

Smart Energy Meter

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Abstract — The advent of smart technologies has revolutionized various sectors, and the energy sector is no exception. The Smart Energy Meter is a cutting-edge innovation designed to enhance the efficiency, reliability, and sustainability of energy consumption and management. Unlike traditional meters, which require manual readings and provide limited data, Smart Energy Meters offer real-time monitoring, data analytics, and automated billing. This paper presents a comprehensive overview of the Smart Energy Meter, highlighting its key features, technological components, and the benefits it brings to both consumers and utility providers. The Smart Energy Meter employs advanced metering infrastructure (AMI) to collect detailed energy usage data, which is then transmitted via secure communication networks to the utility company for analysis and billing.

Keywords: Real-Time Monitoring, Data Analytics, Reliability, Revolutionized, Automated Billing, Infrastructure, Communication

I. INTRODUCTION

In an era where technological advancements permeate every facet of daily life, the energy sector is undergoing a transformative shift toward smarter and more efficient management systems. At the forefront of this evolution is the Smart Energy Meter, a sophisticated device designed to revolutionize how energy consumption is monitored, managed, and billed. Traditional energy meters, which require manual readings and provide limited data, are increasingly being replaced by smart meters that offer real-time monitoring, advanced data analytics, and automated billing processes.

The Smart Energy Meter operates through an advanced metering infrastructure (AMI) that enables the collection and transmission of detailed energy usage data. This real-time data collection allows consumers to monitor their energy consumption through digital platforms, making it easier to understand and control usage patterns, ultimately leading to cost savings and more sustainable energy use. For utility providers, smart meters facilitate efficient demand response management, helping to balance the grid and prevent outages, while also reducing operational costs through automated processes.

Moreover, Smart Energy Meters enhance the security and reliability of the energy supply by detecting anomalies that may indicate theft or tampering. They also support the integration of renewable energy sources, such as solar and wind, providing crucial data for optimizing energy production and consumption. Despite challenges such as data privacy concerns and the costs of implementation, the long-term benefits—including improved energy efficiency, reduced carbon footprint, and enhanced consumer

engagement—underscore the significant potential of Smart Energy Meters.

The benefits of Smart Energy Meters extend beyond mere operational efficiency. They represent a significant step towards environmental sustainability by enabling more precise control over energy consumption and promoting the use of renewable energy sources. With detailed insights into energy usage, consumers are empowered to adopt more energy-efficient practices, thereby reducing their carbon footprint. This not only helps in combating climate change but also aligns with global sustainability goals.

Despite the numerous advantages, the implementation of Smart Energy Meters does come with its set of challenges. Data privacy concerns are paramount, as the continuous monitoring and transmission of energy usage data could potentially be exploited if not properly secured. Robust cyber security measures are essential to safeguard this sensitive information.

This paper delves into the features, benefits, and challenges of Smart Energy Meters, advocating for their widespread adoption to foster a smarter, more sustainable energy infrastructure.

II. BLOCK DIAGRAM

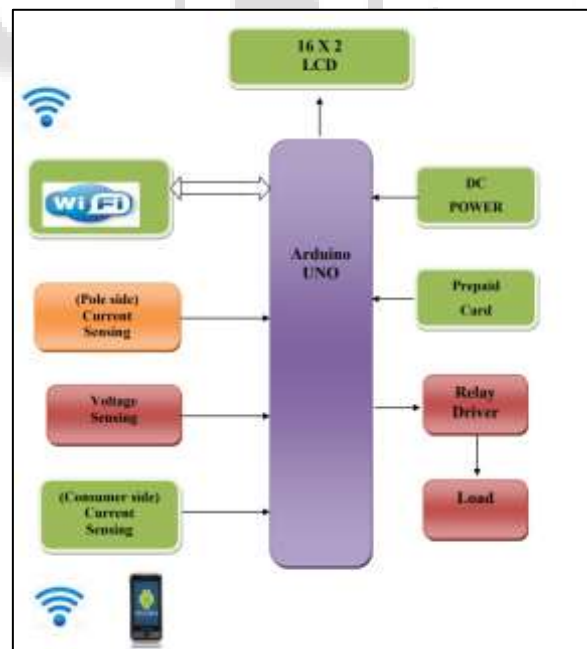


Fig. 1: Block Diagram of the system

The Block diagram of smart energy meter consist of Arduino UNO, power supply, transformer, voltage regulator, 16*2 LCD display, relay, ESP8266 WIFI Module and current sensor. A smart energy meter block diagram typically includes several interconnected components that work together to measure and manage energy consumption. The

arduino uno is the main central processing unit, wherein it will receive information from two current sensors one at the consumer side and the other at the pole side, these current sensors are used to measure power at the pole side and at the consumer side. these current sensors measure this data and send it to arduino. if the consumer has done some theft with the meter in order to save electricity units, if he has used any bypass line, then there will be difference in the readings of these two current sensors and as the difference increase above 10units, this will be notified as power theft and the arduino will send a low triggering pulse to relay so that it becomes closed hence the flow of electricity from pole side to consumer side is stopped temporarily until the consumer removes that bypass line, and after that the relay once now becomes open and as result of this it becomes open and now the flow of electricity will be continued from pole side to consumer side, and an intimation about this power theft can be given to the electricity supply board through esp8266 wifi module through iot app and the board can intimate some charges for this so in regards with this the power thefts can be prevented as much as possible. The block diagram consists of a prepaid card interfacing with the arduino which allows the user to get recharged for their energy meter for a fixed amount and he can use that much of electricity after getting exhausted with the prepaid amount the power supply will be stopped to the consumer if he recharges again he can continue with the usage of electricity.

III. PROPOSED METHODOLOGY

The development and implementation of Smart Energy Meters involve a comprehensive and multi-faceted approach, integrating various technological, analytical, and operational processes. This section details the methodology adopted for the deployment of Smart Energy Meters, covering the design, installation, data collection, communication infrastructure, data analysis, and consumer engagement processes.

A. Design and Development:

- **Hardware Components:** The Smart Energy Meter consists of several key hardware components, including sensors, microcontrollers, communication modules, and display interfaces. Sensors measure electrical parameters such as voltage, current, and power consumption. Microcontrollers process this data, and communication modules (e.g., GSM, Wi-Fi, Zigbee) transmit it to utility providers.
- **Software Development:** Custom software is developed to handle data collection, storage, processing, and transmission. This includes firmware for the meter itself and applications for consumers and utility providers to access real-time data.

B. Installation and Integration:

- **Site Assessment:** Before installation, a site assessment is conducted to determine the optimal placement of meters, ensuring strong signal reception for data transmission and minimal interference.
- **Meter Installation:** Technicians install the Smart Energy Meters at consumer premises, replacing traditional

meters. The installation process includes configuring the meter to connect with the utility's central system.

- **System Integration:** The meters are integrated into the existing energy management systems of utility providers. This involves configuring the communication protocols and ensuring compatibility with existing software and hardware infrastructure.

C. Data Collection and Transmission:

- **Real-Time Data Acquisition:** The meters continuously collect data on energy usage, voltage, current, and other relevant parameters. This data is stored locally in the meter's memory and periodically transmitted to the central server.
- **Communication Infrastructure:** A robust communication network is established using technologies such as GSM, Wi-Fi, or Zigbee. This network ensures reliable and secure data transmission from the meters to the central server of the utility provider.

D. Data Management and Analysis:

- **Data Storage:** Collected data is stored in a secure central database. The database is designed to handle large volumes of data, ensuring data integrity and availability.
- **Data Processing and Analysis:** Advanced analytics tools and algorithms are employed to process and analyze the collected data. This includes anomaly detection, load forecasting, and usage pattern analysis. Machine learning algorithms can be used to predict consumption trends and identify potential issues such as energy theft or meter tampering.

E. Consumer Engagement and Interface:

- **User Interface Development:** User-friendly interfaces are developed for consumers to monitor their energy usage. These interfaces can be in the form of mobile apps or web portals, providing real-time data, usage reports.

F. Security and Privacy Measures:

- **Data Encryption:** All data transmitted between the meters and the central server is encrypted to protect against unauthorized access.
- **Access Control:** Strict access control mechanisms are implemented to ensure that only authorized personnel can access the data. This includes role-based access controls and multi-factor authentication.
- **Compliance with Regulations:** The system is designed to comply with relevant data privacy and security regulations, ensuring that consumer data is protected at all stages.

G. Performance Monitoring and Maintenance:

- o **System Monitoring:** Continuous monitoring of the system's performance is conducted to ensure its reliability and efficiency. This includes tracking data transmission success rates, identifying any communication issues, and ensuring data accuracy.
- o **Regular Maintenance:** Scheduled maintenance is performed to keep the meters and communication infrastructure in optimal condition. This includes

software updates, hardware checks, and calibration of sensors.

By implementing this comprehensive methodology, the deployment of Smart Energy Meters can achieve significant improvements in energy management, providing benefits to both consumers and utility providers. The integration of advanced technologies, robust data management, and consumer-focused interfaces ensures that the Smart Energy Meter system is efficient, reliable, and user-friendly.

IV. HARDWARE AND SOFTWARE REQUIREMENTS:

A. Hardware Description

1) Arduino UNO:

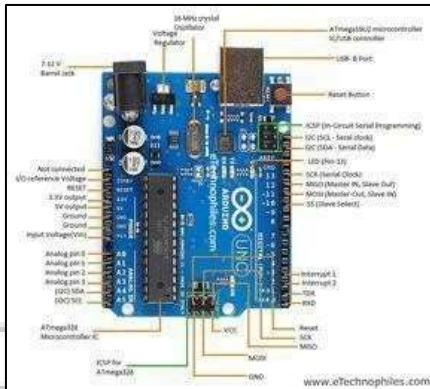


Fig. 2: Arduino Uno Pin Description

The Arduino Uno is a popular microcontroller board based on the ATmega328P microcontroller. Renowned for its simplicity and versatility, it serves as an excellent platform for beginners and experienced developers to create a wide array of electronic projects, including Smart Energy Meters. Below is a detailed description of the Arduino Uno, covering its key features, components, and functionality.

Key Features

- a) Microcontroller: ATmega328P
 - 8-bit microcontroller with RISC architecture.
 - Operating voltage: 5V.
 - Clock speed: 16 MHz.
- b) Digital I/O Pins: 14 (of which 6 can provide PWM output)
 - Used to interface with various digital sensors and components.
 - PWM (Pulse Width Modulation) pins are useful for tasks like controlling motor speed and LED brightness.
- c) Analog Input Pins: 6
 - Can read voltages from sensors, providing a range of 0-1023.
 - Useful for interfacing with analog sensors like temperature, light, and voltage sensors.
- d) Flash Memory: 32 KB (of which 0.5 KB used by bootloader)
 - Stores the program code uploaded to the board.
- e) SRAM: 2 KB
 - Used for runtime data storage.
- f) EEPROM: 1 KB
 - Non-volatile memory for storing long-term data.

- g) Power Supply:
 - USB connection or external power supply (7-12V recommended).
 - Built-in voltage regulator ensures stable operation.
- h) Communication:
 - UART (Serial Communication): Used for serial communication with a computer or other devices.
 - I2C and SPI: Communication protocols for interfacing with various peripherals like sensors and displays.

B. Regulated power supply:

A regulated power supply is essential for the reliable operation of electronic devices, including the Arduino Uno. It ensures that the device receives a stable and constant voltage, protecting it from fluctuations that could damage the components or cause erratic behavior. Here, we will discuss the characteristics, components, and design of a regulated power supply suitable for the Arduino Uno.

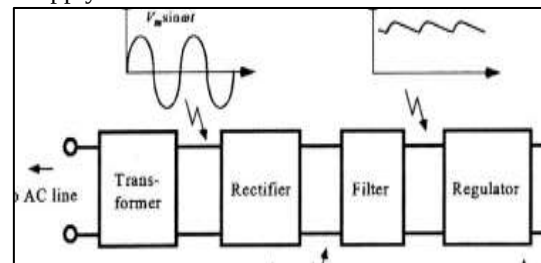


Fig. 3: Regulated power Supply

C. Transformer:

A transformer is a critical component in power supplies, especially when converting AC mains voltage to a lower AC voltage suitable for further processing. In the context of designing a regulated power supply for an Arduino Uno, the transformer plays a key role in stepping down the high AC voltage to a safer, lower AC voltage that can be rectified and regulated to provide the necessary DC voltage.



Fig. 4: Transformer (step down)

D. LCD Display 16*2:

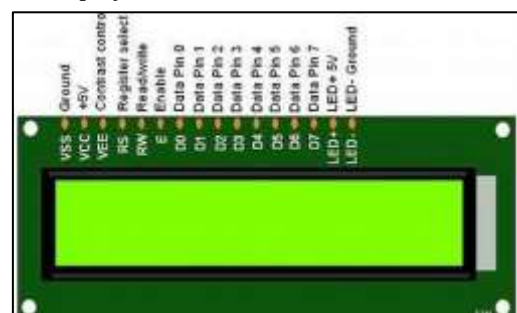


Fig. 5: 16*2 LCD display

The 16x2 LCD (Liquid Crystal Display) is a commonly used alphanumeric display module that provides a simple and efficient way to display text and numeric data in embedded systems and electronic projects. Its compact size, low power consumption, and ease of use make it a popular choice for interfacing with microcontrollers like the Arduino Uno.

1) LCD Features and Technical Specifications:

- a) Size:
 - The display consists of 16 characters in each of the 2 rows, providing a total of 32 characters.
- b) Character Size:
 - Each character is typically composed of a 5x8 dot matrix, allowing the display of alphanumeric characters, symbols, and custom characters.
- c) Backlight:
 - Many 16x2 LCD displays come with an LED backlight, which improves visibility in low-light conditions. Backlighting can be controlled separately from the text display.
- d) Interface:
 - The display is typically interfaced with a microcontroller using a parallel interface. It requires several digital I/O pins for data (D4-D7) and control signals (RS, RW, EN).
- e) Operating Voltage:
 - Most 16x2 LCD displays operate at 5V, making them compatible with common microcontroller systems like the Arduino Uno.
- f) Contrast Adjustment:
 - Some displays feature a contrast adjustment potentiometer, allowing the user to adjust the contrast of the displayed text.
- g) Low Power Consumption:
 - LCD displays consume minimal power, making them suitable for battery-powered applications.

E. Capacitor filter:

A capacitor filter, also known as a capacitor-input filter or a reservoir capacitor, is a simple yet effective circuit used in power supplies to smooth out the pulsating DC voltage produced by rectification. It consists of a capacitor connected in parallel with the load resistor, effectively reducing the ripple voltage and providing a more stable DC output.

1) Purpose:

The primary purpose of a capacitor filter is to convert the pulsating DC output of a rectifier into a smoother, more consistent DC voltage suitable for powering electronic devices. It accomplishes this by storing charge during the peaks of the input voltage and releasing it during the troughs, effectively "smoothing" the waveform. Ripples and to improve the DC component.

F. Regulator:

Voltage regulator ICs are available with fixed (typically 5, 12 and 15V) or variable output voltages. A voltage regulator is an essential electronic component used to maintain a stable output voltage regardless of variations in input voltage or load conditions. It ensures that electronic devices receive a consistent and reliable supply of voltage, crucial for their proper operation and longevity. Here's an overview of voltage

regulators, including their types, operation, applications, and advantages.

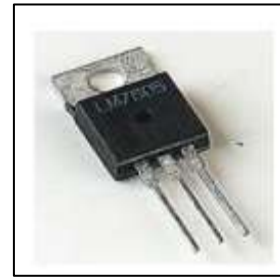


Fig. 6: A Three Terminal Voltage Regulator

G. ACS712 Current Sensor:

The ACS712 current sensor is a hall-effect based sensor that can measure both AC and DC current. It's widely used in electronic projects and devices to monitor current consumption and for applications such as energy monitoring, motor control, battery management, and more. Here's an overview of the ACS712 current sensor, including its features, operation, applications, and advantages:

1) Features:

- a) Hall Effect Sensing:
 - The ACS712 utilizes the Hall effect principle to measure current. It detects the magnetic field generated by current flowing through a conductor.
- b) Analog Output:
 - The sensor provides an analog voltage output proportional to the measured current. The output voltage varies linearly with the current passing through the sensor.
- c) Low-Noise Amplification:
 - Internal amplification circuitry provides a low-noise output signal, improving accuracy and reliability.
- d) Wide Range of Measurement:
 - Available in different variants with measurement ranges such as 5A, 20A, and 30A, allowing for a wide range of current sensing applications.
- e) Low Offset and Drift:
 - The sensor exhibits low offset voltage and drift over temperature, enhancing accuracy and stability.
- f) Galvanic Isolation:
 - Some variants of the ACS712 feature galvanic isolation, providing electrical isolation between the current-carrying conductor and the sensor output.

2) Operation:

- a) Hall Effect Principle:
 - When current flows through the conductor near the sensor, it generates a magnetic field perpendicular to the direction of current flow.
 - The Hall sensor inside the ACS712 detects this magnetic field and outputs a voltage proportional to the strength of the magnetic field, which is directly related to the current passing through the conductor.
- b) Output Voltage:
 - The output voltage of the sensor is typically calibrated to a specific sensitivity (e.g., mV/A). For example, a sensitivity of 100mV/A means that for every ampere of current passing through the sensor, the output voltage increases by 100mV.

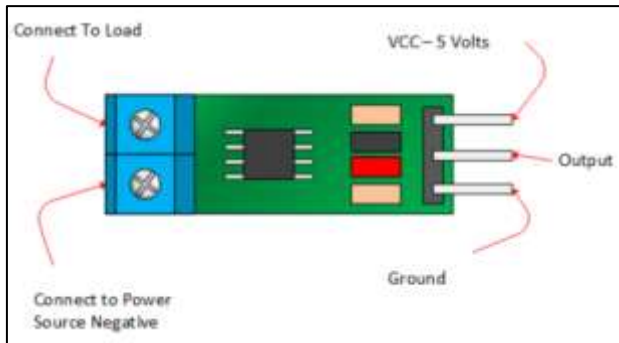


Fig. 7: ACS712 Current Sensor

H. Magnetic Relay:

A magnetic relay, also known simply as a relay, is an electromechanical switch that uses an electromagnet to control the opening and closing of one or more sets of contacts. Relays are widely used in various applications to control high-power circuits with low-power signals or to provide electrical isolation between different parts of a circuit. Here's an overview of magnetic relays, including their components, operation, types, applications, and advantages:

1) Components:

- a) Electromagnet:
 - The core component of a relay is the electromagnet, typically made of a coil of wire wound around an iron core. When current flows through the coil, it generates a magnetic field that attracts or repels an armature or movable contact.
- b) Contacts:
 - Relays have one or more sets of contacts that are opened or closed when the relay is energized. These contacts can be normally open (NO), normally closed (NC), or changeover (CO), providing different switching configurations.
- c) Spring Mechanism:
 - Some relays include a spring mechanism to ensure that the contacts return to their default position (normally open or normally closed) when the coil is de-energized.
- d) Enclosure:
 - Relays are often housed in a protective enclosure to shield the internal components from environmental factors and to provide safety to users.

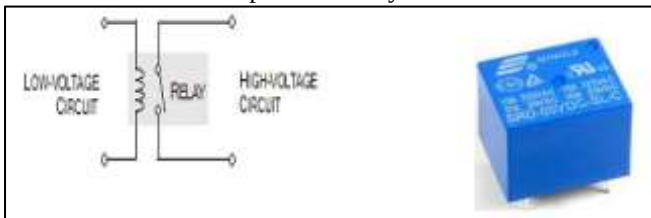


Fig. 8: Relay Providing Isolation between two circuits

I. Wi-Fi ESP8266:

The ESP8266 is a popular and versatile Wi-Fi module widely used in IoT (Internet of Things) projects due to its low cost, low power consumption, and ease of use. Here's an overview of the ESP8266 Wi-Fi module, including its features, operation, applications, and advantages:

1) Features:

- a) Integrated Wi-Fi Connectivity:
 - The ESP8266 module includes built-in Wi-Fi connectivity, allowing devices to connect to Wi-Fi networks and communicate with other devices or the internet.
- b) Microcontroller Core:
 - Many ESP8266 modules also integrate a microcontroller core (usually based on the Tensilica Xtensa architecture), providing processing capabilities for running embedded applications.
- c) GPIO Pins:
 - The module typically includes several General Purpose Input/Output (GPIO) pins that can be used for interfacing with sensors, actuators, and other peripheral devices.
- d) SPI, I2C, UART Interfaces:
 - The ESP8266 supports popular communication interfaces such as SPI (Serial Peripheral Interface), I2C (Inter-Integrated Circuit), and UART (Universal Asynchronous Receiver-Transmitter), allowing easy integration with various sensors and devices.
- e) Low Power Consumption:
 - The ESP8266 is designed for low power consumption, making it suitable for battery-powered IoT applications.
- f) Programmable via AT Commands or SDK:
 - The module can be programmed using AT commands via a serial interface or using the ESP8266 Software Development Kit (SDK) in C or Arduino IDE.
- g) OTA (Over-The-Air) Updates:
 - Some variants of the ESP8266 support OTA updates, allowing firmware updates to be deployed remotely over Wi-Fi without physical access to the device.

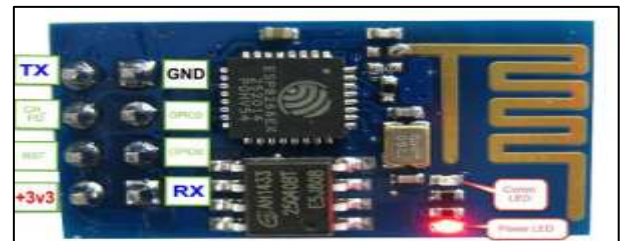


Fig. 9: ESP8266 Wifi Module

J. Rectifier:

A bridge rectifier is a type of circuit configuration used to convert alternating current (AC) into direct current (DC). It rectifies AC voltage by allowing current flow in only one direction, effectively converting the negative portion of the AC waveform into positive voltage. Here's an overview of the bridge rectifier, including its components, operation, applications, and advantages:

1) Components:

- a) Diodes (Four Diodes):
 - The bridge rectifier circuit consists of four diodes arranged in a specific configuration known as a bridge configuration. These diodes conduct current in only one direction, allowing the positive half-

cycles of the AC input to pass through while blocking the negative half-cycles.

b) Load Resistor:

- The load resistor represents the electrical load or device connected to the output of the bridge rectifier. It consumes the rectified DC voltage.

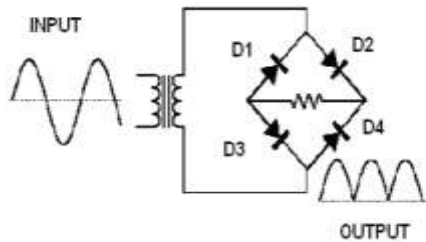


Fig. 10: Bridge Rectifier

K. Software Description

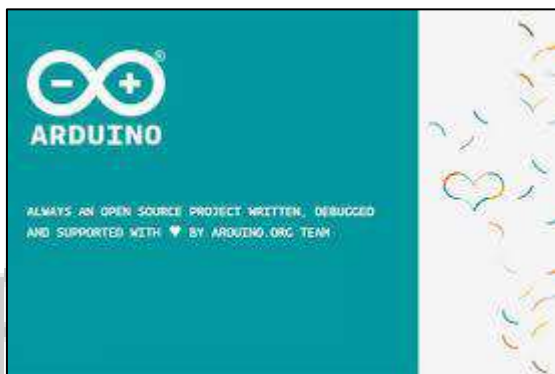


Fig. 11: Arduino IDE Interface

The Arduino IDE (Integrated Development Environment) is a software application used for writing, compiling, and uploading code to Arduino microcontroller boards. It provides an easy-to-use platform for both beginners and experienced developers to create and upload programs (known as sketches) to Arduino boards. Here's an overview of the Arduino IDE, including its features and how to use it:

1) Features:

- Code Editor:**
 - The Arduino IDE provides a text editor where you can write and edit your Arduino sketches. It supports syntax highlighting, auto-indentation, and code completion to make programming easier.
- Sketch Management:**
 - You can create, open, save, and manage multiple sketches within the IDE. Each sketch consists of two main functions: `setup()` (executed once when the board starts) and `loop()` (executed repeatedly).
- Library Manager:**
 - The IDE includes a Library Manager that allows you to easily search for and install Arduino libraries, which are pre-written code modules that provide additional functionality for your sketches.
- Serial Monitor:**
 - The Serial Monitor tool allows you to communicate with your Arduino board via serial communication. You can send data to the board and receive data from it, which is useful for debugging and testing your sketches.

e) Board Manager:

- The Board Manager enables you to select the type of Arduino board you are using and install the necessary board definitions and drivers.

f) Built-in Examples:

- The IDE includes a collection of built-in example sketches that demonstrate various Arduino functionalities. These examples cover topics such as digital and analog I/O, communication protocols, sensors, actuators, and more.

L. BLYNK:



Fig. 12: Blynk

Blynk is a platform that allows users to create IoT (Internet of Things) applications for controlling and monitoring devices remotely. It provides a simple and intuitive way to build custom mobile apps to interact with hardware such as Arduino, Raspberry Pi, ESP8266, and other microcontroller-based projects. Here's an overview of Blynk, including its features, components, and how it works:

1) Features:

- Drag-and-Drop Interface:**
 - Blynk offers a user-friendly drag-and-drop interface for designing custom mobile apps. Users can easily add buttons, sliders, gauges, graphs, and other widgets to create interactive interfaces.
- Real-Time Data Monitoring:**
 - Blynk allows users to monitor real-time data from sensors and devices connected to their projects. This includes temperature, humidity, light levels, motion detection, and more.
- Control and Automation:**
 - With Blynk, users can remotely control devices and trigger actions based on specific conditions. For example, turning on lights, activating motors, or adjusting thermostat settings.
- Notifications:**
 - Blynk supports push notifications, allowing users to receive alerts and notifications on their mobile devices based on predefined events or sensor readings.
- Cloud Connectivity:**
 - Blynk provides cloud connectivity, enabling users to access and control their projects from anywhere with an internet connection.
- Widgets and Customization:**
 - Blynk offers a variety of widgets and customization options to suit different project requirements. Users can customize the appearance and behavior of widgets to match their preferences.

2) Components:

a) Blynk App:

The Blynk mobile app is available for both iOS and Android devices. It serves as the interface for interacting with Blynk projects and controlling connected devices.

b) Blynk Cloud:

Blynk Cloud is the cloud-based server infrastructure that facilitates communication between the Blynk app and hardware devices. It manages user accounts, project configurations, and data transfer.

c) Blynk Library:

The Blynk library provides the necessary code and functions for integrating Blynk functionality into hardware projects. It supports a wide range of development platforms, including Arduino, Raspberry Pi, ESP8266, and more.

V. CONCLUSION

Smart energy meters play a crucial role in modernizing the energy sector by providing real-time monitoring, remote access, and data analytics capabilities. By enabling consumers to track and manage their energy consumption more effectively, smart meters contribute to energy efficiency, cost savings, and environmental sustainability. As the world transitions to a more digital and connected future, smart energy meters will continue to play a key role in shaping the way we use and manage electricity.

VI. FUTURE SCOPE

The future scope of smart energy meters is vast and promising, with ongoing advancements in technology, policy initiatives, and consumer awareness driving innovation and adoption. Here are several areas where smart energy meters are expected to have a significant impact in the future:

A. Advanced Data Analytics:

Future smart energy meters will likely incorporate more sophisticated data analytics capabilities, leveraging machine learning and artificial intelligence to provide deeper insights into energy consumption patterns. This will enable more accurate demand forecasting, load balancing, and optimization of energy distribution networks.

B. Integration with Renewable Energy Sources:

As renewable energy sources such as solar and wind power become more prevalent, smart meters will play a crucial role in integrating these distributed energy resources into the grid. Advanced metering infrastructure (AMI) will enable bidirectional communication, allowing consumers to feed excess energy back into the grid and participate in energy trading and peer-to-peer transactions.

C. Grid Modernization:

Smart meters will contribute to the modernization of the electrical grid, facilitating the transition to a more decentralized, resilient, and adaptive grid infrastructure. By providing real-time data on energy consumption and grid conditions, smart meters will enable utilities to optimize grid operations, improve reliability, and respond more effectively to grid disturbances and emergencies.

D. Demand Response Programs:

Smart meters will support the implementation of demand response programs, where consumers can adjust their energy usage in response to pricing signals or grid conditions.

REFERENCES

- [1] G. P. Harrison, "Smart Metering and Smart Grids: A Handbook for Smart Grids Research, Policy and Practice," John Wiley & Sons, 2014.
- [2] F. Li, J. Chen, and Y. Qian, "A review on the smart meters in smart grid," *Renewable and Sustainable Energy Reviews*, vol. 68, pp. 1-18, 2017.
- [3] J. M. Guerrero, L. G. de Vicuna, J. Matas, M. Castilla, and J. Miret, "Wireless communication in smart grid: Evaluation of new technologies," *IEEE Transactions on Industrial Informatics*, vol. 9, no. 1, pp. 28-37, 2013.
- [4] A. Kurs, A. Karalis, R. Moffatt, J. D. Joannopoulos, P. Fisher, and M. Soljačić, "Wireless power transfer via strongly coupled magnetic resonances," *Science*, vol. 317, no. 5834, pp. 83-86, 2007.
- [5] C. Li, C. Chen, Y. Guo, S. Li, and D. L. Guo, "Integrating energy harvesting with wireless power transfer in modern grid communications," *IEEE Communications Magazine*, vol. 54, no. 9, pp. 53-59, 2016.
- [6] A. Bazanella, A. Zanella, M. D. Rosa, and M. Zorzi, "Wireless communications in the smart grid: A comprehensive overview," *IEEE Wireless Communications*, vol. 18, no. 6, pp. 10-18, 2011.
- [7] N. Hatziaargyriou, N. Jenkins, and R. H. Allan, "Microgrids: Architectures and control," John Wiley & Sons, 2014.
- [8] M. B. A. Motlagh, M. Bagaa, and T. Taleb, "Green internet of things for smart world: A survey," *IEEE Access*, vol. 3, pp. 1-22, 2015.
- [9] S. Khullar, S. Aggarwal, and M. Singh, "A review of smart meters in power systems," *Renewable and Sustainable Energy Reviews*, vol. 82, pp. 10-17, 2018.
- [10] G. Chicco and I. Macii, "Smart metering in the smart grid: A review of modern technologies for an energy and infrastructure efficient future," *Renewable and Sustainable Energy Reviews*, vol. 30, pp. 810-821, 2014.
- [11] These papers cover a range of topics related to smart energy meters, including communication technologies, wireless power transfer, microgrids, IoT applications, and the integration of smart meters into the broader smart grid infrastructure.