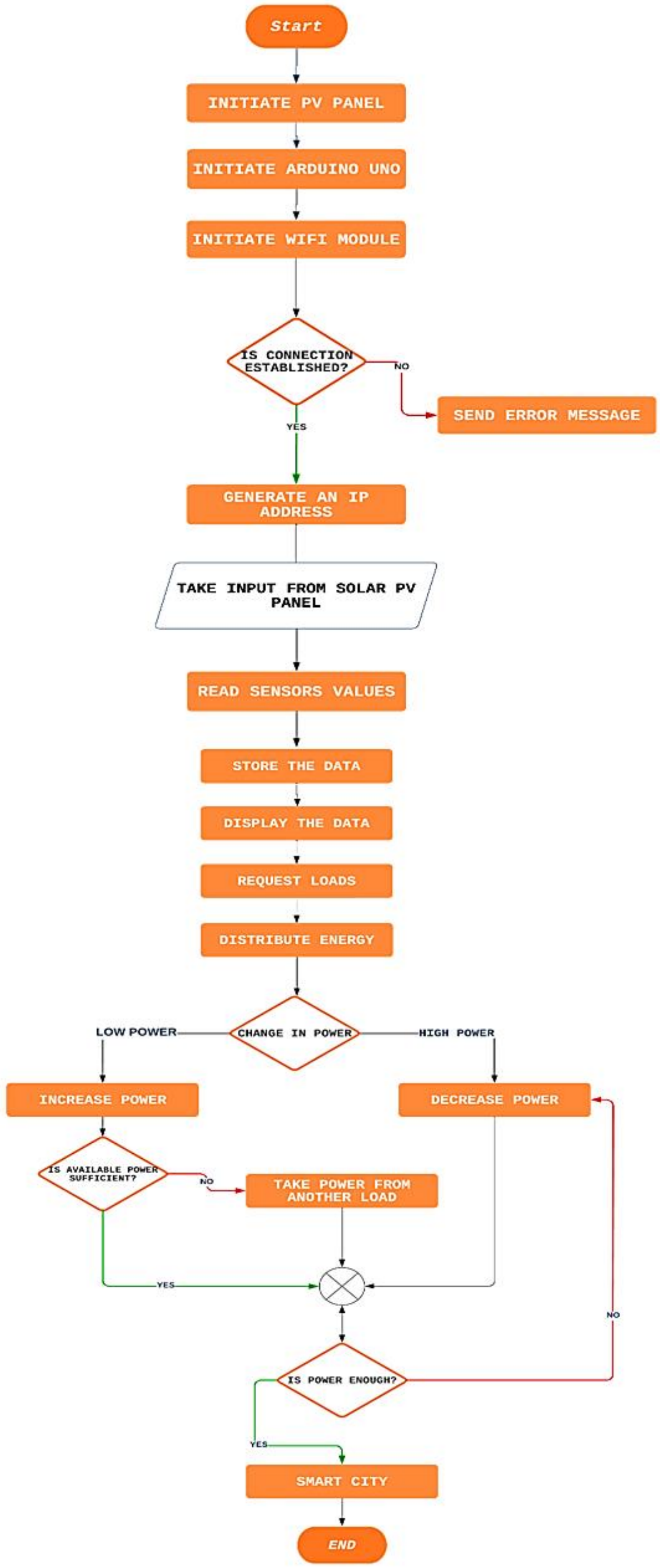


Fig.9. Proposed System Flowchart.

4.1.1. Design Constraints and Ethics

<u>PV controller circuit</u>

Circuit requirements for implementation:

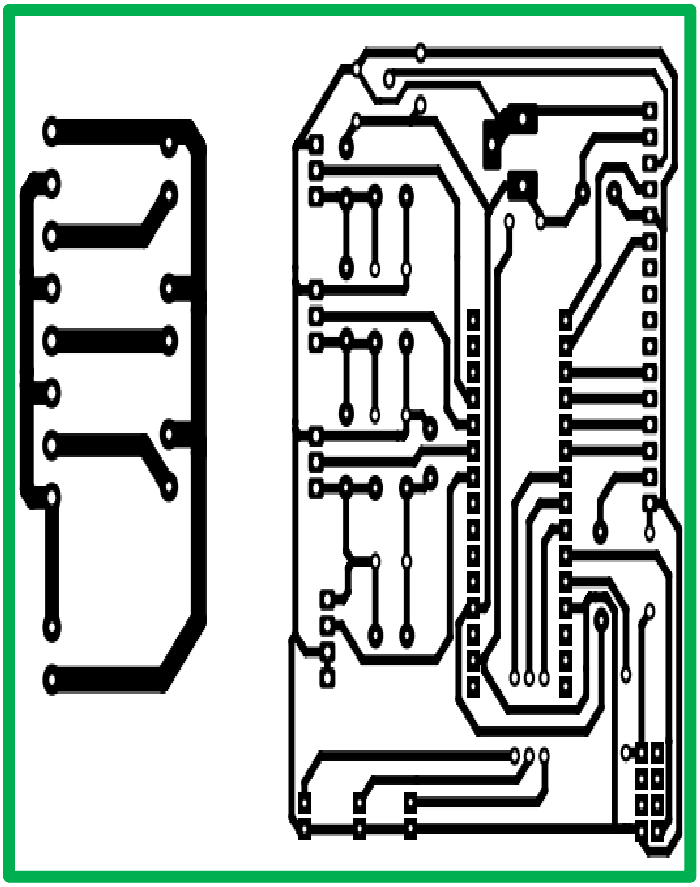
Hardware

- **Atmega Microcontroller 328P**
- **Ac Voltage Sensor**
- **Arduino NANO**
- **Current Sensor**
- **Wifi Module ESP-01**
- **LCD Display**
- **Resistors**
- **Capacitors**
- **Cables and Connectors**
- **PCB and Breadboards**
- **LED**
- **IC Sockets**
- **Load (Lamps)**

Software

- **Arduino Compiler**
- **MC Programming Language: C**
- **Proteus Professional**

IOT Smart Grid Designs:



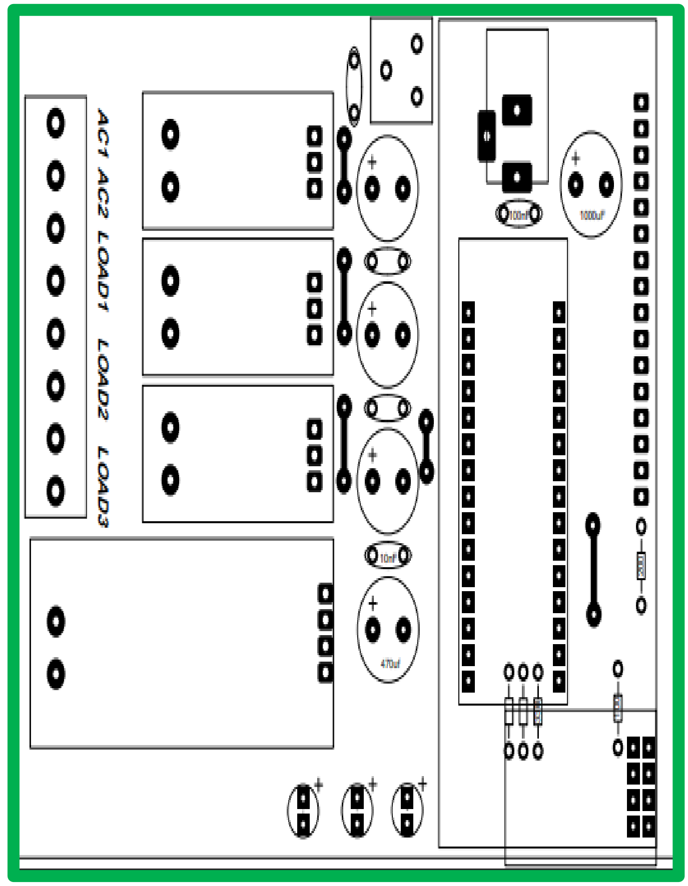


Figure10.a. PCB Layout Bottom **Figure10.b. PCB Layout Top**

Fig.10. PCB Manufacturing Designs

We used Proteus software to make accurate designs for a good implementation of the IOT circuit As shown in the following figures.

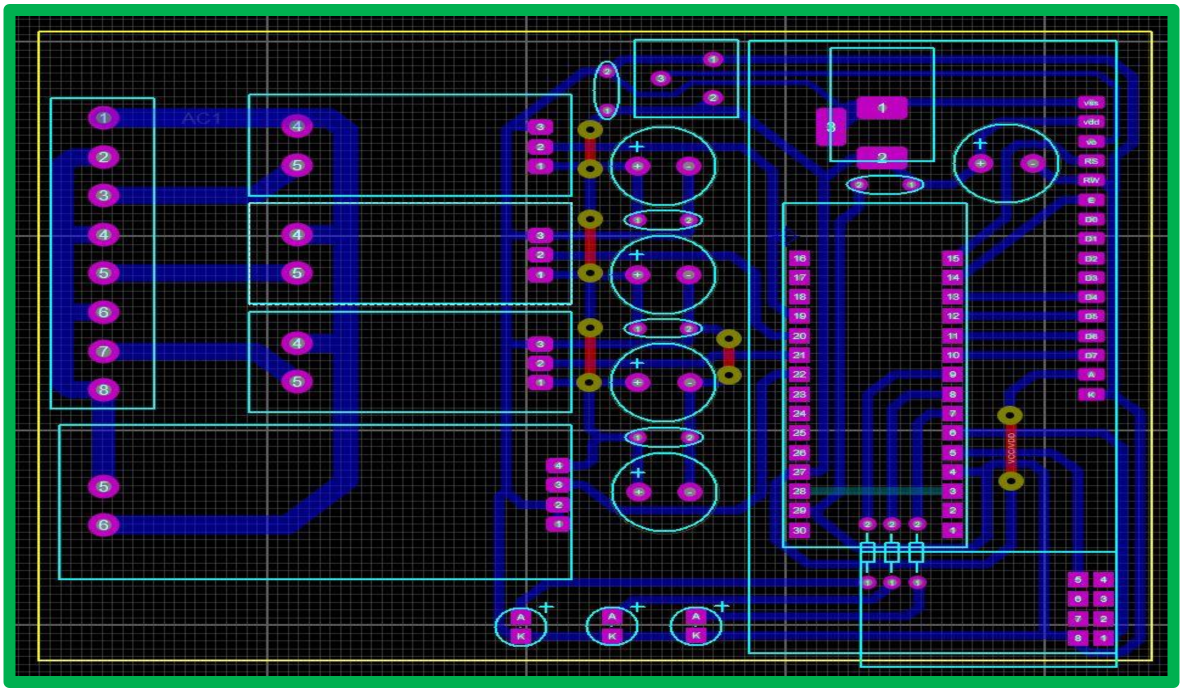


Fig.11. PCB Layout on proteus

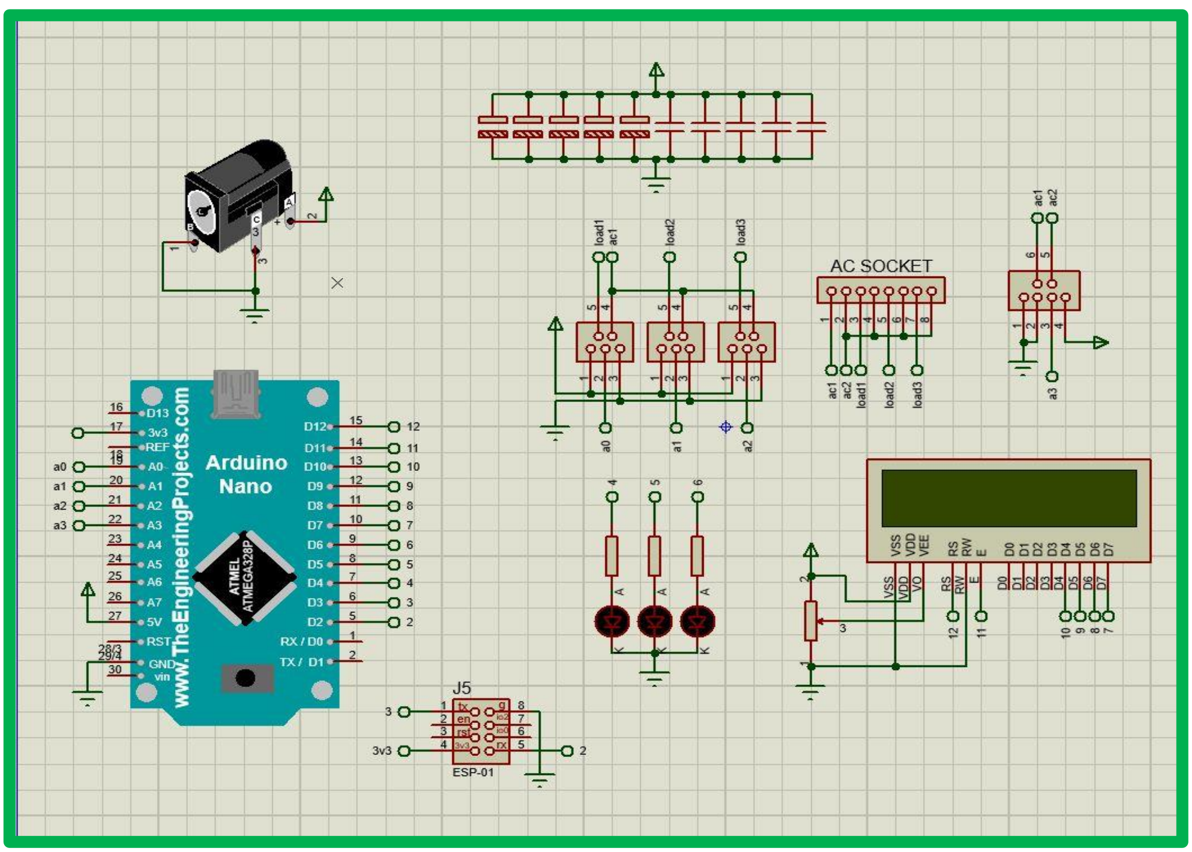


Fig.12. Schematic Capture in Proteus

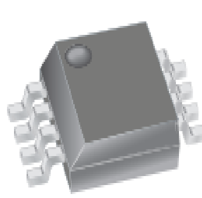
Data sheet for electrical components

Current Sensor ACS712:

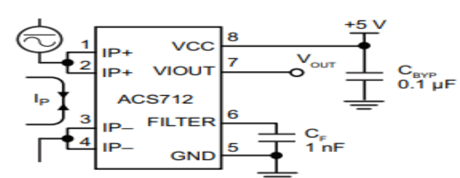
DESCRIPTION

The Allegro™ ACS712 provides economical and precise solutions for AC or DC current sensing in industrial, commercial, and communications systems. The device package allows for easy implementation by the customer. Typical applications include motor control, load detection and management, switchmode power supplies, and overcurrent fault protection. The device is not intended for automotive applications. The device consists of a precise, low-offset, linear Hall circuit with a copper conduction path located near the surface of the die. Applied current flowing through this copper conduction path generates a magnetic field which the Hall IC converts into a proportional voltage. Device accuracy is optimized through the close proximity of the magnetic signal to the Hall transducer. A precise, proportional voltage is provided by the low-offset, chopper-stabilized BiCMOS Hall IC, which is programmed for accuracy after packaging. The output of the device has a positive slope (>VIOUT(Q)) when an increasing current flows through the primary copper conduction path (from pins 1 and 2, to pins 3 and 4), which is the path used for current sampling. The internal resistance of this conductive path is 1.2 mΩ typical, providing low power loss. The thickness of the copper conductor allows survival of the device at up to 5× overcurrent conditions. The terminals of the conductive path are electrically isolated from the signal leads (pins 5 through 8). This allows the ACS712 to be used in applications requiring electrical isolation without the use of opto-isolators or other costly isolation techniques.

PACKAGE: 8-Lead SOIC (suffix LC)



Typical Application



Application 1. The ACS712 outputs an analog signal, V_{OUT}, that varies linearly with the uni- or bi-directional AC or DC primary sampled current, I_P, within the range specified. C_F is recommended for noise management, with values that depend on the application.

SELECTION GUIDE

Part Number	Packing*	T_A (°C)	Optimized Range, I_P (A)	Sensitivity, Sens (Typ) (mV/A)
ACS712ELCTR-05B-T	Tape and reel, 3000 pieces/reel	–40 to 85	±5	185
ACS712ELCTR-20A-T	Tape and reel, 3000 pieces/reel	–40 to 85	±20	100
ACS712ELCTR-30A-T	Tape and reel, 3000 pieces/reel	–40 to 85	±30	66

*Contact Allegro for additional packing options.

ABSOLUTE MAXIMUM RATINGS

Characteristic	Symbol	Notes	Rating	Units
Supply Voltage	V_{CC}		8	V
Reverse Supply Voltage	V_{RCC}		–0.1	V
Output Voltage	V_{IOUT}		8	V
Reverse Output Voltage	V_{RIOUT}		–0.1	V
Output Current Source	$I_{IOUT(Source)}$		3	mA
Output Current Sink	$I_{IOUT(Sink)}$		10	mA
Overcurrent Transient Tolerance	I_P	1 pulse, 100 ms	100	A
Nominal Operating Ambient Temperature	T_A	Range E	–40 to 85	°C
Maximum Junction Temperature	$T_J(max)$		165	°C
Storage Temperature	T_{stg}		–65 to 170	°C

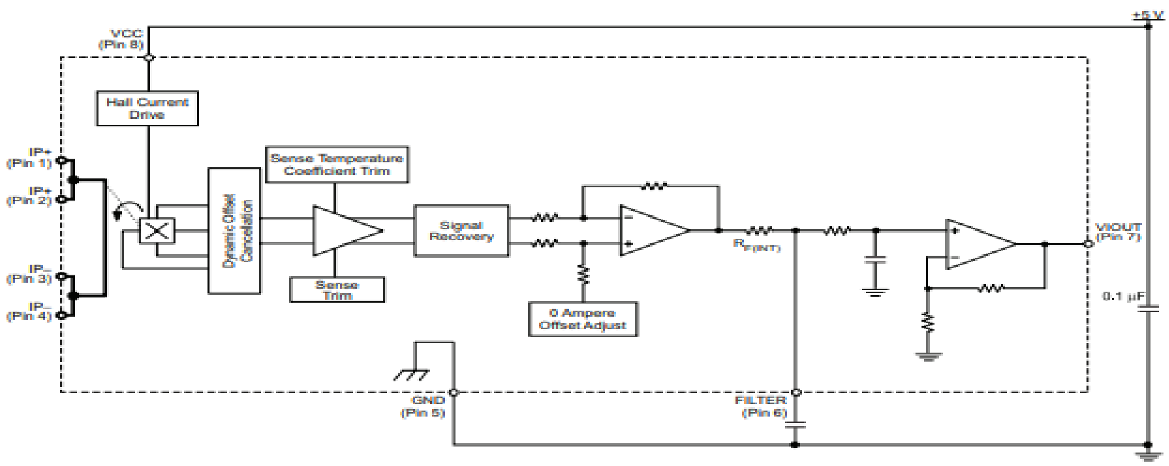
ISOLATION CHARACTERISTICS

Characteristic	Symbol	Notes	Rating	Unit
Dielectric Strength Test Voltage*	V_{ISO}	Agency type-tested for 60 seconds per UL standard 60950-1, 1st Edition	2100	VAC
Working Voltage for Basic Isolation	V_{WFSI}	For basic (single) isolation per UL standard 60950-1, 1st Edition	354	VDC or V_{pk}
Working Voltage for Reinforced Isolation	V_{WFRI}	For reinforced (double) isolation per UL standard 60950-1, 1st Edition	184	VDC or V_{pk}

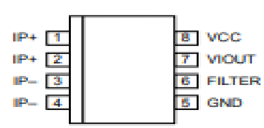
* Allegro does not conduct 60-second testing. It is done only during the UL certification process.

Parameter	Specification
Fire and Electric Shock	CAN/CSA-C22.2 No. 60950-1-03 UL 60950-1:2003 EN 60950-1:2001

FUNCTIONAL BLOCK DIAGRAM



Pinout Diagram



Terminal List

Number	Name	Description
1 and 2	IP+	Terminals for current being sampled; fused internally
3 and 4	IP–	Terminals for current being sampled; fused internally
5	GND	Signal ground terminal
6	FILTER	Terminal for external capacitor that sets bandwidth
7	VIOUT	Analog output signal
8	VCC	Device power supply terminal

COMMON OPERATING CHARACTERISTICS [1]: Over full range of T_A, C_F = 1 nF, and V_{CC} = 5 V, unless otherwise specified

Characteristic	Symbol	Test Conditions	Min.	Typ.	Max.	Units
ELECTRICAL CHARACTERISTICS						
Supply Voltage	V_{CC}		4.5	5.0	5.5	V
Supply Current	I_{CC}	V_{CC} = 5.0 V, output open	–	10	13	mA
Output Capacitance Load	C_{LOAD}	VIOUT to GND	–	–	10	nF
Output Resistive Load	R_{LOAD}	VIOUT to GND	4.7	–	–	kΩ
Primary Conductor Resistance	$R_{PRIMARY}$	T_A = 25°C	–	1.2	–	mΩ
Rise Time	t_r	$I_P = I_P$(max), T_A = 25°C, C_{OUT} = open	–	3.5	–	μs
Frequency Bandwidth	f	–3 dB, T_A = 25°C; I_P is 10 A peak-to-peak	–	80	–	kHz
Nonlinearity	E_{LIN}	Over full range of I_P	–	1.5	–	%
Symmetry	E_{SYM}	Over full range of I_P	98	100	102	%
Zero Current Output Voltage	$V_{IOUT(Q)}$	Bidirectional; I_P = 0 A, T_A = 25°C	–	V_{CC} × 0.5	–	V
Power-On Time	t_{PO}	Output reaches 90% of steady-state level, T_J = 25°C, 20 A present on leadframe	–	35	–	μs
Magnetic Coupling [2]			–	12	–	G/A
Internal Filter Resistance [3]	$R_{F(INT)}$			1.7		kΩ

[1] Device may be operated at higher primary current levels, I_P, and ambient, T_A, and internal leadframe temperatures, T_A, provided that the Maximum Junction Temperature, T_J(max), is not exceeded.
[2] 1G = 0.1 mT.
[3] $R_{F(INT)}$ forms an RC circuit via the FILTER pin.

COMMON THERMAL CHARACTERISTICS [1]

Characteristic	Symbol	Test Conditions	Min.	Typ.	Max.	Units
Operating Internal Leadframe Temperature	T_A	E range	–40	–	85	°C
Characteristic	**Symbol**	**Test Conditions**			**Value**	**Units**
Junction-to-Lead Thermal Resistance [2]	$R_{\theta JL}$	Mounted on the Allegro ASEK 712 evaluation board			5	°C/W
Junction-to-Ambient Thermal Resistance	$R_{\theta JA}$	Mounted on the Allegro 85-0322 evaluation board, includes the power consumed by the board			23	°C/W

x05B PERFORMANCE CHARACTERISTICS [1] : T_A = –40°C to 85°C, C_F = 1 nF, and V_{CC} = 5 V, unless otherwise specified

Characteristic	Symbol	Test Conditions	Min.	Typ.	Max.	Units
Optimized Accuracy Range	I_P		–5	–	5	A
Sensitivity	Sens	Over full range of I_P, T_A = 25°C	180	185	190	mV/A
Noise	$V_{NOISE(PP)}$	Peak-to-peak, T_A = 25°C, 185 mV/A programmed Sensitivity, C_F = 47 nF, C_{OUT} = open, 2 kHz bandwidth	–	21	–	mV
Zero Current Output Slope	$\Delta V_{OUT(Q)}$	T_A = –40°C to 25°C	–	–0.26	–	mV/°C
		T_A = 25°C to 150°C	–	–0.08	–	mV/°C
Sensitivity Slope	ΔSens	T_A = –40°C to 25°C	–	0.054	–	mV/A/°C
		T_A = 25°C to 150°C	–	–0.008	–	mV/A/°C
Total Output Error [2]	E_{TOT}	I_P = ±5 A, T_A = 25°C	–	±1.5	–	%

[1] Device may be operated at higher primary current levels, I_P, and ambient temperatures, T_A, provided that the Maximum Junction Temperature, $T_{J(max)}$, is not exceeded.
[2] Percentage of I_P, with I_P = 5 A. Output filtered.

x20A PERFORMANCE CHARACTERISTICS [1] T_A = –40°C to 85°C, C_F = 1 nF, and V_{CC} = 5 V, unless otherwise specified

Characteristic	Symbol	Test Conditions	Min.	Typ.	Max.	Units
Optimized Accuracy Range	I_P		–20	–	20	A
Sensitivity	Sens	Over full range of I_P, T_A = 25°C	96	100	104	mV/A
Noise	$V_{NOISE(PP)}$	Peak-to-peak, T_A = 25°C, 100 mV/A programmed Sensitivity, C_F = 47 nF, C_{OUT} = open, 2 kHz bandwidth	–	11	–	mV
Zero Current Output Slope	$\Delta V_{OUT(Q)}$	T_A = –40°C to 25°C	–	–0.34	–	mV/°C
		T_A = 25°C to 150°C	–	–0.07	–	mV/°C
Sensitivity Slope	ΔSens	T_A = –40°C to 25°C	–	0.017	–	mV/A/°C
		T_A = 25°C to 150°C	–	–0.004	–	mV/A/°C
Total Output Error [2]	E_{TOT}	I_P = ±20 A, T_A = 25°C	–	±1.5	–	%

[1] Device may be operated at higher primary current levels, I_P, and ambient temperatures, T_A, provided that the Maximum Junction Temperature, T_J(max), is not exceeded.
[2] Percentage of I_P, with I_P = 20 A. Output filtered.

x30A PERFORMANCE CHARACTERISTICS [1]: T_A = –40°C to 85°C, C_F = 1 nF, and V_{CC} = 5 V, unless otherwise specified

Characteristic	Symbol	Test Conditions	Min.	Typ.	Max.	Units
Optimized Accuracy Range	I_P		–30	–	30	A
Sensitivity	Sens	Over full range of I_P, T_A = 25°C	63	66	69	mV/A
Noise	$V_{NOISE(PP)}$	Peak-to-peak, T_A = 25°C, 66 mV/A programmed Sensitivity, C_F = 47 nF, C_{OUT} = open, 2 kHz bandwidth	–	7	–	mV
Zero Current Output Slope	$\Delta V_{OUT(Q)}$	T_A = –40°C to 25°C	–	–0.35	–	mV/°C
		T_A = 25°C to 150°C	–	–0.08	–	mV/°C
Sensitivity Slope	ΔSens	T_A = –40°C to 25°C	–	0.007	–	mV/A/°C
		T_A = 25°C to 150°C	–	–0.002	–	mV/A/°C
Total Output Error [2]	E_{TOT}	I_P = ±30 A, T_A = 25°C	–	±1.5	–	%

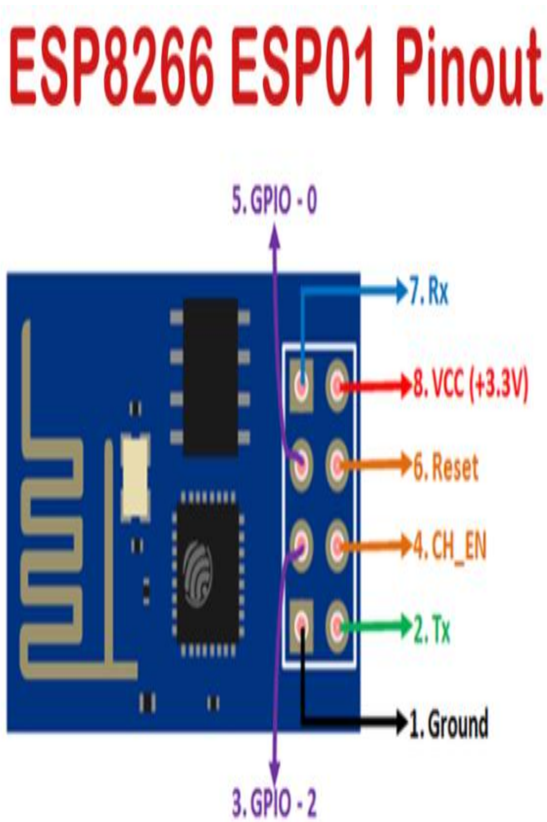
[1] Device may be operated at higher primary current levels, I_P, and ambient temperatures, T_A, provided that the Maximum Junction Temperature, T_J(max), is not exceeded.
[2] Percentage of I_P, with I_P = 30 A. Output filtered.

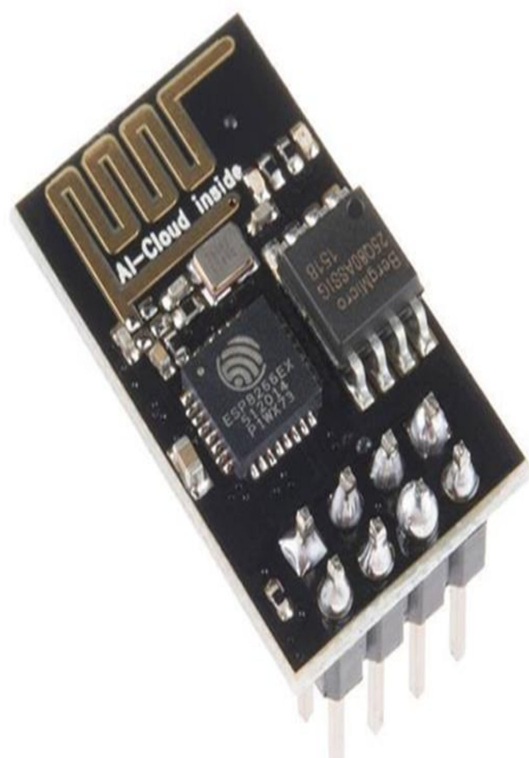
Espressif ESP8266 Serial ESP-01:

DESCRIPTION

Espressif ESP8266 Serial ESP-01 WiFi Module offers a user-friendly WiFi SoC (system on a chip) solution to meet the continuous demands for a power-friendly, compact and reliable solution to a vast range of issues in the IoT Industry. The Espressif ESP8266 Serial ESP-01 WiFi Module is integrated with TCP/IP protocol stack that can give any MCU access to your home, work, or industrial WiFi network.

The module can perform either as a standalone application or as a slave to a host MCU. Espressif ESP8266 Serial ESP-01 WiFi Module can be applied to any MCU design as a Wi-Fi adaptor through SPI/SDIO or UART interfaces. The ESP8266 WIFI module also features an upgraded version of Ten silica's L106 Diamond series 32-bit processor and SoC SRAM, allowing easy interfacing with external sensors and other devices through the GPIOs.





Pin Description

Pin Name	Pin No.	Description
Ground	1	Ground Pin
TX/GPIO-1	2	Acts as a general purpose I/O, can also be connected to the RX pin of the programmer to upload the source program
GPIO-2	3	General purpose Input/output pin
CH_EN	4	Chip Enable – Active high
GPIO – 0	5	General purpose Input/output pin 0
Reset	6	Resets the module
RX/GPIO-3	7	General purpose Input/output pin 3
Vcc	8	Chip Supply Voltage (3.3V Only)

Espressif ESP8266 Serial ESP-01 Specifications

- Power Supply: +3.3V only
- Current Consumption: 100mA
- I/O Voltage: 3.6V (max)
- I/O source current: 12mA (max)
- Built-in low power 32-bit MCU @ 80MHz
- 512kB Flash Memory
- 8Mbit external QSPI flash memory (1MByte)
- 32-bit Tensilica Xtensa LX106 CPU running 80MHz
- 3.3V supply (current can spike 300mA+, depending on mode)
- PCB-trace antenna
- 2 x 4 dual-in-line pinout
- Dimensions: 14.3 x 24.8mm
- weight: 1.5g

AC Voltage Sensor Module ZMPT101B:

DESCRIPTION

This AC Voltage Sensor Module ZMPT101B Single-phase AC active output voltage mutual inductance module equipped with ZMPT101B series of high-precision voltage transformer and high-precision op amp current, easy to 250v within the AC power signal acquisition.

Features

Measure within 250V AC

Rated input current: 2mA

Onboard micro-precision voltage transformer

Analog output corresponding quantity can be adjusted

Good consistency for voltage and power measurement

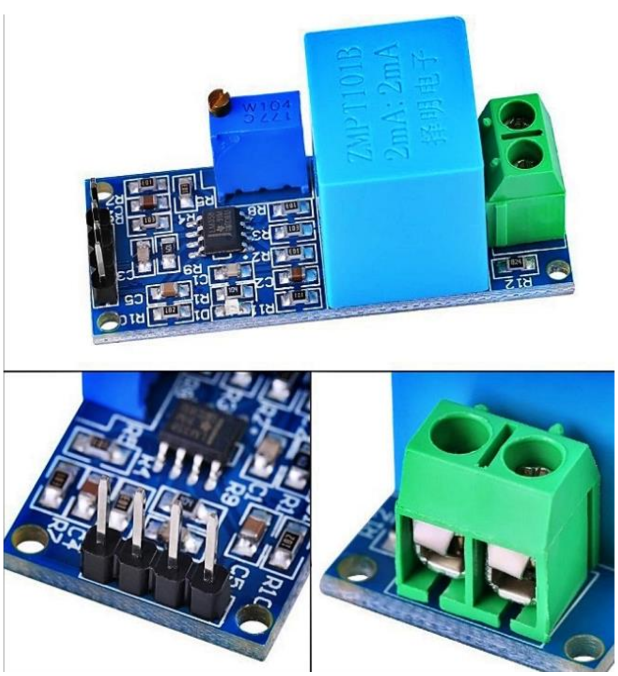
Active output single-phase AC voltage sensor module

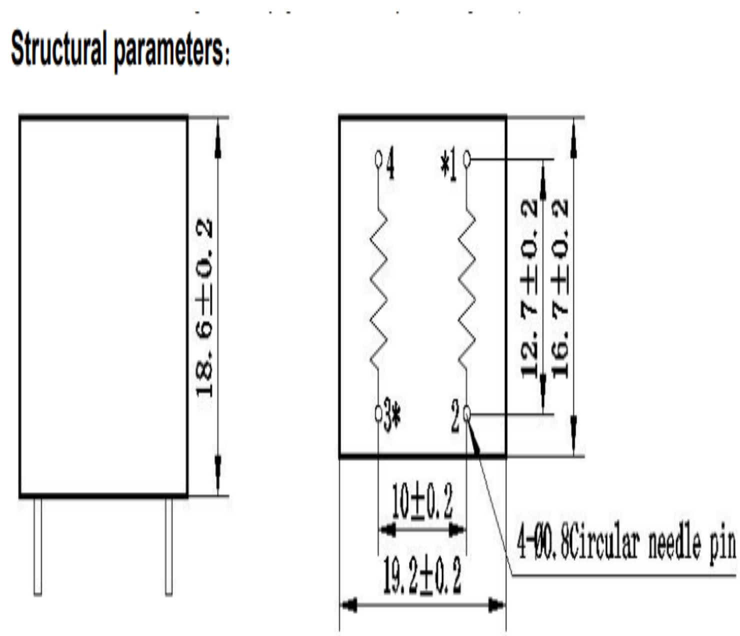
Specifications

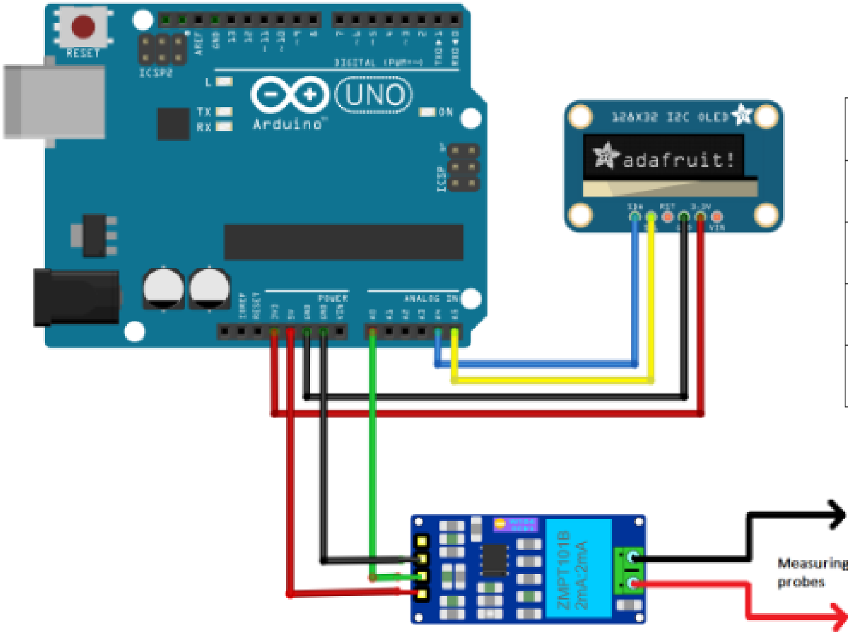
Output Signal: Analog 0 – 5V

Size: 49.5 mm x 19.4 mm

Operating temperature: 40’C ~ + 70′ C







Pin Name	Description
VCC	Module power supply: 5V.
OUT	Module output which is analog.
GND	Ground
GND	Ground

Model	ZMPT101B
Rated input current	2mA
Rated output current	2mA
turns ratio	1000:1000
phase angle error	≤20′ （input 2mA，sampling resistor 100Ω）
operating range	**0~1000V 0~10mA（sampling resistor 100Ω）**
linearity	≤0.2%(20%dot~120%dot)
Permissible error	-0.3%≤ f ≤+0.2%（input 2mA，sampling resistor 100Ω）
isolation voltage	4000V
application	voltage and power measurement
Encapsulation	Epoxy
installation	PCB mounting（Pin Length>3mm）
Operating temperature	-40℃~+60℃
Case Material	**ABS (Note: ABS CASE is NOT available for wave-soldering)**

ATmega328P Microcontroller

The Atmel® ATmega328P is a low-power CMOS 8-bit microcontroller based on the AVR® enhanced RISC architecture. By executing powerful instructions in a single clock cycle, the ATmega328P achieves throughputs approaching 1MIPS per MHz allowing the system designer to optimize power consumption versus processing speed.

Features

●High performance, low power AVR® 8-bit microcontroller

●Advanced RISC architecture

131powerful instructions – most single clock cycle execution

32*8 general purpose working registers

●Fully static operation

●Up to 16MIPS throughput at 16MHz

●On-chip 2-cycle multiplier

●High endurance non-volatile memory segments

- 32K bytes of in-system self-programmable flash program memory
- 1Kbytes EEPROM
- 2Kbytes internal SRAM

●Write/erase cycles: 10,000 flash/100,000 EEPROM

●Optional boot code section with independent lock bits

●In-system programming by on-chip boot program

●True read-while-write operation

●Programming lock for software security

●Peripheral features

●Two 8-bit Timer/Counters with separate prescaler and compare mode

●One 16-bit Timer/Counter with separate prescaler, compare mode, and capture mode

●Real time counter with separate oscillator

●Six PWM channels

- 8 -channel 10-bit ADC in TQFP and QFN/MLF package

●Temperature measurement

●Programmable serial USART

●Master/slave SPI serial interface

●Byte-oriented 2-wire serial interface (Phillips I2 C compatible)

●Programmable watchdog timer with separate on-chip oscillator

●On-chip analog comparator

●Interrupt and wake-up on pin change

●Special microcontroller features

●Power-on reset and programmable brown-out detection

●Internal calibrated oscillator

●External and internal interrupt sources

●Six sleep modes: Idle, ADC noise reduction, power-save, power-down, standby,and extended standby

I/O and packages

- 23programmable I/O lines
- 32-lead TQFP, and 32-pad QFN/MLF

Operating voltage

2.7V to 5.5V for ATmega328

Temperature range

●Automotive temperature range: –40°C to +125°C

Speed grade

0to 8MHz at 2.7 to 5.5V (automotive temperature range: –40°C to +125°C)

0to 16MHz at 4.5 to 5.5V (automotive temperature range: –40°C to +125°C)

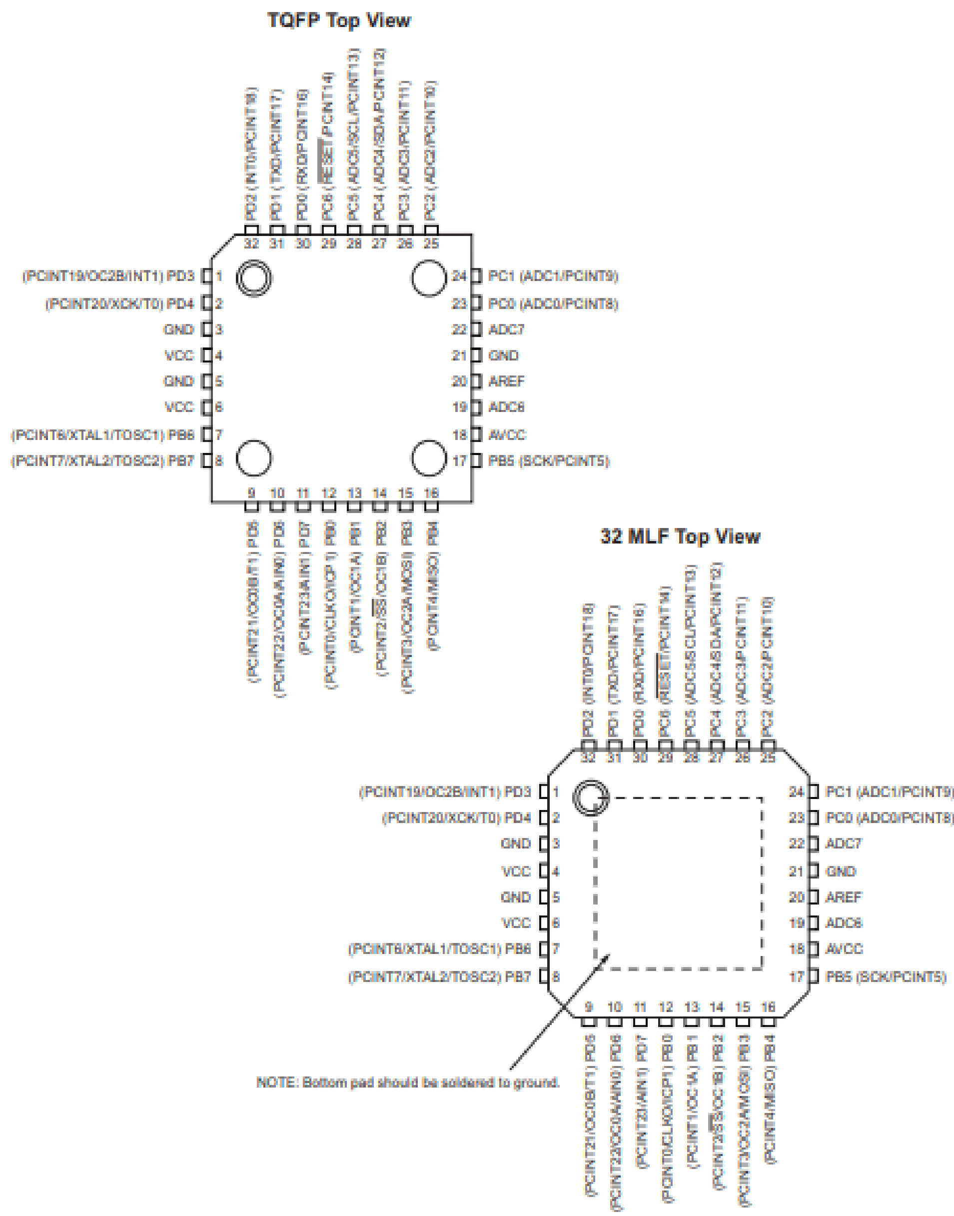
Low power consumption

●Active mode: 1.5mA at 3V - 4MHz

● Power-down mode: 1µA at 3V

Pin Configurations

Figure 1-1. Pinout



1.1 Pin Descriptions

1.1.1 VCC

Digital supply voltage.

1.1.2 GND

Ground.

1.1.3 Port B (PB7:0) XTAL1/XTAL2/TOSC1/TOSC2

Port B is an 8-bit bi-directional I/O port with internal pull-up resistors (selected for each bit). The Port B output buffers have symmetrical drive characteristics with both high sink and source capability. As inputs, port B pins that are externally pulled low will source current if the pull-up resistors are activated. The Port B pins are tri-stated when a reset condition becomes active, even if the clock is not running.

Depending on the clock selection fuse settings, PB6 can be used as input to the inverting oscillator amplifier and input to the internal clock operating circuit.

Depending on the clock selection fuse settings, PB7 can be used as output from the inverting oscillator amplifier.

If the internal calibrated RC oscillator is used as chip clock source, PB7..6 is used as TOSC2..1 input for the asynchronous Timer/Counter2 if the AS2 bit in ASSR is set.

The various special features of port B are elaborated in Section 13.3.1 "Alternate Functions of Port B" on page 65 and Section 8. "System Clock and Clock Options" on page 24.

1.1.4 Port C (PC5:0)

Port C is a 7-bit bi-directional I/O port with internal pull-up resistors (selected for each bit). The PC5..0 output buffers have symmetrical drive characteristics with both high sink and source capability. As inputs, Port C pins that are externally pulled low will source current if the pull-up resistors are activated. The port C pins are tri-stated when a reset condition becomes active, even if the clock is not running.

1.1.5 PC6/$\overline{\text{RESET}}$

If the RSTDISBL fuse is programmed, PC6 is used as an input pin. If the RSTDISBL fuse is unprogrammed, PC6 is used as a reset input. A low level on this pin for longer than the minimum pulse length will generate a reset, even if the clock is not running. The minimum pulse length is given in Table 28-4 on page 261. Shorter pulses are not guaranteed to generate a reset.

The various special features of port C are elaborated in Section 13.3.2 "Alternate Functions of Port C" on page 68.

1.1.6 Port D (PD7:0)

Port D is an 8-bit bi-directional I/O port with internal pull-up resistors (selected for each bit). The port D output buffers have symmetrical drive characteristics with both high sink and source capability. As inputs, port D pins that are externally pulled low will source current if the pull-up resistors are activated. The port D pins are tri-stated when a reset condition becomes active, even if the clock is not running.

The various special features of port D are elaborated in Section 13.3.3 "Alternate Functions of Port D" on page 70.

1.1.7 AV_{CC}

AV_{CC} is the supply voltage pin for the A/D converter, PC3:0, and ADC7:6. It should be externally connected to V_{CC}, even if the ADC is not used. If the ADC is used, it should be connected to V_{CC} through a low-pass filter. Note that PC6..4 use digital supply voltage, V_{CC}.

1.1.8 AREF

AREF is the analog reference pin for the A/D converter.

1.1.9 ADC7:6 (TQFP and QFN/MLF Package Only)

In the TQFP and QFN/MLF package, ADC7:6 serve as analog inputs to the A/D converter. These pins are powered from the analog supply and serve as 10-bit ADC channels.

1.2 Disclaimer

Typical values contained in this datasheet are based on simulations and characterization of actual ATmega328P AVR® microcontrollers manufactured on the typical process technology. automotive min and max values are based on characterization of actual ATmega328P AVR microcontrollers manufactured on the whole process excursion (corner run).

1.3 Automotive Quality Grade

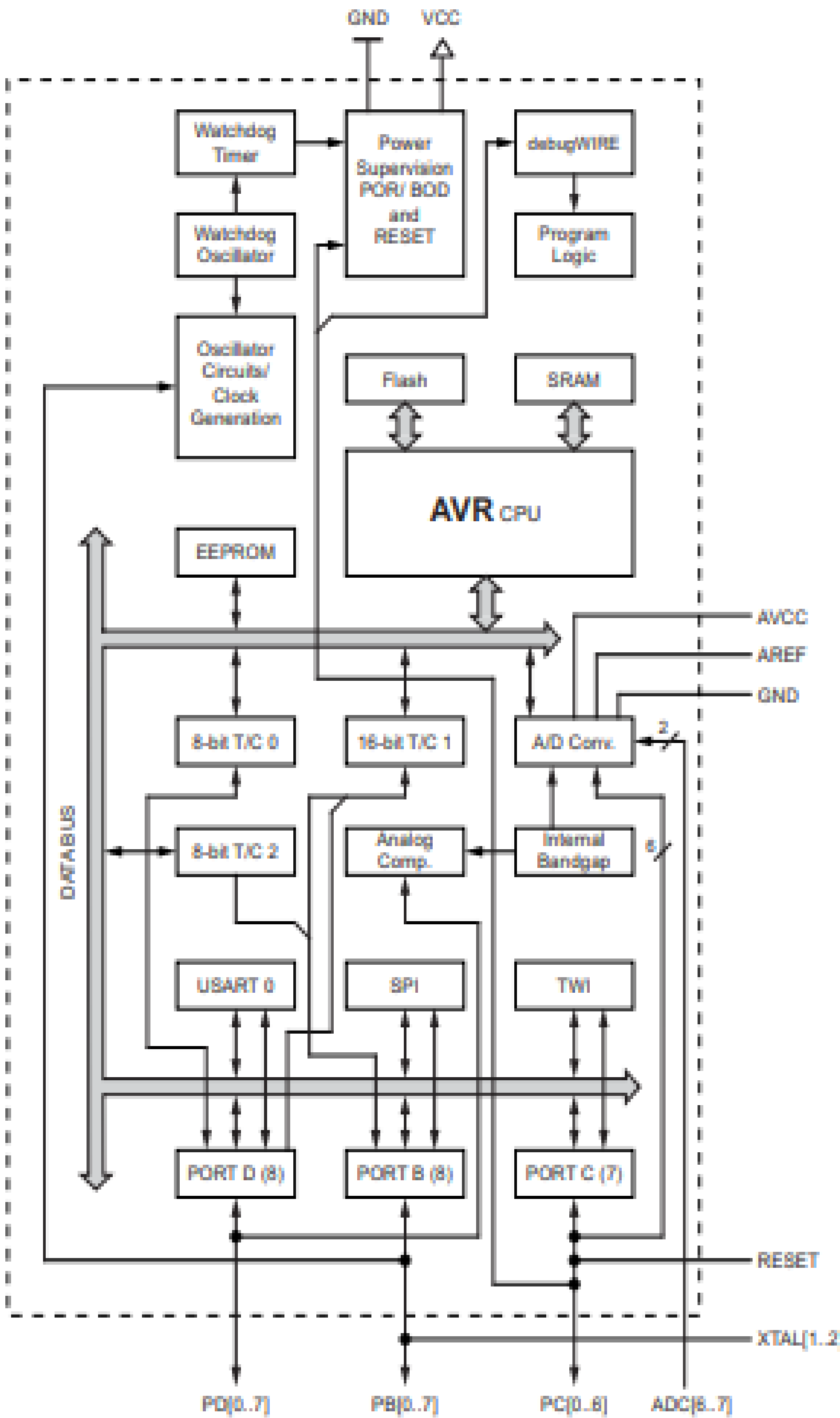
The ATmega328P have been developed and manufactured according to the most stringent requirements of the international standard ISO-TS-16949. This data sheet contains limit values extracted from the results of extensive characterization (temperature and voltage). The quality and reliability of the ATmega328P have been verified during regular product qualification as per AEC-Q100 grade 1. As indicated in the ordering information paragraph, the products are available in only one temperature.

Table 1-1. Temperature Grade Identification for Automotive Products

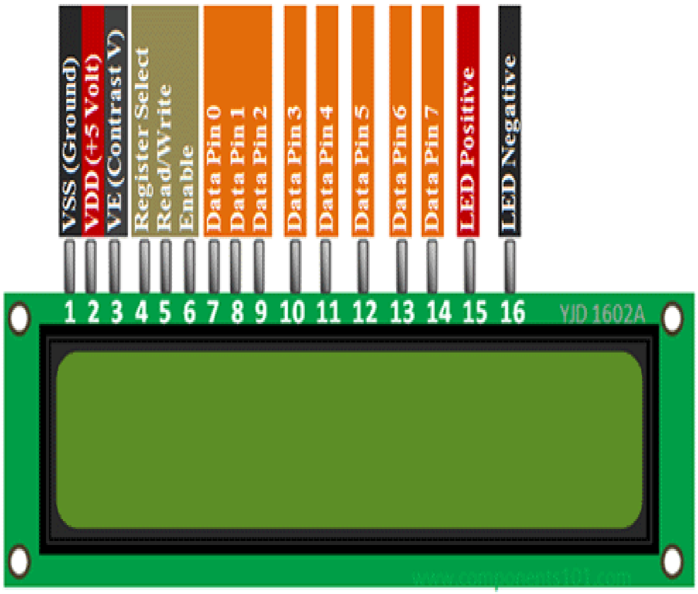
Temperature	Temperature Identifier	Comments
–40°C; +125°C	Z	Full automotive temperature range

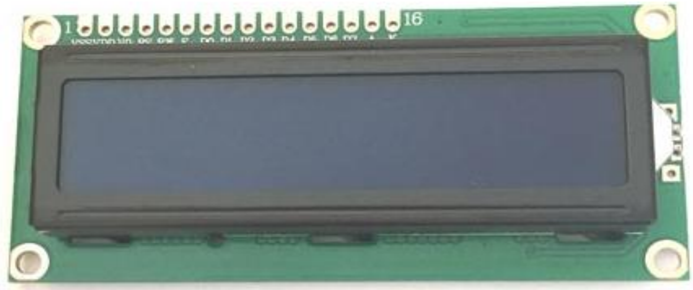
Block Diagram

Figure 2-1. Block Diagram



16x2 LCD Display Module





Description

16x2 LCD modules are very commonly used in most embedded projects, the reason being its cheap price, availability, programmer friendly and available educational resources.

LCD Features and Technical Specifications

- Operating Voltage is 4.7V to 5.3V
- Current consumption is 1mA without backlight
- Alphanumeric LCD display module, meaning can display alphabets and numbers
- Consists of two rows and each row can print 16 characters.
- Each character is build by a 5×8 pixel box
- Can work on both 8-bit and 4-bit mode
- It can also display any custom generated characters

- Available in Green and Blue Backlight

16×2 LCD is named so because; it has 16 Columns and 2 Rows. There are a lot of combinations available like, 8×1, 8×2, 10×2, 16×1, etc. but the most used one is the 16×2 LCD. So, it will have (16×2=32) 32 characters in total and each character will be made of 5×8 Pixel Dots. A Single character with all its Pixels is shown in the below picture.

16x2 LCD Pinout Configuration

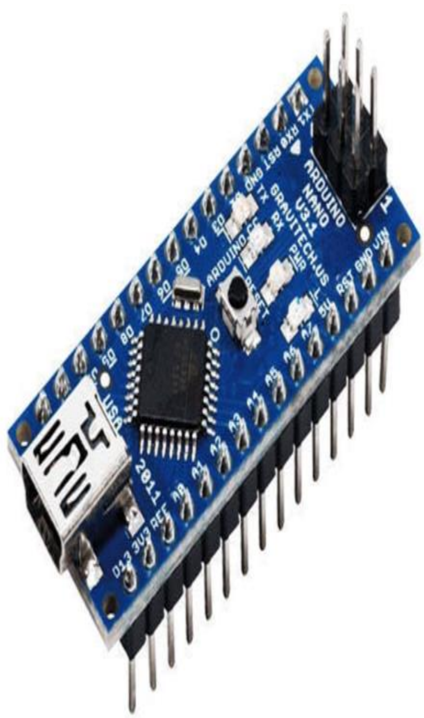
Pin No:	Pin Name:	Description
1	Vss (Ground)	Ground pin connected to system ground
2	Vdd (+5 Volt)	Powers the LCD with +5V (4.7V – 5.3V)
3	VE (Contrast V)	Decides the contrast level of display. Grounded to get maximum contrast.
4	Register Select	Connected to Microcontroller to shift between command/data register
5	Read/Write	Used to read or write data. Normally grounded to write data to LCD
6	Enable	Connected to Microcontroller Pin and toggled between 1 and 0 for data acknowledgement
7	Data Pin 0	Data pins 0 to 7 forms a 8-bit data line. They can be connected to Microcontroller to send 8-bit data. These LCD's can also operate on 4-bit mode in such case Data pin 4,5,6 and 7 will be left free.
8	Data Pin 1	
9	Data Pin 2	
10	Data Pin 3	
11	Data Pin 4	

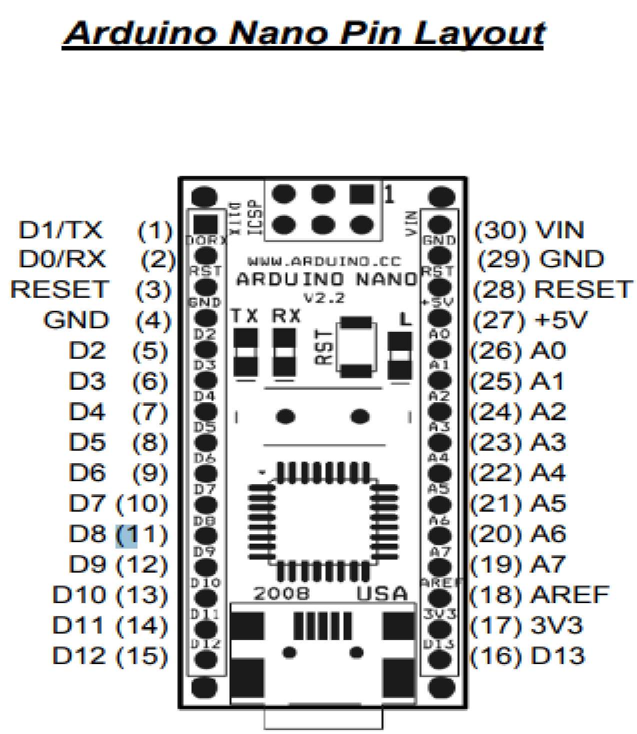
12	Data Pin 5	
13	Data Pin 6	
14	Data Pin 7	
15	LED Positive	Backlight LED pin positive terminal
16	LED Negative	Backlight LED pin negative terminal

Arduino NANO

Description

The Arduino Nano is another popular Arduino development board very much similar to the Arduino UNO. They use the same Processor (Atmega328p) and hence they both can share the same program.





Arduino Nano Pinout Configuration

Pin Category	Pin Name	Details
Power	**Vin, 3.3V, 5V, GND**	**Vin:** Input voltage to Arduino when using an external power source (6-12V). **5V:** Regulated power supply used to power microcontroller and other components on the board. **3.3V:** 3.3V supply generated by on-board voltage regulator. Maximum current draw is 50mA. **GND:** Ground pins.
Reset	**Reset**	Resets the microcontroller.
Analog Pins	**A0 – A7**	Used to measure analog voltage in the range of 0-5V
Input/Output Pins	**Digital Pins D0 - D13**	Can be used as input or output pins. 0V (low) and 5V (high)
Serial	Rx, **Tx**	Used to receive and transmit TTL serial data.
External Interrupts	2, 3	To trigger an interrupt.
PWM	3, 5, 6, 9, 11	Provides 8-bit PWM output.

SPI	10 (SS), 11 (MOSI), 12 (MISO) and 13 (SCK)	Used for SPI communication.
Inbuilt LED	**13**	To turn on the inbuilt LED.
IIC	A4 (SDA), A5 (SCA)	Used for TWI communication.
AREF	**AREF**	To provide a reference voltage for input voltage.

Arduino Nano Technical Specifications

Microcontroller	ATmega328P – 8-bit AVR family microcontroller
Operating Voltage	5V
Recommended Input Voltage for Vin pin	7-12V
Analog Input Pins	6 (A0 – A5)
Digital I/O Pins	14 (Out of which 6 provide PWM output)
DC Current on I/O Pins	40 mA
DC Current on 3.3V Pin	50 mA
Flash Memory	32 KB (2 KB is used for Bootloader)

SRAM	2 KB
EEPROM	1 KB
Frequency (Clock Speed)	16 MHz
Communication	IIC, SPI, USART

Sun Tracking Solar Panel

Description

As the non renewable energy resources are decreasing, use of renewable resources for producing electricity is increasing. Solar panels are becoming more popular day by day.Solar panel absorbs the energy from the Sun, converts it into electrical energy and stores the energy in a battery.

This energy can be utilized when required or can be used as a direct alternative to the grid supply. Utilization of the energy stored in batteries.

The position of the Sun with respect to the solar panel is not fixed due to the rotation of the Earth. For an efficient usage of the solar energy, the Solar panels should absorb energy to a maximum extent.

This can be done only if the panels are continuously placed towards the direction of the Sun. So, solar panel should continuously rotate in the direction of Sun.

Principle of Sun Tracking Solar Panel

The Sun tracking solar panel consists of 4 LDRs, solar panel and a servo motor and ATmega328 Micro controller.

Light dependent resistors produce low resistance when light falls on them. The servo motor connected to the panel rotates the panel in the direction of Sun. Panel is arranged in such a way that light on 4 LDRs is compared and panel is rotated towards LDR which have high intensity i.e. low resistance compared to other. Servo motor rotates the panel at certain angle.

When the intensity of the light falling on right LDR is more, panel slowly moves towards right and if intensity on the left LDR is more, panel slowly moves towards left.

When the intensity of the light falling on Up LDR is more, panel slowly moves towards Up and if intensity on the Down LDR is more, panel slowly moves towards Down.

In the noon time, Sun is ahead and intensity of light on both the panels is same. In such cases, panel is constant and there is no rotation.

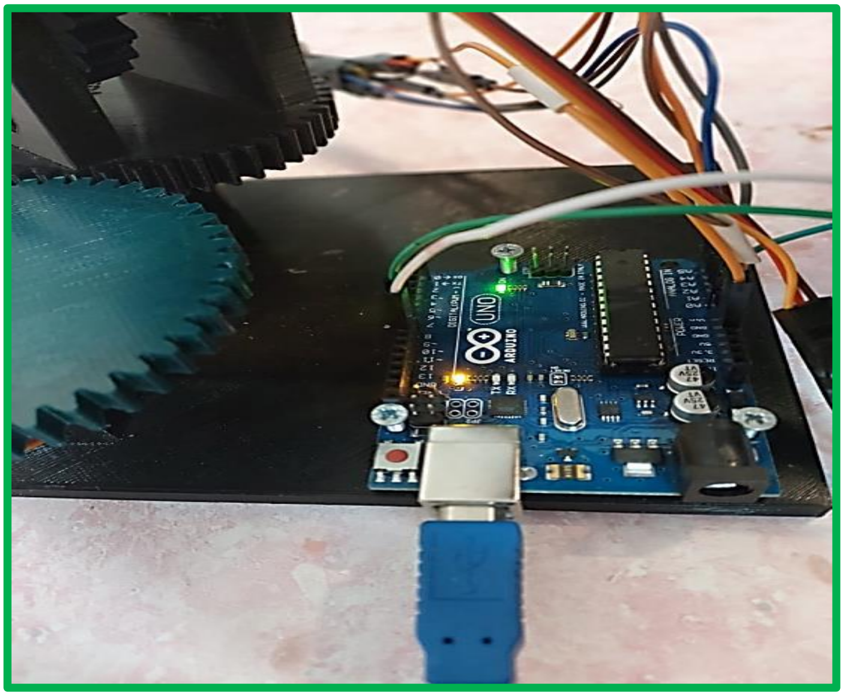


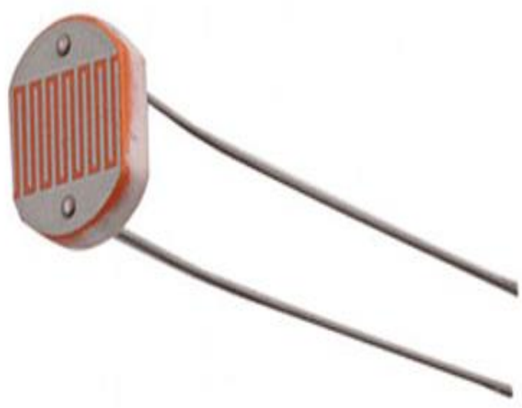
Fig.13. Sun Tracker Solar Panel Circuit

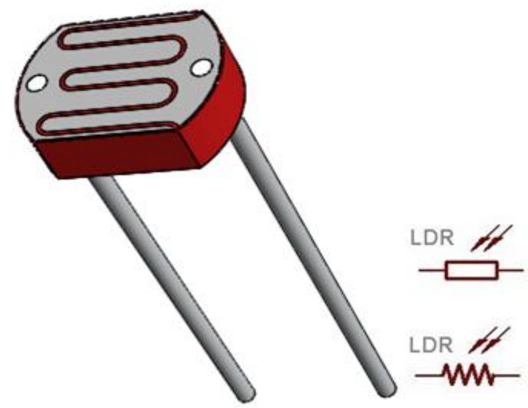
Components in the Circuit

- Solar panel
- ATmega328 Micro Controller
- Light Dependent Resistor (LDR) x 4
- 10KΩ
- Servo Motor SG-90
- Capacitors
- Resistors
- Push Button
- Breadboard
- Cardboard
- Connecting Wires

Data sheet for electrical components

Light Dependent Resistor (LDR)





The **Light Dependent Resistor** (**LDR**) or also popularly known as Photoresistor is just another special type of Resistor and hence has no polarity so they can be connected in any direction. They are breadboard friendly and can be easily used on a perf board also. The symbol for LDR is similar to Resistor but includes inward arrows as shown above in the LDR pinout diagram. The arrows indicate the light signals.

LDR Features

- Can be used to sense Light
- Easy to use on Breadboard or Perf Board
- Easy to use with Microcontrollers or even with normal Digital/Analog IC
- Small, cheap and easily available

- Available in PG5 ,PG5-MP, PG12, PG12-MP, PG20 and PG20-MP series

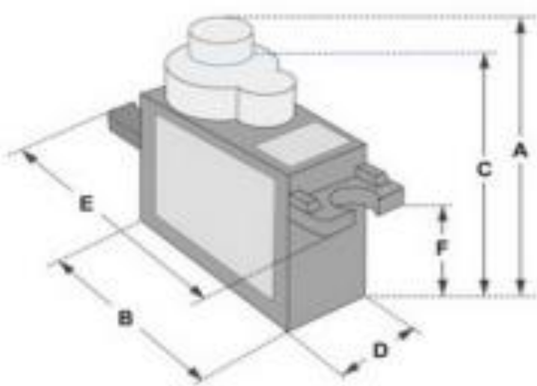
Electrical Characteristics

Parameter	Conditions	Min	Typ	Max	Unit
Cell resistance	1000 LUX 10 LUX	- -	400 9	- -	Ohm K Ohm
Dark Resistance	-	-	1	-	M Ohm
Dark Capacitance	-	-	3.5	-	pF
Rise Time	1000 LUX 10 LUX	- -	2.8 18	- -	ms ms
Fall Time	1000 LUX 10 LUX	- -	48 120	- -	ms ms
Voltage AC/DC Peak		-	-	320	V max
Current		-	-	75	mA max
Power Dissipation				100	mW max
Operating Temperature		-60	-	+75	Deg. C

Servo Motor SG90

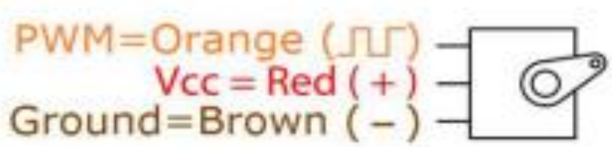
SERVO MOTOR SG90 DATA SHEET

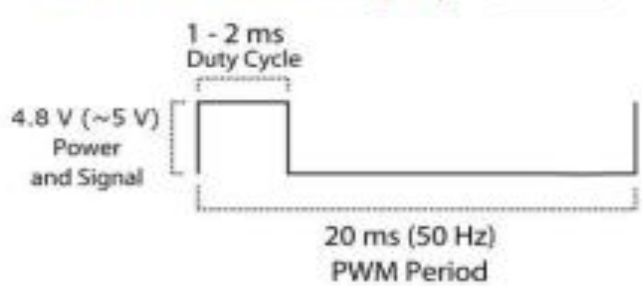
Tiny and lightweight with high output power. Servo can rotate approximately 180 degrees (90 in each direction), and works just like the standard kinds but smaller. You can use any servo code, hardware or library to control these servos. Good for beginners who want to make stuff move without building a motor controller with feedback & gear box, especially since it will fit in small places. It comes with a 3 horns (arms) and hardware.



Dimensions & Specifications
A (mm) : 32
B (mm) : 23
C (mm) : 28.5
D (mm) : 12
E (mm) : 32
F (mm) : 19.5
Speed (sec) : 0.1
Torque (kg-cm) : 2.5
Weight (g) : 14.7
Voltage : 4.8 - 6

Position "0" (1.5 ms pulse) is middle, "90" (~2ms pulse) is middle, is all the way to the right, "-90" (~1ms pulse) is all the way to the left.

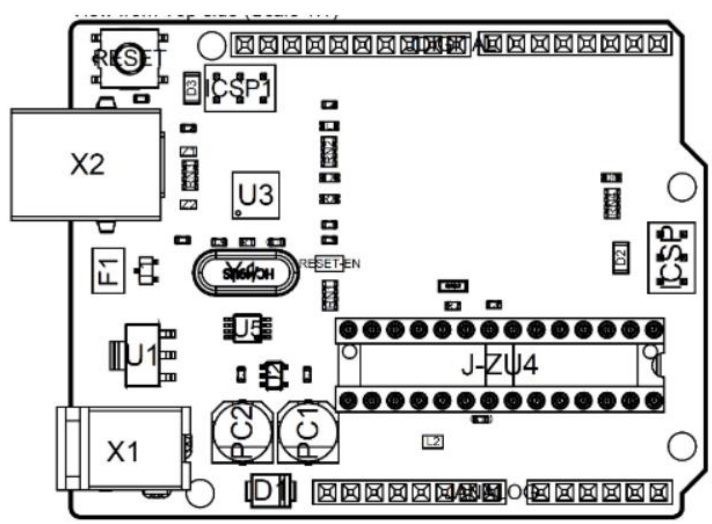




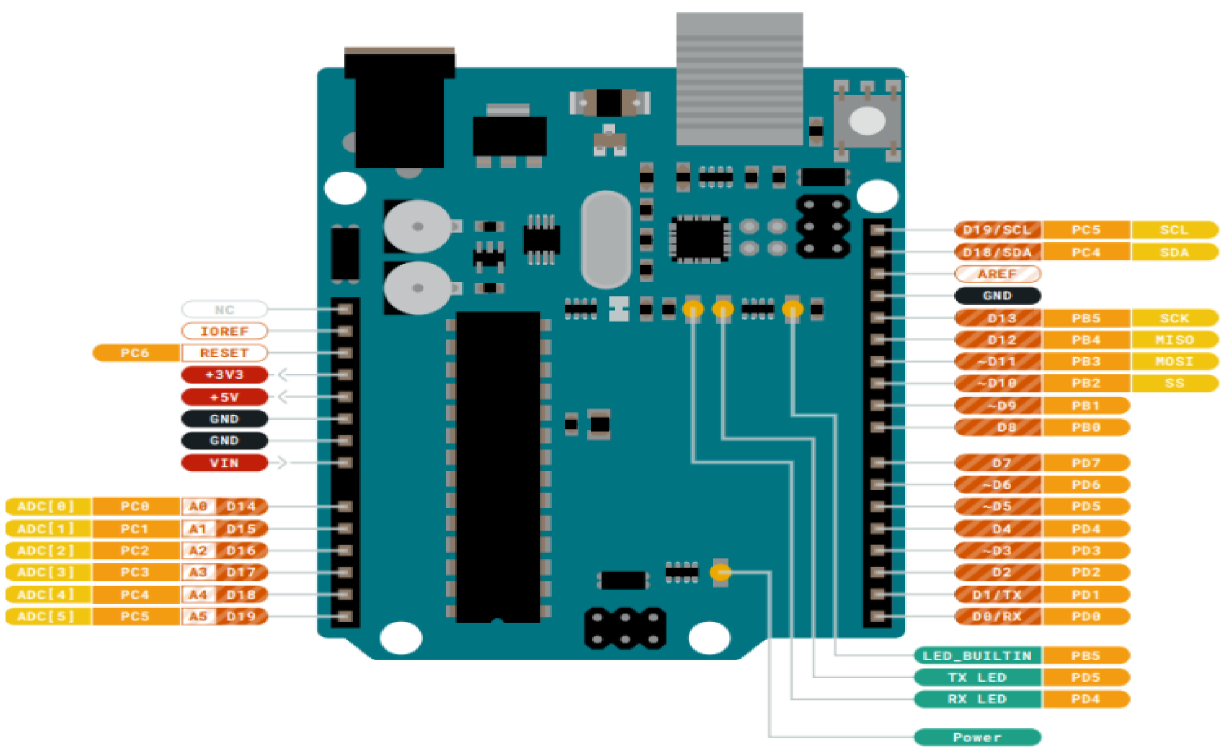
Arduino UNO

Description

The Arduino UNO R3 is the perfect board to get familiar with electronics and coding. This versatile microcontroller is equipped with the well-known ATmega328P and the ATMega 16U2 Processor. This board will give you a great first experience within the world of Arduino



Connector Pinouts



5.1 JANALOG

Pin	Function	Type	Description
1	NC	NC	Not connected
2	IOREF	IOREF	Reference for digital logic V - connected to 5V
3	Reset	Reset	Reset
4	+3V3	Power	+3V3 Power Rail
5	+5V	Power	+5V Power Rail
6	GND	Power	Ground
7	GND	Power	Ground
8	VIN	Power	Voltage Input
9	A0	Analog/GPIO	Analog input 0 /GPIO
10	A1	Analog/GPIO	Analog input 1 /GPIO
11	A2	Analog/GPIO	Analog input 2 /GPIO
12	A3	Analog/GPIO	Analog input 3 /GPIO
13	A4/SDA	Analog input/I2C	Analog input 4/I2C Data line
14	A5/SCL	Analog input/I2C	Analog input 5/I2C Clock line

5.2 JDIGITAL

Pin	Function	Type	Description
1	D0	Digital/GPIO	Digital pin 0/GPIO
2	D1	Digital/GPIO	Digital pin 1/GPIO
3	D2	Digital/GPIO	Digital pin 2/GPIO
4	D3	Digital/GPIO	Digital pin 3/GPIO
5	D4	Digital/GPIO	Digital pin 4/GPIO
6	D5	Digital/GPIO	Digital pin 5/GPIO
7	D6	Digital/GPIO	Digital pin 6/GPIO
8	D7	Digital/GPIO	Digital pin 7/GPIO
9	D8	Digital/GPIO	Digital pin 8/GPIO
10	D9	Digital/GPIO	Digital pin 9/GPIO
11	SS	Digital	SPI Chip Select
12	MOSI	Digital	SPI1 Main Out Secondary In
13	MISO	Digital	SPI Main In Secondary Out
14	SCK	Digital	SPI serial clock output
15	GND	Power	Ground
16	AREF	Digital	Analog reference voltage
17	A4/SD4	Digital	Analog input 4/I2C Data line (duplicated)
18	A5/SD5	Digital	Analog input 5/I2C Clock line (duplicated)

4.2. Methodology and Hardware Requirements

Table 3. Hardware Requirements

Index	Component	Price in L.E.
1	Arduino NANO	175
2	Current sensor module (ACS712)	84
3	Energy meter	358
4	Wi-FI Module ESP-01	70
5	LCD display	50
6	Crystal oscillator	2
7	Led	32
8	Capacitors	1-5
9	Transistors	1
10	Cables and connectors	92
11	Diodes	0.5-20
12	PCB and breadboards	32
13	PCB and breadboards	50
14	Adapter	35
15	Transformer	65
16	Push buttons	25
17	IC	18
18	IC sockets	30
19	Arduino UNO	345
20	Ac Voltage Sensor	100
21	Servo motor	78
22	DC motor	208
23	L293D motor driver	52
24	DHT11	94
25	Solar panel	500
26	LDR sensor X2	46
27	Rotary potentiometer	3.50
28	Arduino Uno cable long	15
29	Jumper wires and Pot 10Kohm	30
30	Atmega 32 microcontroller	290

CHAPTER 5

Results and Discussion

Chapter 5: Results and Discussion

5.1. Simulation Parameters

In this simulation, PV solar panel model using solar cell model available in Simscape library in MATLAB. 36 solar cell are connected in series. Each solar cell having short circuit current of 8.9A and open circuit voltage of 0.632V. **Figures (15, 16 and 17) show output results from solar panel as Oscilloscope graph.**

Table 4. Standard test condition

Parameter	Symbol	Value	Unit
Irradiance at normal incidence	G	1000	Wm2
Cell temperature	T	25	0C
Solar spectrum	AM	1.5	-

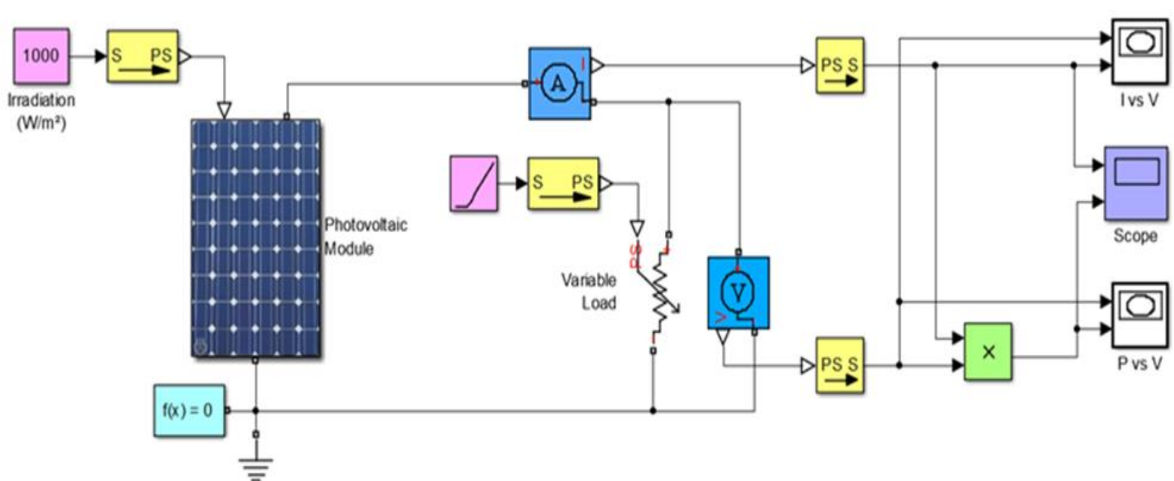


Fig.14. System Workflow.

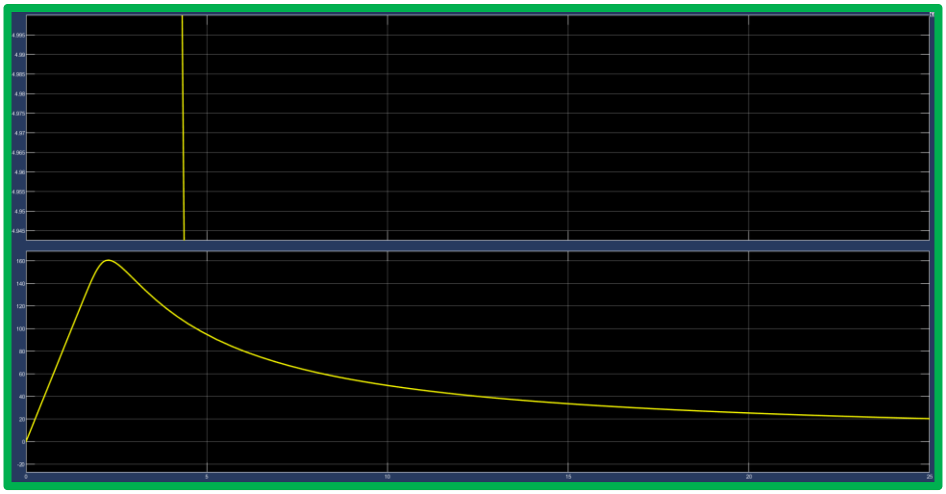


Fig.15. Scope Result.

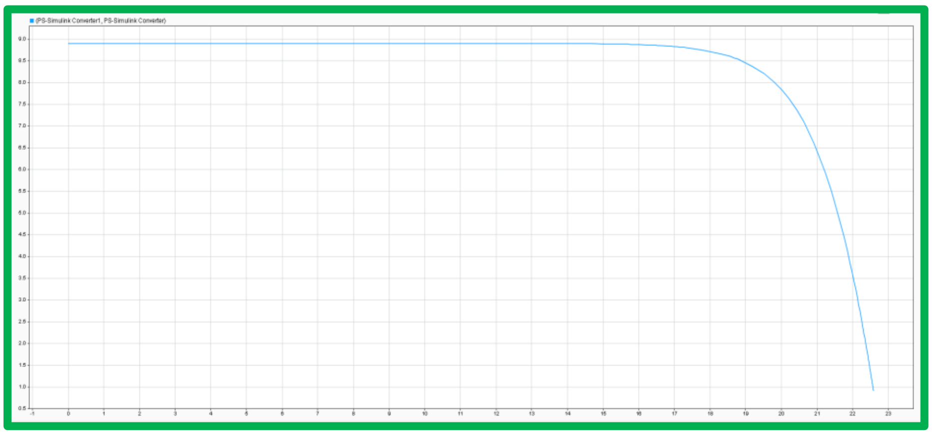


Fig.16. I (current) vs V (voltage) Result.

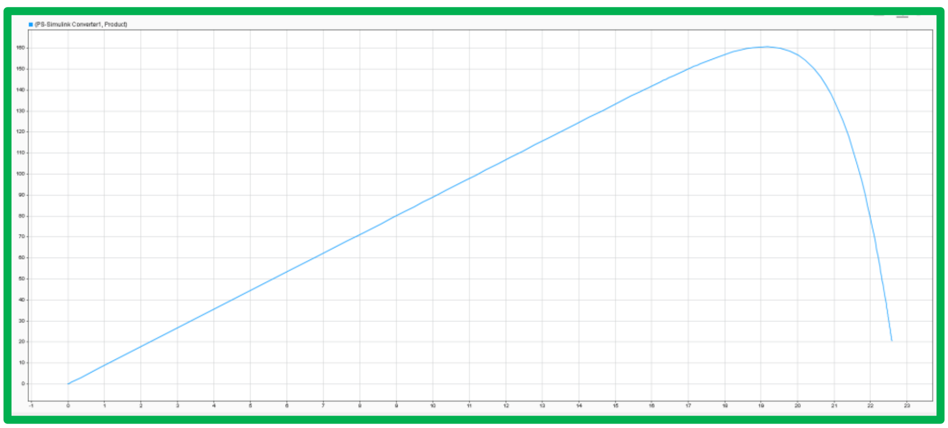


Fig.17. P (power) vs V (voltage) Result.

5.2. Simulation Results and Discussions

The PV Array block is a five-parameter model using a light-generated current source (I_L), diode, series resistance (Rs), and shunt resistance (Rsh) to represent the irradiance- and temperature-dependent I-V characteristics of the modules. **As shown in Figure 18 (a)**

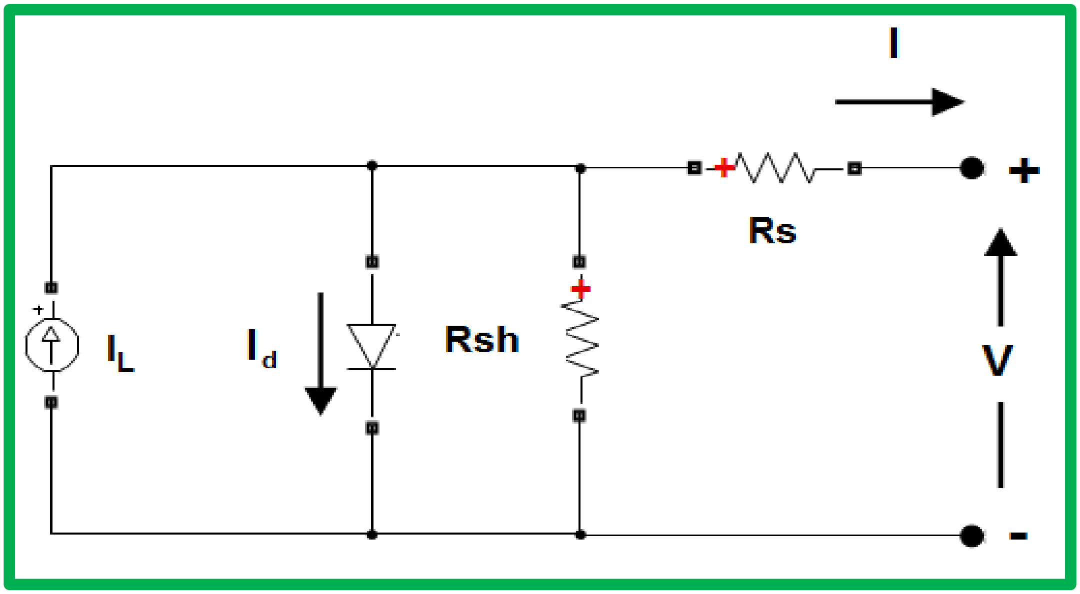


Figure 18 (a) Solar Panel circuit

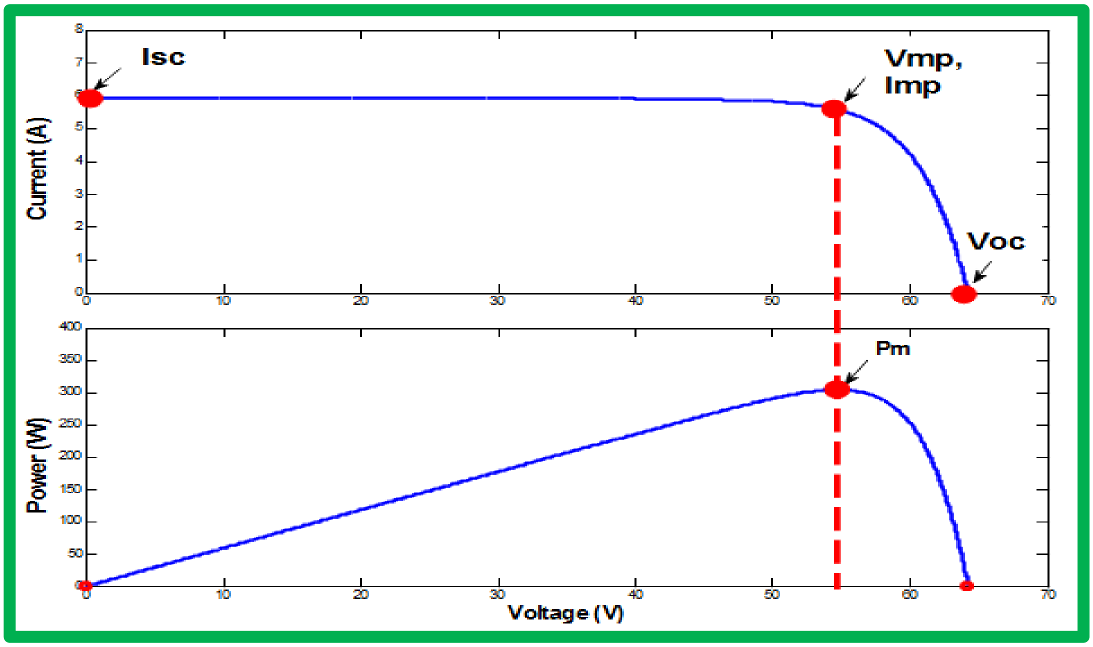


Figure 18 (b) IV and PV Characteristics

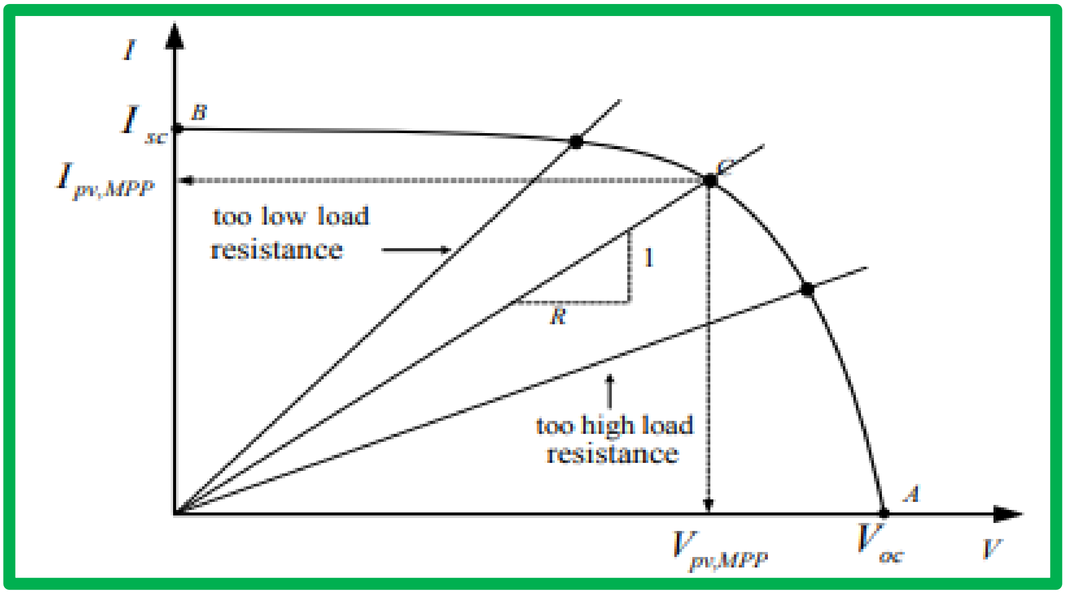


Figure 18 (c) IV Characteristicshows the I-V operating characteristics of a solar cell. A PV array comprises individual PV cells connected into a unit of suitable power rating. Its characteristics are determinable by multiplying the voltage of an individual cell by the number of cells connected in series and multiplying the current by the number of cells connected in parallel. Three important operating points are open-circuit voltage, short-circuit current and Maximum Power Point (MPP). **As shown in Figure 18 (b)**

The operating point of a PV array under constant irradiance and cell temperature is the intersection point of the characteristics and the load characteristics; A straight line with gradient M=1/R= ILoad/VLoad represents the load characteristic. The system operating point moves along the Pv Panel I-V characteristic curve, from B to A, as load resistance increases from zero to infinity. The MPP is at C, where the area (equivalent to output power) under the I-V characteristic curve is maxima. For too-high load resistances, the operating points go into the CA region. For too-low load resistances, the operating points go into the CB region. MPP can, thus, be obtained by matching load resistance to PV array characteristics. **As shown in Figure 18 (c)**

Solar Panel Tracker

As the non renewable energy resources are decreasing, use renewable resources for producing electricity is increasing. Solar panels are becoming more popular day by day.Solar panel absorbs the energy from the Sun, converts it into electrical energy and stores the energy in a battery.

This energy can be utilized when required or can be used as a direct alternative to the grid supply. Utilization of the energy stored in batteries.

The Sun tracking solar panel consists of 4 LDRs, solar panel and a servo motor and ATmega328 Micro controller.

Light dependent resistors produce low resistance when light falls on them. The servo motor connected to the panel rotates the panel in the direction of Sun. Panel is arranged in such a way that light on 4 LDRs is compared and panel is rotated towards LDR which have high intensity i.e. low resistance compared to other. Servo motor rotates the panel at certain angle.

When the intensity of the light falling on right LDR is more, panel slowly moves towards right and if intensity on the left LDR is more, panel slowly moves towards left.

When the intensity of the light falling on Up LDR is more, panel slowly moves towards Up and if intensity on the Down LDR is more, panel slowly moves towards Down.

In the noon time, Sun is ahead and intensity of light on both the panels is same. In such cases, panel is constant and there is no rotation.

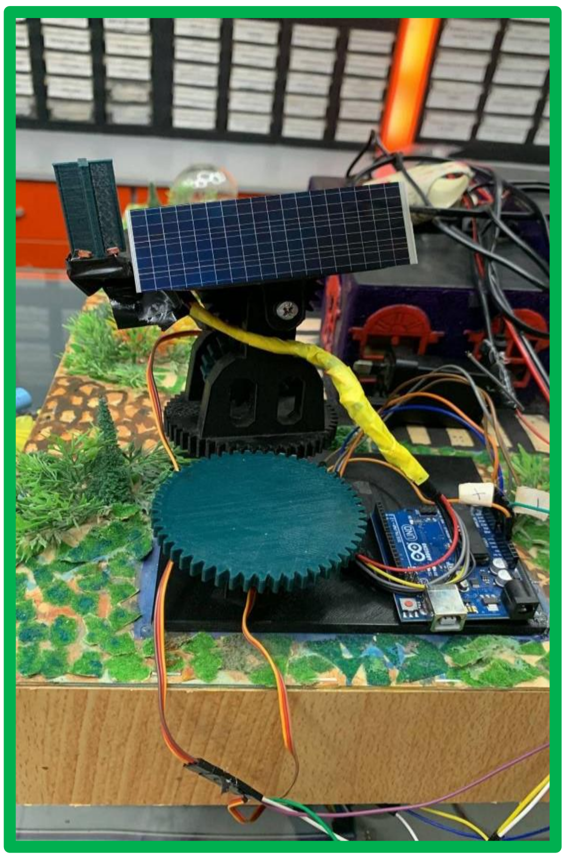


Figure (a) Solar Panel Tracker

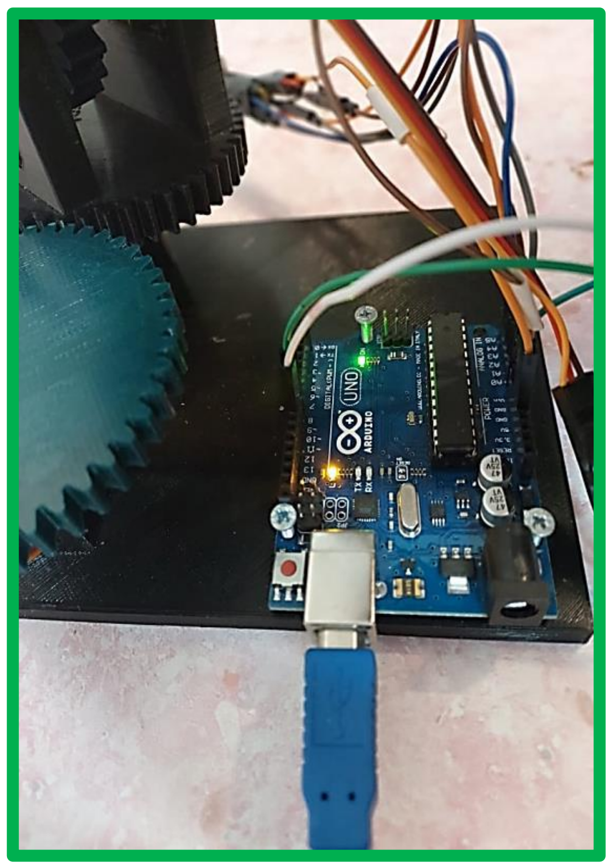


Figure (b) Solar Panel Circuit

Fig.19(a and b). presents the implemented PV controller circuit of the proposed system.

SMART INVERTERS: Inverters and other power electronics can provide control to system operators, as well as to automatically provide some level of grid support. Demand response. • Smart meters, coupled with intelligent appliances and even industrial scale loads, can allow demand-side contributionsto balancing.

INTEGRATED STORAGE: Storage can help to smooth short-term variations in RE output, as well as to manage mismatches in supply and demand. REAL-TIME.

IOT Smart Energy Grid Circuit

IOT: The IOT allows objects to be sensed or controlled remotely across existing network infrastructure, creating opportunities for more direct integration of the physical world into computer-based systems, and resulting in improved efficiency, accuracy and economic benefit in addition to reduced human intervention. When IOT is augmented with sensors and actuators, the technology becomes an instance of the more general class of cyber-physical systems, which also encompasses technologies such as smart grids, virtual power plants, and smart homes.

The smart grid is part of IOT framework which can be used to remotely monitor and manage everything from lighting, traffic signs, traffic congestion, parking spaces , road warnings and early detection of things like power influxes. The role of IOT in smart grid is very crucial. Internet of things is in large part the enabler of smart grid as it technological and infrastructural components are mostly IOT based. The data on energy consumption comes from sensor enabled IOT devices, appliances and hubs which control a smart house or any connected space. This data is then use to analyze electricity usage , calculate cost , remotely control appliances , make decission on load distribution , recognize devices, detect malfunctions and risk of outages etc.

Energy generation companies supply electricity to all the households via intermediate controlled power transmission hubs known as Electricity Grid. Sometimes problems arise due to failure of the electricity grid leading to black out of an entire area which was getting supply from that particular grid. This project aims to solve this problem using IOT as the means of communication and also tackling various other issues which a smart system can deal with to avoid unnecessary losses to the Energy producers.

IOT Smart Energy Grid is based on Arduino UNO and NANO family controller which controls the various activities of the system. The system communicates over internet by using Wi-Fi technology. A bulb is used in this project to demonstrate as a valid consumer and a bulb to demonstrate an invalid consumer. The foremost thing that this project facilitates is re-connection of transmission line to active grid. If an Energy Grid becomes faulty and there is an another Energy Grid, the system switches the Transmission Lines towards this Grid thus facilitating uninterrupted electricity supply to that particular region whose Energy Grid went OFF. And this information of which Grid is active is updated over IOT webpage where the authorities can login and can view the updates. Apart from monitoring the Grid this project has advances capabilities of monitoring energy consumption and even detect theft of electricity. The amount of electricity consumed and the estimated cost of the usage gets updated on the IOT webpage along with the Energy Grid information. Theft conditions are simulated in the system using two switches. Switching one each time will simulate a theft condition and also will notify the authorities over the IOT interface. In this way the Smart Energy Grid project makes sure that the electricity supply is continuous and helps in maintaining a updated record of consumption and theft information which is quite a valuable information for the energy producing companies.

ARDUINO UNO: Arduino is an open source computer hardware and software company, project, and user community that designs and manufactures single-board microcontrollers and microcontroller kits for building digital devices and interactive objects that can sense and control objects in the physical and digital world.

WIFI MODULE : Wi-Fi is a technology for wireless local area networking i-Fi he ure And Islanding Topology Radial Network TRADITIONAL GRID SMART GRID with devices based on the IEEE 802.11 standards. W is a trademark of the Wi-Fi Alliance, which restrictst use of the term Wi-Fi Certified to products that successfully complete interoperability certification testing. ROLE OF IOT IN SMART GRID

IOT Smart Energy Grid Circuit

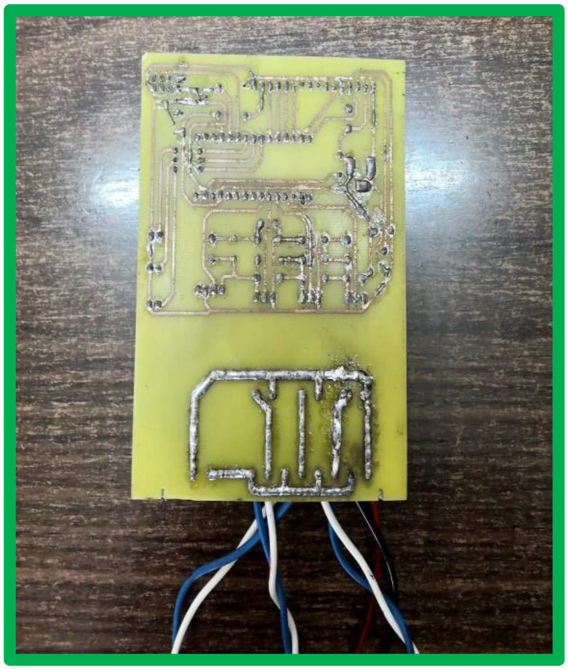


Figure (a) Bottom Side of smart grid

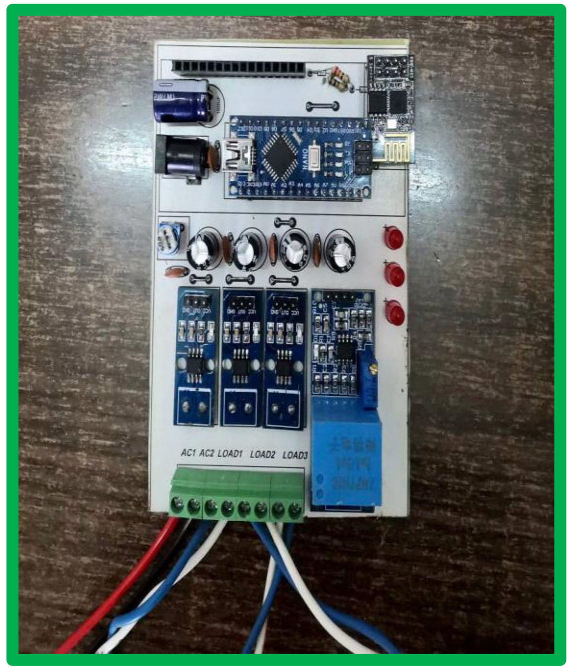


Figure (b) Top Side of smart grid

Figure (c) Iot smart grid with LCD

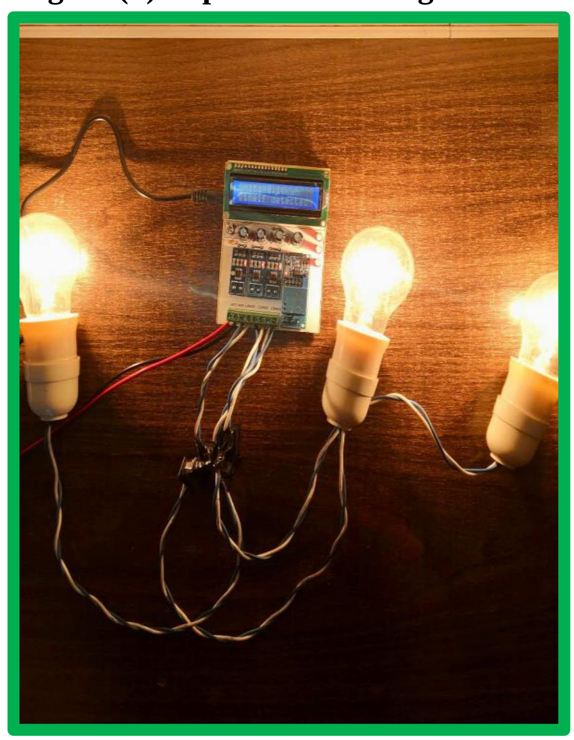


Figure (c) Iot smart grid with LEDS

Fig.20 (a,b,c and d). presents the implemented IOT Smart Energy Grid Circuit of the proposed system.

If only one load is running (Switch:On) It reads the power of the load and reads whether the load exceeds the consumer limits or not. The electrical power is still less than the maximum limit, so it writes that it is **not theft. as shown in following figure 21.a**

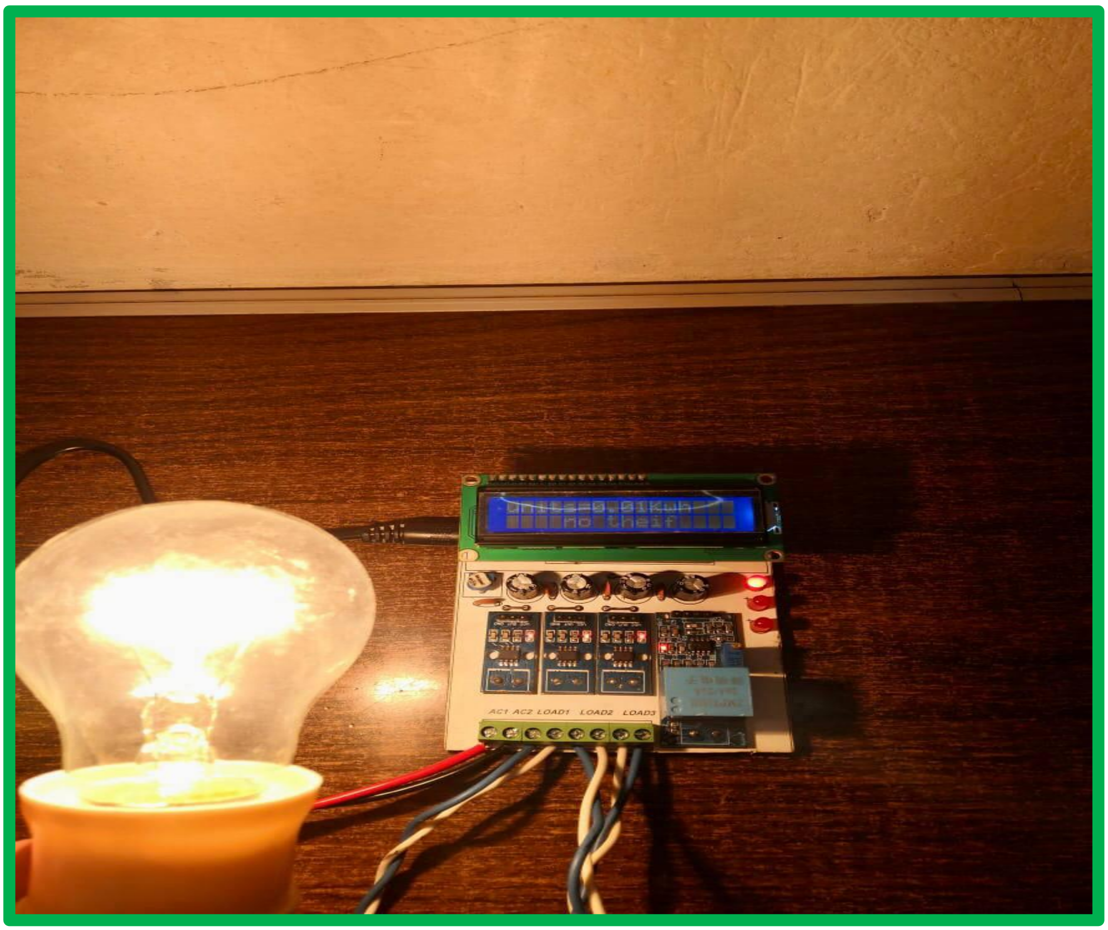


Figure (a) one load is running

If two loads is running. It reads the power of the loads and reads whether the load exceeds the consumer limits or not .The electrical power is still less than the maximum limit, so it writes that it is **not theft. as shown in following figure 21.b**

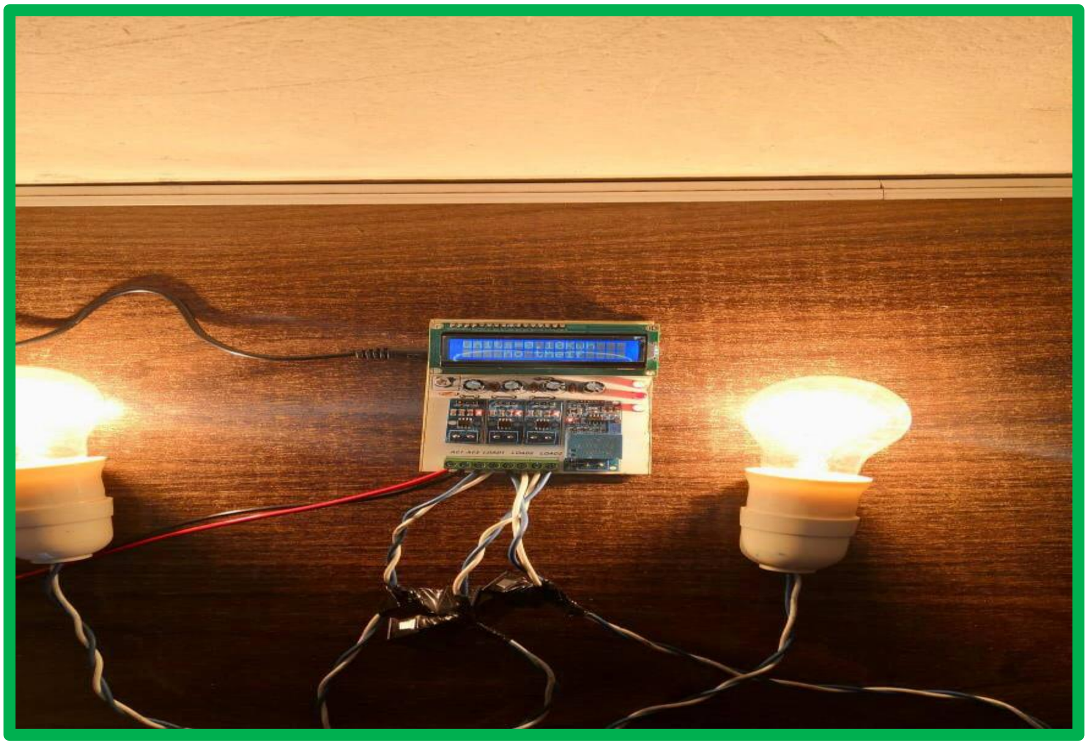


Figure (b) two loads is running

If 3 loads is running. It reads the power of the loads and reads whether the load exceeds the consumer limits or not. Here it appears that the apower is more than the maximum limit, so it appears that there is a **theft. as shown in figure 21.c**

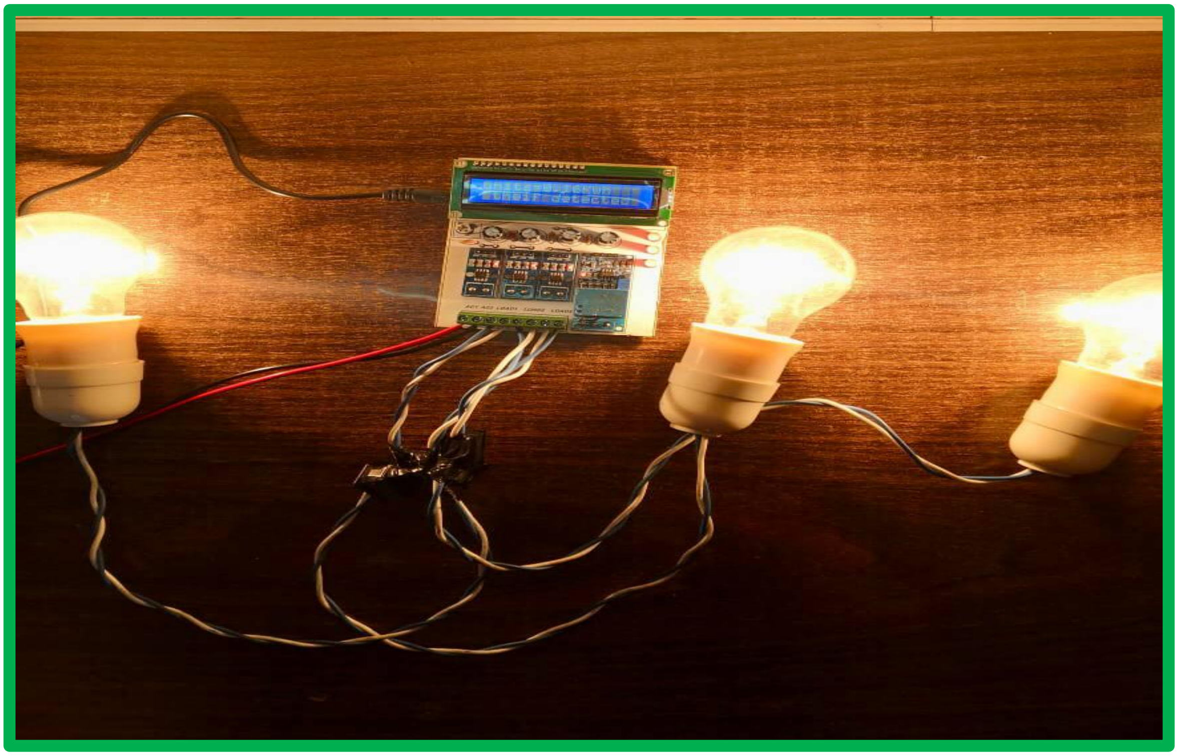


Figure (c) 3 loads is running

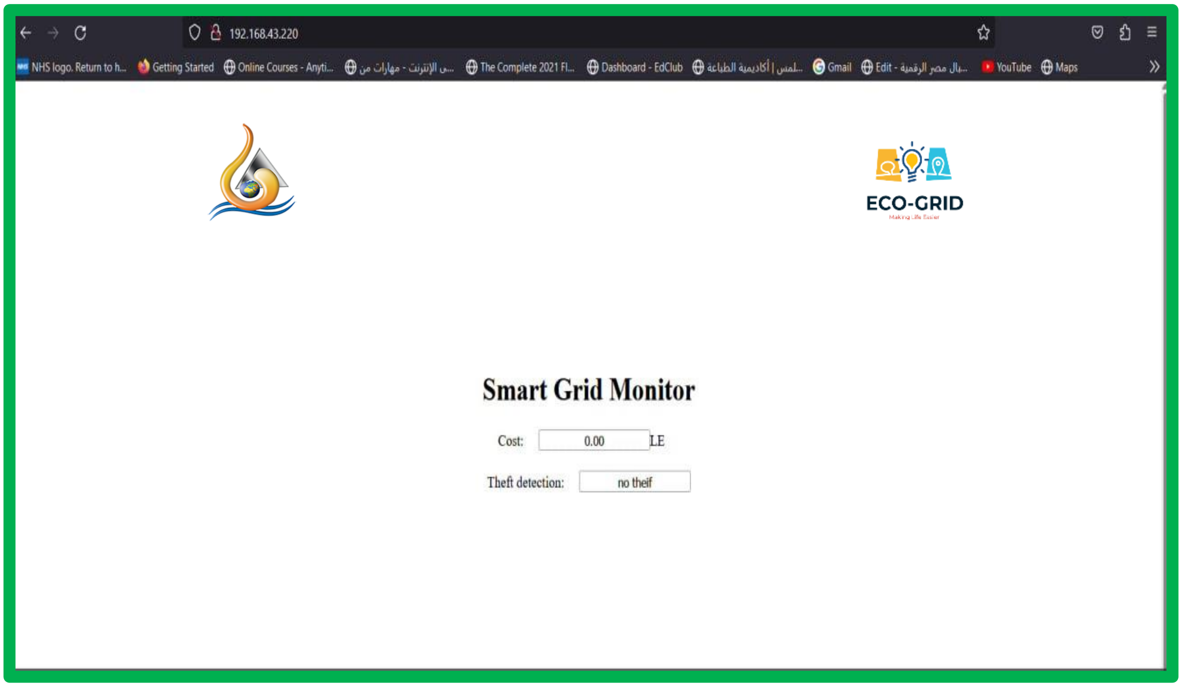


Figure (a) Webbage No theif result

Figure (b) Webbage theif result

Fig.22.(a and b) shows the webpage of our project.

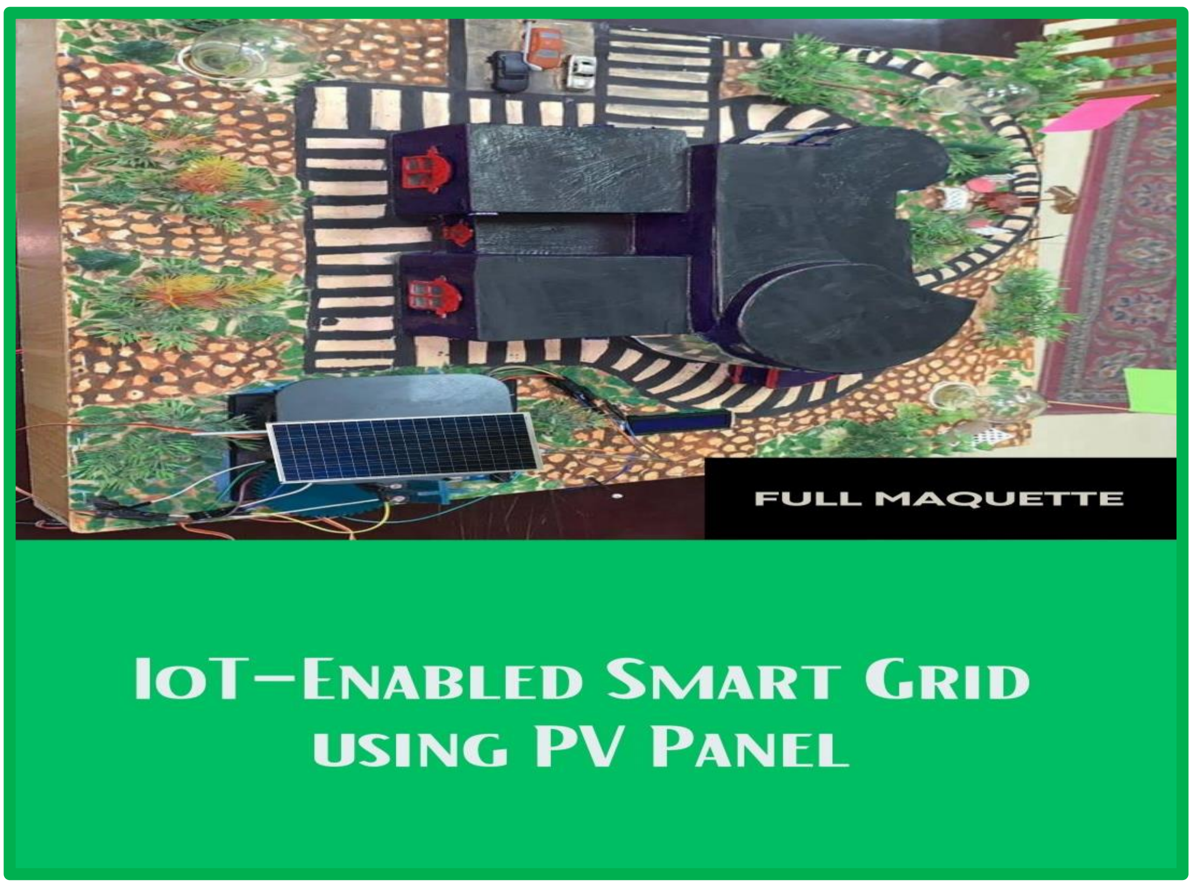


Fig.23.shows the complete maquette of the project after implementation.

Impact on Cost

It is simpler to establish a wireless network whereas implementation of wired network involves proper planning and

instalkation. While implementing smart grids, power failure are insolate. This factor may lead to increased cost of

implementation. Despite the huge implementation costs, smart grids and IOT save large amounts of energy by rerouting power instantly on detection of power failure.

Finally, Smart grid represents one of the most promising and prominent internet of thing application. By applying IOT technologies , various

intelligent services can be created. The development of most aspects of the smart grid would be enhanced by applying IOT. It provides very effective measures of delivering electric power to various consumers.

CHAPTER 6

Conclusion and Future Work

Chapter 6: Conclusions and Future Work

6.1. Conclusion

The Internet of Things (IoT) is the next step towards global pervasive connectivity to any device capable of communication and computing, regardless of access technology, available resources, or geographic location. The smart grid is the largest he IoT implementation using smart devices distributed throughout the energy chain from power plants to final consumers.

IoT will enhance the existing smart energy grid by enabling real-time control and monitoring of grid components. However, over the past decade, as described in the literature, cybersecurity has been viewed as one of the major barriers to his IoT adoption and further deployment in smart energy grid systems worldwide.

Due to the enormous number of devices connected to communication networks, which raises the possibility of a cyberattack and the danger of serious consequences, it is difficult to assure the safety of grid-connected devices. With the continued integration of IoT-enabled devices in smart grids, the size of the attack surface will become significantly larger in this regard.

6.2. Future Work

To cope with the abovementioned issues and challenges, the subsequent guidelines for the development of IoT-primarily based totally clever strength structures are made [31-35]: (i) The framework and modeling of clever strength grids must be improved, and appropriate reconfiguration technology need to be advanced for the healing issue of energy grids. (ii) Secure AMI technology need to be broadly deployed in mixture with superior cloud and edge-computing centers and 5G telecommunication technology to beautify the capability and safety of the clever grids. (iii) Smart grids need to be geared up with extra stable conversation protocols that bear in mind the heterogeneity of IoT gadgets even as permitting the deployment of AI algorithms. (iv) onto the tool itself in place of being managed from afar to lessen the probability of conversation breaches. Advanced stable and records conversation structures primarily based totally on blockchain strategies need to be appreciably applied in IoT-primarily based totally clever strength structures. Figure24 summarizes these future research directions.

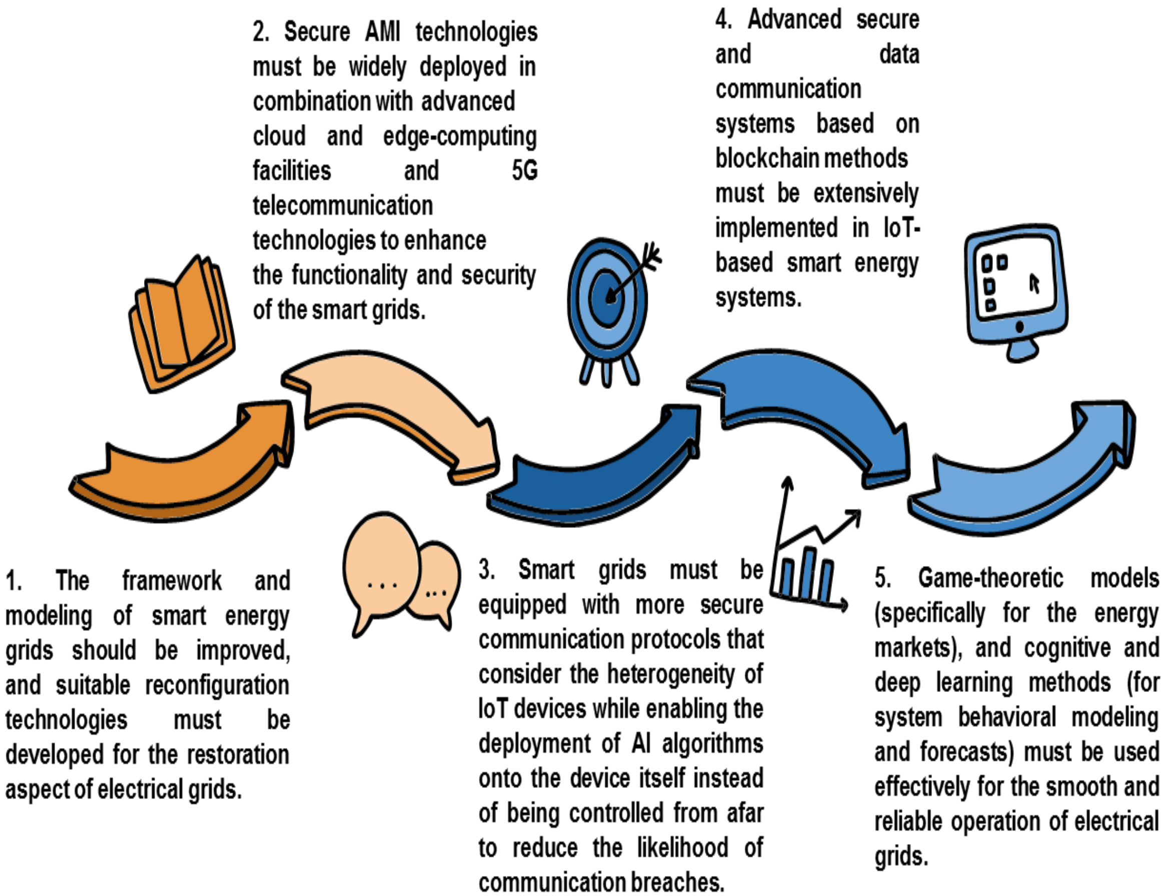


Fig.24. Future Research Directions.

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Appendix

Software Codes (Tracker,Wifi Module and IoT)

Tracker Code:

```
#include <Servo.h>


Servo myservo1, myservo2;

int LDR1 = A0, LDR2 = A1, LDR3 = A2, LDR4 = A3;

double rRDL1 = 0.0, rRDL2 = 0, rRDL3 = 0, rRDL4 = 0;

double max1=0, max2=0, max3=0;

int ser1 = 80, ser2=0;


void setup() {

  myservo1.attach(9);

  myservo2.attach(8);

  Serial.begin(9600);
```

```
  myservo1.write(0);

  myservo2.write(90);

  delay(4000);

}
```

void loop() {

```
  rRDL1 =(double) analogRead(LDR1) / 10;

  rRDL2 = (double)analogRead(LDR2) / 10;

  rRDL3 = (double)analogRead(LDR3) / 10;

  rRDL4 = (double)analogRead(LDR4) / 10;

Serial.println(double(rRDL1));

Serial.println(String(rRDL2));

Serial.println(String(rRDL3));

Serial.println(String(rRDL4));

  max1 = max(rRDL1, rRDL2);

  max2 = max(rRDL3, rRDL4);

  max3 = max(max1, max2);
```

```
 Serial.println("max is "+String(max3));

 //Serial.println(String(rRDL1) +", "+String(rRDL2) +", "+String(rRDL3)
+", "+String(rRDL4));

if(max3==rRDL1){

 myservo1.write(0);

 myservo2.write(0);

 }

 else if(max3==rRDL2){

  myservo1.write(0);

 myservo2.write(180);

 }

 else if(max3==rRDL3){

  myservo1.write(90);

 myservo2.write(0);

 }

 else if(max3==rRDL4){

 myservo1.write(90);
```

```
  myservo2.write(180);
  }
    Serial.println("----------------");
  delay(1000);
}
```

Wifi Module Code:

```
#include <ESP8266WiFi.h>
#include <WiFiClient.h>
#include <ESP8266WebServer.h>

const char* ssid = "honor";
const char* password = "12345678";
ESP8266WebServer server(80);
String sensorValue = "";
String value2 = "";
```

```
String data1 = "";

void handleRoot() {

  String page = "<html>"

              "<head>"

              "<title>Smart Grid Monitor</title>"

              "<meta name=\"viewport\" content=\"width=device-width, initial-scale=1\">"

              "<style>"

              "html, body {"

              "height: 100%;"

              "}"

              "body {"

              "display: flex;"

              "flex-direction: column;"

              "justify-content: center;"

              "align-items: center;"

              "}"

              "input[type=text] {"
```

```
"text-align: center;"

"}"

"label {"

"margin-right: 20px;"

"margin-bottom: 10px;"

"}"

"div {"

"margin-bottom: 20px;"

"}"

"</style>"

"</head>"

"<body>"

"<h1>Smart Grid Monitor</h1>"

"<div>"

"<label for=\"cost\">Cost:</label>"

"<input type=\"text\" id=\"cost\" value=\"\" readonly>"

"<label for=\"le\">LE</label>"

"</div>"
```

```
"<div>"
"<label for=\"value2\">Theft detection:</label>"
"<input type=\"text\" id=\"theft_detection\" value=\"\" readonly>"
"</div>"
"</body>"
"<script>"
"setInterval(function() {"
"var xhttp = new XMLHttpRequest();"
"xhttp.onreadystatechange = function() {"
"if (this.readyState == 4 && this.status == 200) {"
"document.getElementById(\"cost\").value = this.responseText;"
"}"
"};"
"xhttp.open(\"GET\", \"/cost\", true);"
"xhttp.send();"
"}, 1000);"
"setInterval(function() {"
"var xhttp = new XMLHttpRequest();"
```

```
"xhttp.onreadystatechange = function() {"
"if (this.readyState == 4 && this.status == 200) {"
"document.getElementById(\"theft_detection\").value = this.responseText;"
"}"
"};"
"xhttp.open(\"GET\", \"/theft_detection\", true);"
"xhttp.send();"
"}, 1000);"
"</script>"
"</html>";
  server.send(200, "text/html", page);
}

void handleSensorValue() {
  server.send(200, "text/plain", sensorValue);
}
```

```
void handleTheftDetection() {
  server.send(200, "text/plain", value2);
}


void setup() {
  Serial.begin(9600);
  WiFi.begin(ssid, password);
  while (WiFi.status() != WL_CONNECTED) {
    delay(1000);
    Serial.println("Connecting to WiFi...");
  }
  Serial.println("Connected to WiFi");


  server.on("/", handleRoot);
  server.on("/cost", handleSensorValue);
  server.on("/theft_detection", handleTheftDetection);
  server.begin();
  Serial.println("HTTP server started");
```

```
}

void loop() {
  if (Serial.available()) {
    data1 = Serial.readStringUntil('\n');
    int colonPos = data1.indexOf(':');
    if (colonPos != -1) { // if the colon is found
      // extract the two numbers before and after the colon
      sensorValue = data1.substring(0, colonPos);
      value2 = data1.substring(colonPos + 1);
    }
  }
  server.handleClient();
}
```

IoT Code:

```
#include "ACS712.h"
#include <LiquidCrystal.h>
#include <SoftwareSerial.h>
SoftwareSerial myserial(3, 2);


#define acvolt_pin A3
#define cost 10
#define led1 4
#define led2 5
#define led3 6
double acvolt_val = 0, ac_volt = 0, ac_voltD = 0, VmaxD = 0;
int val[100];
int max_v = 0;
double units = 0.0, load1 = 0.0, load2 = 0.0, load3 = 0.0, ac_amp = 0.0, energy
= 0.0, counter = 0.0, oldenergy;
const int rs = 12, en = 11, d4 = 10, d5 = 9, d6 = 8, d7 = 7;
```

```
unsigned long previousMillis = 0;

const long interval = 1000;


String datasend = "";


ACS712  ACS1(A0, 5.0, 1023, 200);

ACS712  ACS2(A1, 5.0, 1023, 200);

ACS712  ACS3(A2, 5.0, 1023, 200);

LiquidCrystal lcd(rs, en, d4, d5, d6, d7);


void voltage_measure()

{

  for ( int i = 0; i < 100; i++ ) {

    acvolt_val = analogRead(acvolt_pin);

    if (analogRead(acvolt_pin) > 511) val[i] = acvolt_val;

    else val[i] = 0;

    delay(1);

  }
```

```
  max_v = 0;
  for ( int i = 0; i < 100; i++ )
  {
    if ( val[i] > max_v ) max_v = val[i];
    val[i] = 0;
  }
  if (max_v != 0) {
    VmaxD = max_v;
    ac_voltD = VmaxD / sqrt(2);
    ac_volt = (((ac_voltD - 420.76) / -90.24) * -210.2) + 210.2;
  }
  else ac_volt = 0;
  //Serial.print("Voltage "); Serial.println(ac_volt);
  VmaxD = 0;
  delay(100);
}
```

void ampere_measure()

```
{
```

```
load1 = ACS1.mA_AC();
load2 = ACS2.mA_AC();
load3 = ACS3.mA_AC();
if (load1 < 220) {
  load1 = 0;
  digitalWrite(led1, LOW);
}
else digitalWrite(led1, HIGH);
if (load2 < 120) {
  load2 = 0;
  digitalWrite(led2, LOW);
}
else digitalWrite(led2, HIGH);
if (load3 < 220) {
  load3 = 0;
  digitalWrite(led3, LOW);
}
else {
```

```
    digitalWrite(led3, HIGH);
  }
  ac_amp = load1 + load2 + load3;
  if (ac_amp > 1000) {
    lcd.setCursor(0, 1);
    lcd.print(" theif detected ");
    datasend = String(energy) + ":" + "theif detected";
  }
  else {
    lcd.setCursor(0, 1);
    lcd.print("    no theif    ");
    datasend = String(energy) + ":" + "no theif";
  }
  //Serial.print("amp "); Serial.println(ac_amp / 1000);
}
```

void setup() {

```
  Serial.begin(9600);
  myserial.begin(9600);
```

```
  pinMode(led1, OUTPUT); pinMode(led2, OUTPUT); pinMode(led3, OUTPUT);

  digitalWrite(led1, LOW); digitalWrite(led2, LOW); digitalWrite(led3, LOW);

  lcd.begin(16, 2);

  ACS1.autoMidPoint(); ACS2.autoMidPoint(); ACS3.autoMidPoint();

}
```

void loop() {

```
  voltage_measure();

  ampere_measure();

  lcd.setCursor(0, 0);

  lcd.print(ac_amp);

  units = cost * (((load1 + load3) / 1000) * ac_volt) / 1000;

  //Serial.print("units"); Serial.println(units);

  lcd.setCursor(0, 0);

  lcd.print("units="); lcd.print(energy); lcd.print("Kwh");

  if (units != 0) {

    unsigned long currentMillis = millis();

    if (currentMillis - previousMillis >= interval) {
```

```
      previousMillis = currentMillis;

      counter++;

      energy = units * (counter / 1000) + oldenergy;

      myserial.println(datasend);

      Serial.println(energy);

    }

  }

  else {

    counter = 0;

    oldenergy = energy;

  }

}
```