Semiconductor Optoelectronics, *Vol. 42 No. 2 (2023), 735-743*
https://bdtgd.cn/

Semiconductor Optoelectronics
ISSN: 1001-5868

MACHINE LEARNING BASED ADVANCE METERING SYSTEM WITH RENEWABLE ENERGY MANAGEMENT

Divya B V
Asst. Prof, REVA UNIVERSITY Research Scholar, NIEIT,VTU

Latha N
Asst. Prof, REVA UNIVERSITY Research Scholar, NIEIT,VTU

Dr.Archana N V
Professor, Departemtn of EEE, NIE

Dr. Usha Surendra
Professor, CHRIST, (Deemed to be university)

Abstract – This paper proposes a methodology to ensure uninterrupted power supply to the load by selecting the optimal power source using Machine learning from different energy sources such as solar, wind, battery, and the Main grid, based on cost and available energy resource. As the electricity demand is increasing consumers in various sectors are facing issues due to frequent power outages. An alternative arrangement for power sources is necessary. The proposed methodology can provide a solution by supplying uninterrupted power based on the power generated by different sources and cost also gets reduced.

Based on the optimized solution, the ATMEGA microcontroller gives the input to the relay, which in turn switches the appropriate relay to ensure an uninterrupted power supply to the load. The output can be monitored on an LCD while the power supply is derived from renewable source in the first instance. In the event of failure of the renewable source, the load is then powered by the next available source. If the battery also fails, it switches over to the next available source such as mains. LCD will display the source through which the load is running.
Keyword- Advance Arduino Uno, Battery Metering Infrastructure, Machine learning, Renewable resources.

I. INTRODUCTION

Renewable energy sources have a vital role to play in the generation of electricity. Solar and wind can be used to generate electricity to meet our daily energy needs. Solar can be used as it is available everywhere and easy to generate, in addition to this wind is also used for electricity generation. The primary objective is to ensure an uninterrupted power to a load by optimally selecting the power source from various options. Micro-controller ATMEGA is used to sense both sides that is from load side and source side and using relay for switching purposes. Means it will switch automatically as per the requirement of load. An advance-metering infrastructure is used to know the consumption of power through the optimal source and cost is minimized and can be calculated for the power consumed.

Advance metering Infrastructure is responsible for demand side management, with proper communication infrastructure [1], Advance Metering Infrastructure (AMI) an emerging technology, involving smart meters and networks that facilitate the measurement, collection, and analysis of data regarding energy consumption [2]. This technology enables efficient monitoring of utility usage by customers and more efficient distribution of utilities by service providers [3]. Systems known as advanced metering infrastructure (AMI) interface by utilizing metering devices, water, heat, gas, and electricity. meters can be read either upon demand or at schedule time to measure, gather, and analyse energy usage. A few of these systems are used in metre data management software, customer-associated systems, hardware, and software [4]. As a part of wider "smart grid" ambitions, government organisations and utilities are turning to advanced metering infrastructure (AMI) technologies [5]. By offering two-way metre communications, AMI advances automatic metre reading (AMR) technology. This enables commands to be sent towards the home for a variety of purposes, including as time-based pricing information, demand-response actions, or remote service disconnections [6]. Advanced metering requires security and communication protocol in smart grid [7] To increase the reliability, power quality and to promote green energy, AMI is integrated with Artificial intelligent (AI) nowadays [8] with the introduction of AI to AMI electricity consumption forecast can be done in advance metering system using edge-fog-cloud architecture[9,10] AMI's are also more functional than conventional metering networks for utility companies and customers. AMIs, for instance, stand out due to their ability to provide two-way communication with both the provider and the client.

II. BUILDING BLOCK OF AMI

1. Smart Meters: These are electronic devices installed at customers premises to measure and record energy consumption data in real time.
2. Communication Networks: These are the networks that connect smart meters to utility companies back-end systems.
3. Data Management Systems: These systems are responsible for processing and managing the vast amounts of data generated by smart meters.
4. Customer Information Systems: These systems provide customers with access to their energy consumption data, enabling them to make informed decisions about their energy usage and costs.
5. Metering Data Management Systems: These systems are responsible for collecting, storing, and processing meter data from smart meters.
6. Advanced Analysis: Advanced analytics technologies allow utilities to analyse consumption patterns, identify anomalies, and optimize operations.

Fig 1 shows the basic building blocks of an AMI, These building blocks work together to create a comprehensive and integrated AMI solution that enables utilities to collect and manage energy consumption data more efficiently, improve customer service, and reduce costs.

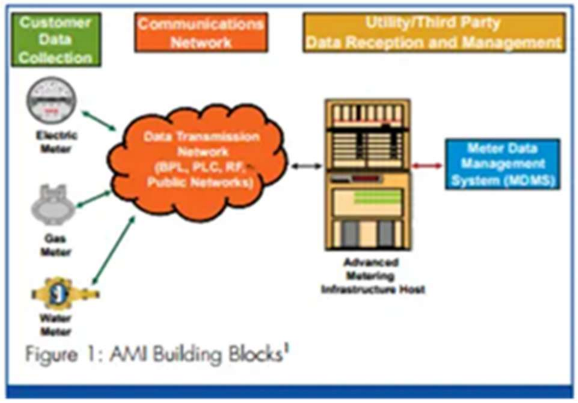

Fig. 1 Building Block Of AMI

III. RENEWABLE ENERGY SOURCES

Renewable energy sources are a source which can be used repeatedly because it will be available free of cost and replaced naturally. These types of energy almost never run out, for example: solar energy is generated by heat from the sun and is inexhaustible. Other examples include wind energy, geothermal energy, hydro energy etc...

A) SOLAR ENERGY

Heat, the energy that comes from the sun, is transformed into solar energy. For countless centuries, individuals across the globe have employed it for diverse purposes. The energy of the sun has been harnessed for heating, cooking, and drying for many centuries. Currently, it is also used to generate electricity in regions where there are no other power sources, such as in remote locations in space.

The expense of generating electricity from solar power is decreasing, leading to an increase in its affordability. Additionally Solar energy is considered a type of a renewable energy source and an alternative to non-renewable resources like coal and oil because the Sun always provides heat and light.

i) SOLAR CELL

Sunlight can be used to create electricity using solar cells. One such device that converts radiant energy into electrical energy is a solar panel. The word photovoltaic cell is often used when there is no clear indication of the light source, but the phrase solar cell is sometimes reserved for systems designed particularly to capture energy from sunlight. A solar cell panel is an assembly of several solar cells that can produce enough electricity for everyday use. Rechargeable solar batteries can be used to store the electricity generated by solar panels, which is then used as needed.

B) WIND ENERGY

Here, to generate electricity using wind we are going to use wind turbines, The conversion of the kinetic energy of wind into electrical energy is achieved using wind turbines. Wind energy, which is derived from this process, is classified as an intermittent source of renewable energy due to its fluctuating and unpredictable nature and used by many countries to reduce the use of

fossil fuels.
There are many types of turbines are there among them two are mostly used, they are horizontal axis and vertical axis. In this project we used horizontal axis.
Currently, most of the global wind energy is produced using large horizontal-axis wind turbines (HAWTs)with the three blades facing upwind of the tower. These wind turbines are designed to be oriented towards the direction of the wind, and they have a primary rotor shaft and electrical generator located at the top of a tower. Smaller turbines are directed using basic wind vanes wind vanes, while larger turbines typically employ wind sensors and yaw systems to determine their direction. Most have a gearbox, which converts the blades' slow spin into a faster rotation better suited for powering an electrical generator.

Lead-acid BATTERY
A rechargeable battery known as a lead acid battery is a type of secondary cell that contains lead and lead (IV) oxide plates immersed in a sulfuric acid solution.
Lead-corrosive batteries are the least expensive battery-powered batteries and can deliver a lot of force. They contain harmful lead, however, and ought to be reused. They are wet cell variety, and there is a risk of the caustic acid spelling out. On the other hand, sealed lead acid batteries are batteries in which the sulfuric acid is contained in a gel that remains in place, even if the battery is inverted.

ADVANTAGES

- Low cost: Lead-acid batteries are relatively inexpensive to manufacture.
- High energy density: Lead-acid batteries can store a large amount of energy in small space.
- High Surge current: Lead-acid batteries can deliver a high surge of current.
- Easy maintenance: Lead-acid batteries are simple to maintain and can be recharged quickly.

IV. METHODOLOGY
Fig 1 shows the flow chart of the proposed methodology used for advanced metering.

Phase 1: Calculations are necessary to obtain total power generated by solar panel, and how much time taken by the battery to charge completely. Calculating the power generated through wind turbines because it is dependent upon the wind speed and the length of the blades. Calculations are required to determine the watt-hour capacity of the battery and convert it to ampere-hour capacity. Here we are using gearless DC dynamo to generate power through wind, so it is necessary to note down the ratings of motor.
Phase 2: When examining the connections, it’s important to exercise caution during the installation process to prevent a short circuit from occurring, and equipment damage may happen.
Phase 3: When all the connections are made, first we go for solar energy whether it is available are not if it is available note down the output. Next, we go for wind energy if it is available then note down the output. If both the renewable sources are not available, then we go for mains to run the load.

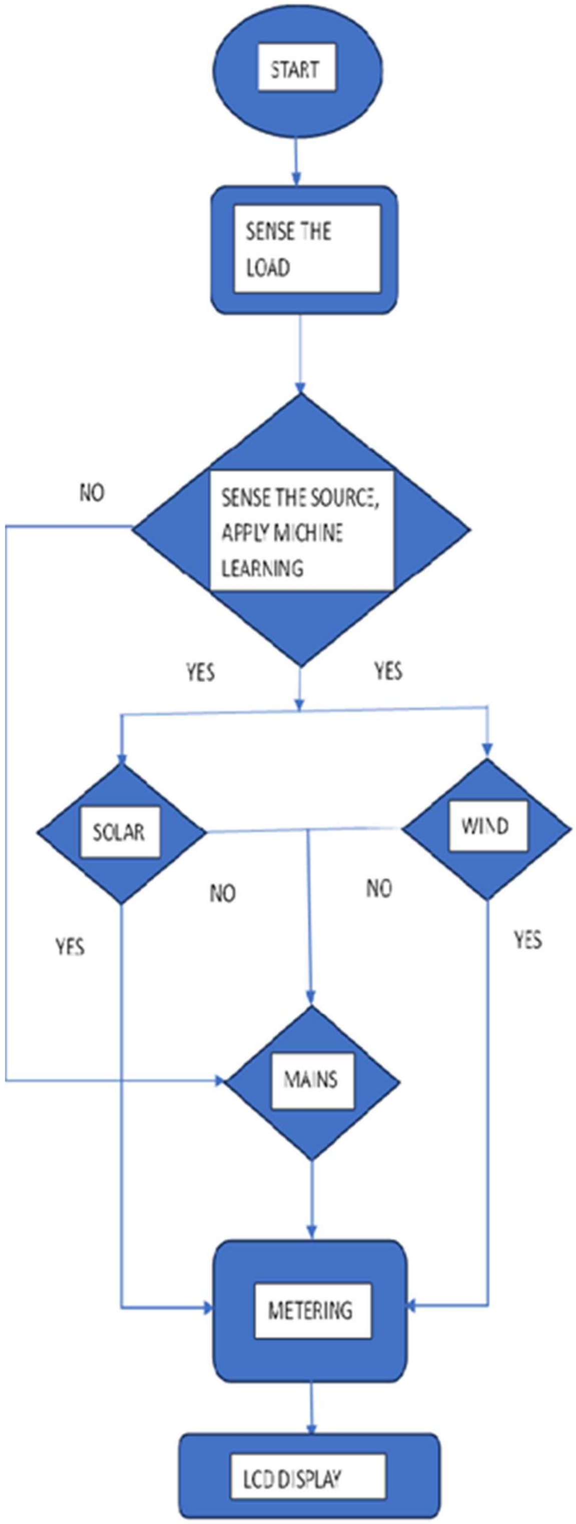

Fig. 2 Flow chart of the Methodology

When the load is turned on the Arduino will sense the requirement of power to run the load. The optimization will be applied, based on the result the optimized source is selected. If solar is selected as the optimized result based on the availability, then the load will run using solar

energy and it is displayed in the LCD. If renewable sources are not available, then the source will switch to Mains, and it is displayed through LCD. Here to find the optimized renewable source gradient descent algorithm is used with machine learning to minimize the cost. To avoid local minima, the proposed methodology uses logarithmic cost function.
Equation (1) represents the cost function, y is the output, m is the number of times the summation is carried out.

$$f(x) = \frac{-1}{m}\sum_{i=0}^{m}[y \log (y_{pred}) + (1-y)\log (1-y_{pred})]..(1)$$

$$y_{pred} = \sigma(\omega^T x + \text{b}) \qquad ....(2)$$

Fig 2 represents the minimum cost obtained from gradient descent algorithm, for one of the loads.

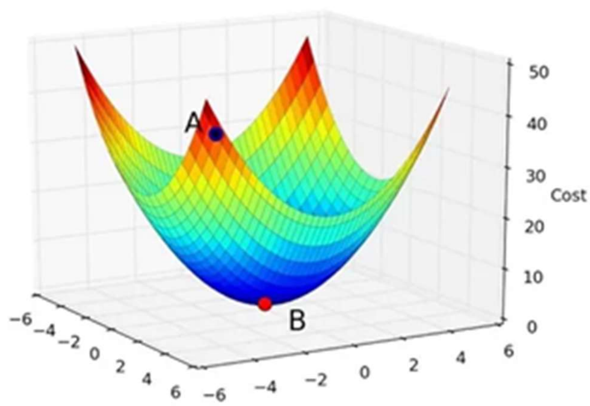

Fig 2. Represents the minimum cost.

V. BLOCK DIAGRAM

All the connections are external, hence re-connections and replacing the equipment are easy. We used jumper wires for connections. We use relays for the switching purpose, which means it will switch automatically as per the availability of the source and requirement of load. Here Arduino uno is used for programming purposes and it receives input from the solar, wind and mains and sends same for relay and LCD. It takes calculations to obtain the total power generated by the solar panel and how much hour the battery will take to charge completely. Calculations are required to determine the watt-hour capacity of the battery and convert it to ampere-hour capacity. It is necessary to analyze the power generated through wind energy because it depends upon the wind speed and the length of the blades.

COMPONENTS

101 Renewable Energy Sources
A Solar Energy
B Wind Energy
102 Mains Supply
103 Arduino Uno
104 Battery
105 Load Part

106 Output Part

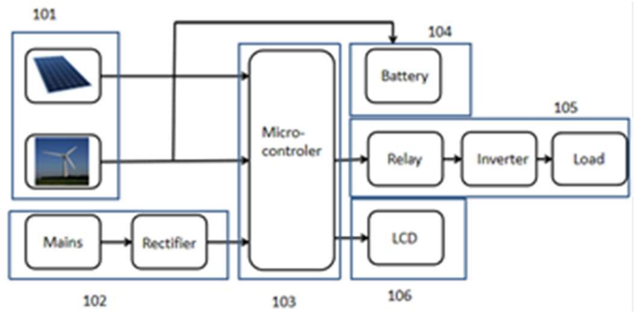

Fig.3. Block Diagram of The Proposed System

The functioning of this project can be delineated into three scenarios.

Case 1: In this case, when both solar power and wind power are available, optimize the source based on cost. Therefore, solar power is optimized to load.

Case 2: In this case, if solar power becomes less available, the system will automatically switch to wind power. The wind power generated by the wind turbine will then be directed to the load for delivery.

Case 3: In this case, if both solar power and wind power are not available or insufficient, the system will automatically draw power from the mains(grid) supply and deliver it to the load.

Whenever renewable sources are not utilized, the energy is stored in a battery that can be employed for specific applications at a later time.

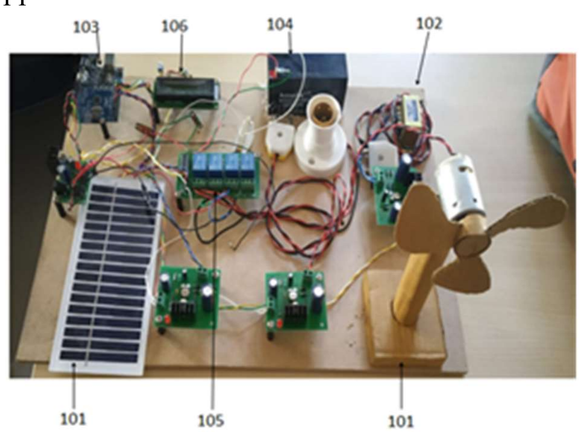

Fig.2. Hardware Of the Proposed System

TABLE1. PARAMETERS OF PROPOSED PROTOTYPE

Sl.No.	Parameters	Values
1	Power generated by solar	1W
2	Battery storage capacity	1300 mAh
3	Battery capacity	1.3 Ah
4	Main supply	230V

V. RESULTS AND DISCUSSION

TABLE 2. OUTPUT OBTAINED

Sl no	Source	Voltage	Load	Disply
01	Solar	>= 5V	Run	SOLAR AVAILABLE SOURCE...
02	Solar	< 4.9V	Switch to wind	NO ONE SOURCE AVAILABLE..
03	Wind	>= 5V	Run	WIND AVAILABLE SOURCE...
04	Wind	< 4.9V	Switch to mains	NO ONE SOURCE AVAILABLE..
05	Mains	230V	Run	MAINS AVAILABLE METER RUNNING

In the proposed work, two types of loads are considered one is LED strip (required small power of 0.5 W) and LED bulb (5-9W).

When the load is turned on Arduino will start to sense the required power to run the load, then it will start to sense the source side, i.e., available source to run the load.

Case1. If only solar is generating, then optimization is not necessary, it will directly display on LCD.
Case 2. If only wind is available then the load will run from the wind, and the same is displayed on the LCD.
Case 3. If both are generating optimization techniques are implemented to reduce the cost and by utilizing the best source the load will run.
Case 4. In case both the sources also we are not getting optimal power through relay Arduino will switch to mains to run the load.

Arduino works on 5V DC, solar panel is 7V and 12V DC dynamo is used for wind in the prototype, 12V step down transformer is connected to run the load.

VI. CONCLUSION

IN this paper the implementation of advanced metering infrastructure (AMI) using Machine learning in smart grid with renewable energy source management is proposed which provides benefits of managing renewable energy sources with reducing the cost. With the integration of AMI, utilities can gather real-time data on energy consumption, production, and storage. Which enables us to manage the distributed generation. AMI also allows for the identification of peak usage periods, allowing for more effective load balancing and the reduction of waste. Overall, the implementation of AMI in smart grid technology provides a more efficient, reliable, and sustainable way to manage renewable energy sources. It is a crucial step towards achieving more sustainable energy growth.

VII. FUTURE WORK

For future we can use Wi-Fi to generate bills. It uses wireless protected access as an encryption standard.
This is the future trend of communication which is going to be implemented and deployed in many countries. It cuts the cost of cables to be run to houses.

VIII. REFERENCE

[1] Mohassel, R.R., Fung, A., Mohammadi, F. and Raahemifar, K., 2014. A survey on advanced metering infrastructure. International Journal of Electrical Power & Energy Systems, 63, pp.473-484.

[2] Selvam, Chenthamarai, Kota Srinivas, G. S. Ayyappan, and M. Venkatachalam Sarma. "Advanced metering infrastructure for smart grid applications." In 2012 International Conference on Recent Trends in Information Technology, pp. 145-150. IEEE, 2012.

[3] Zhou, Jiazhen, Rose Qingyang Hu, and Yi Qian. "Scalable distributed communication architectures to support advanced metering infrastructure in smart grid". IEEE transaction on parallel and distributed system 23, no. 9 (2021) : 1632-1642.

[4] Jiang, Rong, Rongxing Lu, Ye Wang, Jun Luo, Changxiang Shen, and Xuemin Shen. "Energy-theft detection issues for advanced metering infrastructure in smart grid". Tsinghua Science and Technology 19, no. 2(2014): 105-120.

[5] Liu, Nian, Jinshan Chen, Lin Zhu, Jianhua, and Yanling He. "A key management scheme for secure communication of advanced metering infrastructure in smart grid". IEEE transaction on Industrial electronics 60,no, 10 (2012): 4746-4756.

[6] Faisal, Mustafa Amir, Zeyar Aung, John R.Williams, and Sanchez. "Data stream based intrusion detection system for advanced metering infrastructure in smart grid: A feasibility study". IEEE Systems journal 9, no. 1 (2014): 31-44.

[7] Li, D. and Hu, B., 2012, September. Advanced metering standard infrastructure for smart grid. In 2012 China International Conference on Electricity Distribution (pp. 1-4). IEEE.

[8] Aziz, A.F.A., Khalid, S.N., Mustafa, M.W., Shareef, H. and Aliyu, G., 2013. Artificial intelligent meter development based on advanced metering infrastructure technology. Renewable and Sustainable Energy Reviews, 27, pp.191-197.

[9] Gutiérrez-Gnecchi, J.A., Molina-Moreno, I., Téllez-Anguiano, A.C. and Cerda-Jacobo, J., A VAR model to forecast electricity consumption in Smart Metering System using an edge-fog-cloud architecture.

10. H. Liang, D. Liu, X. Zeng and C. Ye, "An Intrusion Detection Method for Advanced Metering Infrastructure System Based on Federated Learning," in Journal of Modern Power Systems and Clean Energy, vol. 11, no. 3, pp. 927-937, May 2023, doi: 10.35833/MPCE.2021.000279.