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Centralized Energy Management System Using Ethernet Communication for Cement Industry

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Abstract: This paper presents the design and implementation of a centralized energy monitoring system for industrial applications. The system enables real-time monitoring of electrical parameters such as voltage, current, power, and energy consumption from multiple energy meters. These meters are interconnected using RS-485 communication, which provides reliable data transmission over long distances. The Modbus protocol is used to ensure structured and accurate data exchange between devices. A data converter is employed to convert Modbus RTU communication into Modbus TCP format, allowing integration with Ethernet networks. The converted data is transmitted to a central server, which acts as the main unit for data collection, processing, and storage. The system continuously updates electrical parameters, enabling real-time observation and analysis of system performance. Time-stamped data storage allows detailed evaluation of energy usage over a period of time. The proposed system reduces the need for manual data collection and minimizes human errors, thereby improving monitoring efficiency. It also provides better visibility of system behaviour and supports informed decision-making. The communication network ensures stable and uninterrupted data transfer under continuous operation. The system is flexible and can be expanded by adding more devices as required. Overall, the proposed system offers a cost-effective and scalable solution for centralized energy monitoring and enhances efficient utilization of electrical energy in industrial environments

Keywords: Energy Monitoring, RS-485, Modbus TCP, Ethernet Communication, Industrial Automation, Real-Time Monitoring

I. INTRODUCTION

Energy consumption in industrial systems is significantly high due to continuous operation and the use of large electrical equipment. Efficient monitoring and management of electrical parameters are essential to ensure optimal energy utilization, reduce operational costs, and improve system reliability. Conventional methods of monitoring, which involve manual data collection, are time-consuming and prone to human errors.With the advancement of communication technologies, automated energy monitoring systems have emerged as an effective solution for real-time data acquisition and analysis. These systems enable continuous monitoring of important electrical parameters such as voltage, current, power, and energy consumption. Real-time monitoring helps in identifying abnormal conditions, analysing load patterns, and improving overall system performance.

In modern industrial environments, communication protocols play a key role in ensuring reliable data transfer between field devices and monitoring systems. RS-485 communication is widely used due to its robustness and ability to support long-distance communication in noisy industrial conditions. The Modbus protocol provides a standardized method for data exchange, while Ethernet communication enables high-speed data transfer and integration with centralized systems. this paper presents the design and implementation of a centralized energy monitoring system using RS-485 and Modbus TCP communication. The proposed system integrates multiple energy meters with a central server through a data converter and Ethernet network. It provides continuous data acquisition, reliable communication, and real-time monitoring capabilities. The system improves efficiency, reduces manual effort, and offers a scalable solution suitable for industrial energy management applications.

II. SYSTEM ARCHITECTURE

The proposed centralized energy monitoring system is designed to collect, transmit, and process electrical parameters from multiple measurement points in an industrial environment. The overall architecture consists of energy meters, an

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RS-485 communication network, a data converter, an Ethernet switch, and a central server. Each component plays a specific role in ensuring accurate data acquisition and reliable communication.

Energy meters are installed at different locations to measure key electrical parameters such as voltage, current, power, power factor, and energy consumption. These meters are interconnected through an RS-485 communication bus, which allows multiple devices to share a common communication line. The use of RS-485 ensures stable data transmission over long distances and provides immunity to electrical noise, making it suitable for industrial applications. The RS-485 network is connected to a data converter that translates serial communication into Ethernet-based communication. This conversion enables the integration of field-level devices with higher-level monitoring systems. The Ethernet switch facilitates the transfer of data between the converter and the central server, ensuring fast and efficient communication.

The central server acts as the core unit of the system, where all the collected data is received, processed, and stored. It provides a platform for real-time monitoring and visualization of electrical parameters. The server also maintains time-stamped records of data, which can be used for further analysis and performance evaluation.The overall system operates in a continuous loop, where data is periodically collected from the energy meters, transmitted through the communication network, and updated at the server. This architecture ensures centralized monitoring, reduces manual effort, and improves the reliability and efficiency of energy management.

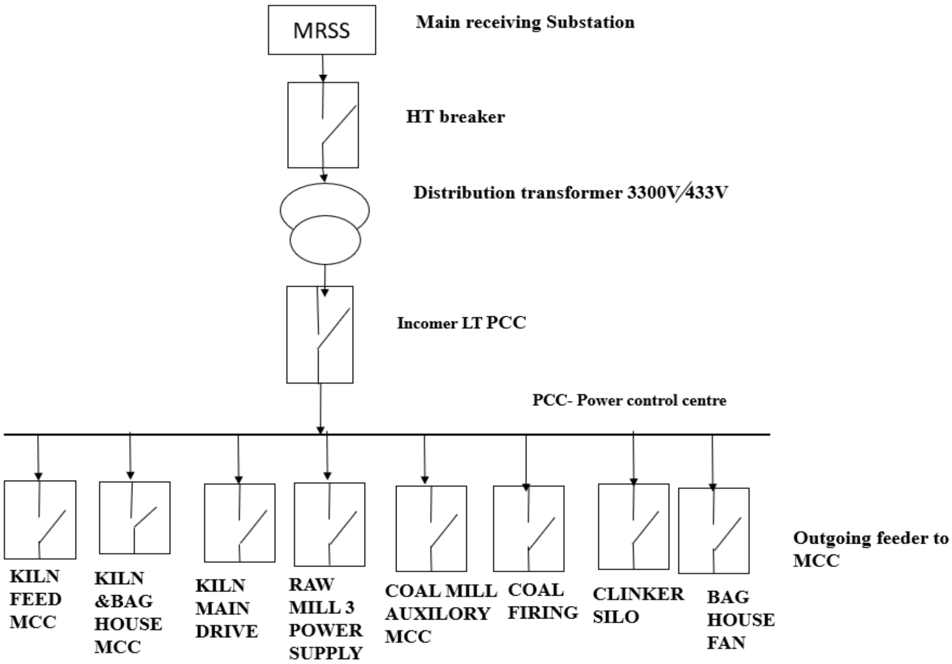

Fig. II. Single line diagram of kiln 1 substation

III. COMMUNICATION METHODOLOGY

The communication framework of the proposed system is designed to ensure reliable and efficient data transfer between field devices and the central monitoring unit. A combination of RS-485 communication and Modbus protocol is used at the field level, while Ethernet communication is employed for data transmission to the central server.RS-485 is selected as the primary communication medium between energy meters due to its ability to support multiple devices on a single bus and its robustness in electrically noisy environments. It enables long-distance communication with minimal signal degradation, making it suitable for industrial applications. Each energy meter connected to the RS-485 network is assigned a unique address, which allows the system to identify and communicate with individual devices.

The Modbus protocol is used to facilitate structured communication between devices. It follows a master-slave architecture, where the central system acts as the master and the energy meters function as slave devices. The master sends requests to the meters, and the corresponding data is returned as a response. This method ensures organized and error-free data exchange. a data converter is used to bridge the communication between RS-485 and Ethernet networks. It converts Modbus RTU signals into Modbus TCP format, allowing seamless integration with the central server. Ethernet

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communication provides high-speed data transfer and supports connectivity over a wider network infrastructure. the combined use of RS-485, Modbus protocol, and Ethernet communication ensures reliable, scalable, and efficient data transmission. This hybrid communication approach enhances system performance and enables continuous real-time monitoring of electrical parameters.

IV. IMPLEMENTATION

The implementation of the proposed centralized energy monitoring system involves the integration of hardware components, communication setup, and data acquisition processes. The system is developed to ensure continuous monitoring of electrical parameters with reliable communication between devices.Energy meters are installed at different measurement points to capture electrical parameters such as voltage, current, power, power factor, and energy consumption. These meters are connected through an RS-485 communication network, which forms the backbone of data transmission at the field level. Proper configuration of communication parameters such as baud rate, parity, and device addressing is carried out to establish stable communication between the devices. a data converter is used to interface the RS-485 network with the Ethernet network. The converter translates serial data into Ethernet-compatible format, enabling communication with the central server. The Ethernet switch is used to connect the converter and the server, ensuring smooth data transfer across the network.

The central server is configured to read data from each energy meter at regular intervals. The received data is processed and updated continuously, allowing real-time monitoring of system parameters. Each data set is stored along with a time stamp, which enables tracking of parameter variations over time. during initial setup, communication issues such as incorrect addressing or connection errors may occur. These issues are resolved by verifying wiring connections and configuration settings. Once the setup is completed, the system operates continuously without interruption, ensuring stable communication and reliable data acquisition. the overall working of the system follows a cyclic process in which data is periodically collected from energy meters, transmitted through the communication network, processed at the server, and updated for monitoring. This continuous loop ensures that the latest system information is always available.

Fig. IV. Connection setup

V. FLOWCHART OF OPERATION

The flowchart is used to understand the working of the system. At first, the system is started and communication setup is done. After that, the server will try to connect with the data converter. If the connection comes, then the system will go to the next step and read the data from the energy meter. If connection is not coming, it will show error and again try for connection. This will keep repeating until connection is ok. After getting the data, it is saved along with time. This helps to know when the reading is taken. Then the system will wait for some time. After waiting, again it will start the same process. So the system will run continuously and data will be updated again and again after some time.

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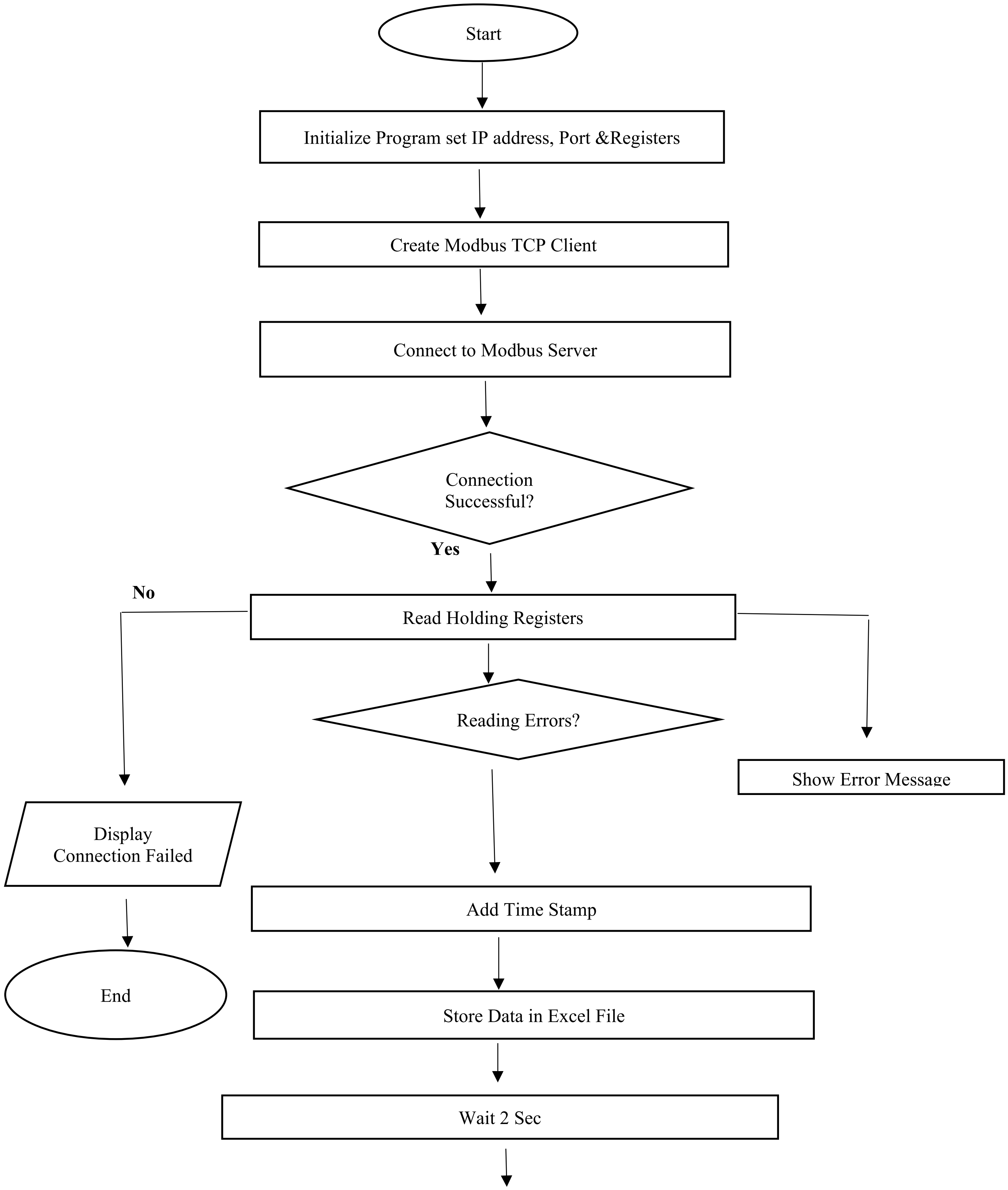

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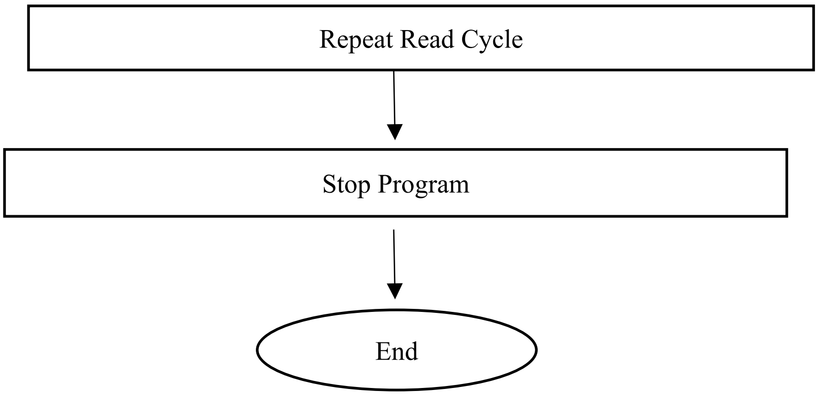
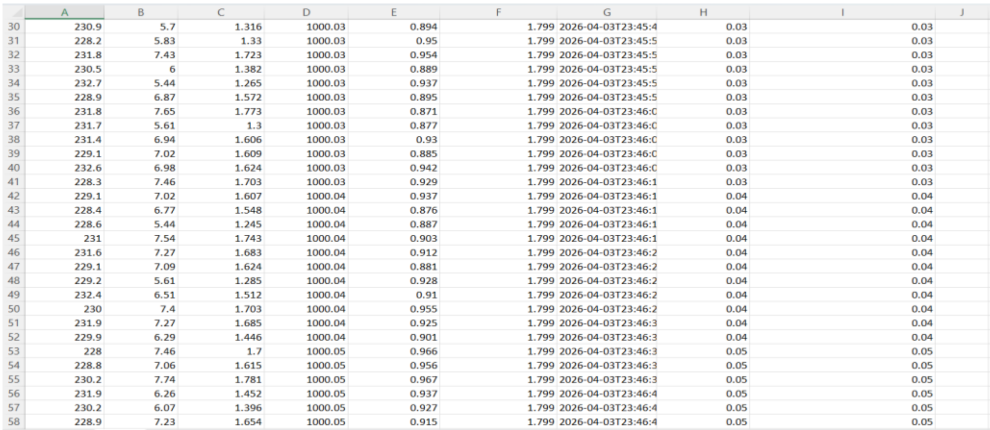


VI. DATA LOGGING AND STORAGE

This dashboard is connected to a data storage system, which stores all the measured values and time stamps. This feature enables the system to keep a record of electrical parameters which can be analysed. These data can be used to recognize trends and patterns in energy usage. For instance, it can be used to see high load durations or to track power consumption changes over time, as well as to generate reports and document system performance. data **logging also helps with report generation and documentation of system performance. This helps in planning** maintenance and checking the performance, and also makes use of the historical data which is available for the system, giving further information than the real-time monitoring.



	A	B	C	D	E	F	G	H	I	J
30	230.9	5.7	1.316	1000.03	0.894	1.799	2026-04-03T23:45:4	0.03	0.03	
31	228.2	5.83	1.33	1000.03	0.95	1.799	2026-04-03T23:45:5	0.03	0.03	
32	231.8	7.43	1.723	1000.03	0.954	1.799	2026-04-03T23:45:5	0.03	0.03	
33	230.5	6	1.382	1000.03	0.889	1.799	2026-04-03T23:45:5	0.03	0.03	
34	232.7	5.44	1.265	1000.03	0.937	1.799	2026-04-03T23:45:5	0.03	0.03	
35	228.9	6.87	1.572	1000.03	0.895	1.799	2026-04-03T23:45:5	0.03	0.03	
36	231.8	7.65	1.773	1000.03	0.871	1.799	2026-04-03T23:46:0	0.03	0.03	
37	231.7	5.61	1.3	1000.03	0.877	1.799	2026-04-03T23:46:0	0.03	0.03	
38	231.4	6.94	1.606	1000.03	0.93	1.799	2026-04-03T23:46:0	0.03	0.03	
39	229.1	7.02	1.609	1000.03	0.885	1.799	2026-04-03T23:46:0	0.03	0.03	
40	232.6	6.98	1.624	1000.03	0.942	1.799	2026-04-03T23:46:0	0.03	0.03	
41	228.3	7.46	1.703	1000.03	0.929	1.799	2026-04-03T23:46:1	0.03	0.03	
42	229.1	7.02	1.607	1000.04	0.937	1.799	2026-04-03T23:46:1	0.04	0.04	
43	228.4	6.77	1.548	1000.04	0.876	1.799	2026-04-03T23:46:1	0.04	0.04	
44	228.6	5.44	1.245	1000.04	0.887	1.799	2026-04-03T23:46:1	0.04	0.04	
45	231	7.54	1.743	1000.04	0.903	1.799	2026-04-03T23:46:1	0.04	0.04	
46	231.6	7.27	1.683	1000.04	0.912	1.799	2026-04-03T23:46:2	0.04	0.04	
47	229.1	7.09	1.624	1000.04	0.881	1.799	2026-04-03T23:46:2	0.04	0.04	
48	229.2	5.61	1.285	1000.04	0.928	1.799	2026-04-03T23:46:2	0.04	0.04	
49	232.4	6.51	1.512	1000.04	0.91	1.799	2026-04-03T23:46:2	0.04	0.04	
50	230	7.4	1.703	1000.04	0.955	1.799	2026-04-03T23:46:2	0.04	0.04	
51	231.9	7.27	1.685	1000.04	0.925	1.799	2026-04-03T23:46:3	0.04	0.04	
52	229.9	6.29	1.446	1000.04	0.901	1.799	2026-04-03T23:46:3	0.04	0.04	
53	228	7.46	1.7	1000.05	0.966	1.799	2026-04-03T23:46:3	0.05	0.05	
54	228.8	7.06	1.615	1000.05	0.956	1.799	2026-04-03T23:46:3	0.05	0.05	
55	230.2	7.74	1.781	1000.05	0.967	1.799	2026-04-03T23:46:3	0.05	0.05	
56	231.9	6.26	1.452	1000.05	0.937	1.799	2026-04-03T23:46:4	0.05	0.05	
57	230.2	6.07	1.396	1000.05	0.927	1.799	2026-04-03T23:46:4	0.05	0.05	
58	228.9	7.23	1.654	1000.05	0.915	1.799	2026-04-03T23:46:4	0.05	0.05	

Fig.VI. Data collected from the industry

VII. VISUALIZATION AND OUTPUT DISPLAY

Electrical parameters are displayed clearly and structured on the dashboard. The output is displayed in a readable, understandable format, allowing users to quickly get the information they want. the layout is optimized to present the maximum information in the least crowded format. All parameters are easily accessible through the use of organized tables and structured arrangement of values which facilitates good readability. The dashboard aims to give a holistic view of the system's performance as easily as possible.

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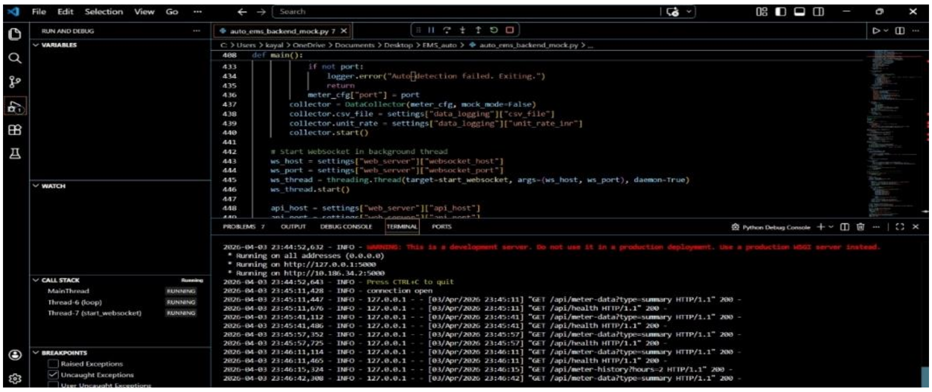

Fig.VII.A. output of connection

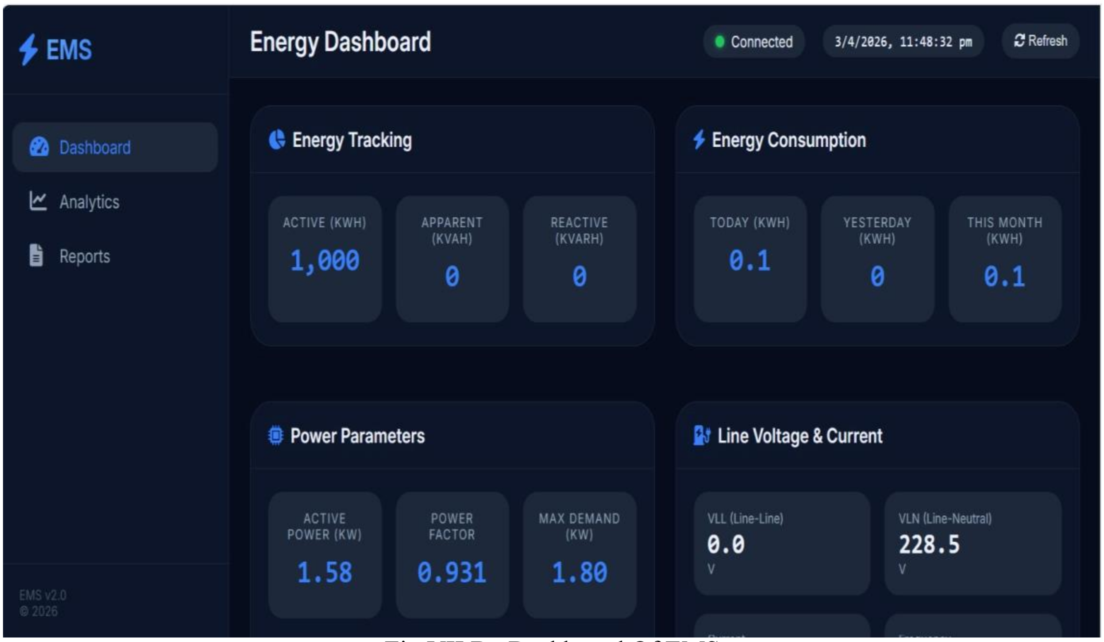

Fig.VII.B. Dashboard Of EMS

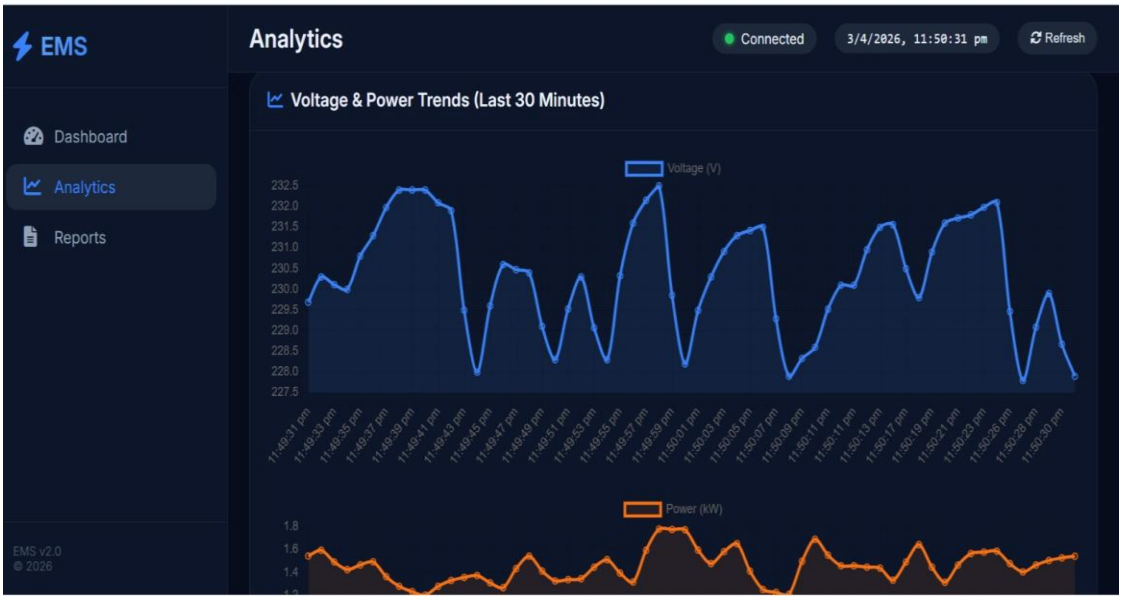

Fig.VII.C. Analysis of Voltage and current

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VIII. CONCLUSION

The centralized energy management system developed in this project successfully demonstrates an effective method for monitoring electrical parameters from multiple locations. The system integrates energy meters, communication networks, and a central processing unit to provide continuous and accurate data acquisition. through the implementation of RS-485 communication and Modbus protocol, reliable data transmission was achieved between field devices and the central server. The system was able to collect important electrical parameters such as voltage, current, power, power factor, and energy consumption in real time. The stability of communication and consistency of data confirm that the system operates effectively under normal working conditions. the use of a centralized monitoring approach significantly reduces the need for manual data collection. It improves accuracy, minimizes human error, and allows operators to observe system performance from a single location. The development of the dashboard further enhances the usability of the system by presenting data in a clear and organized format. the results obtained from the system show that it responds correctly to variations in load conditions and provides reliable measurements. The performance evaluation confirms that the system is capable of supporting real-time energy monitoring applications. overall, the project achieves its intended objectives and demonstrates a practical solution for energy management. The system provides a strong foundation for further development and can be effectively applied in industrial environments to improve energy efficiency and system reliability.

IX. FUTURE SCOPE

Centralized energy management system developed in this project is effective, but there are some opportunities for improvement and enhancement. These enhancements can add to the system's functionality, flexibility and efficiency. A key improvement that could be made is by remote monitoring. The system can be accessed remotely from computers and mobile devices through online communication. This would enable users to access the electrical parameters anywhere which would increase the convenience and accessibility for the users. One more potential enhancement is to include cloud storage. It is possible to upload data to a cloud platform rather than storing it locally. This would ensure the data was more secure, could be easily accessed to historical data and would assist large-scale data analysis. The system can also be enhanced by adding advanced data analytics features. System efficiency can be improved by implementing techniques like trend analysis, predictive maintenance and energy optimization. Such characteristics will assist in the identification of possible problems before they happen and will minimise energy losses. Further, the system may be expanded to incorporate automatic control functions. For instance, the system can be set up to take corrective measures based on specific operating parameters like turning off loads during high demand, or automatically correcting power factor. Flexible and simple wiring can also be achieved using wireless communication technologies. This would facilitate installation and growth of the system. In addition, incorporating charts and trends would enhance the dashboard. This would facilitate data analysis and knowledge on the functioning of the system. The system is generally very well suited for development in the future. It can be upgraded with sophisticated technologies to make it a smarter, more efficient energy management system for use in today's industrial applications.

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