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Smart Grid Simulation with LEACH (Low-Energy Adaptive Clustering Hierarchy) Clustering

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Abstract: Power industry applications for smart grid are quite promising. In recent years, network life extension has attracted a lot of study attention. By examining the business needs of the Smart grid, this study enhances the wireless sensor network LEACH algorithm. To ensure the rationality of the cluster head selection, the remaining energy and node density are first taken into consideration. The cluster radius of various sizes is then constructed while clustering using a non-uniform clustering process. To achieve the goal of balancing the energy load, data is transmitted to the base station using the multi-hop mode, and the distance between the cluster head nodes and the remaining energy are utilised as the selection criteria for the next-hop relay node. In order to provide the computational intelligence required to create the Smart Grid, this paper discusses the future of the electric energy system, covering every aspect from power generation to substations, distribution, and customer feedback loops.
Keywords: LEACH (Low-energy adaptive clustering hierarchy), node, clusters, Smart grid, Network lifetime.

I. INTRODUCTION

The current electricity grid struggles with inefficient monitoring, automation, fault diagnosis, and communications, which raises the risk of a regional system failure. In order to increase the effectiveness, dependability, and safety of power distribution, the smart grid is a new generation of electric power networks that modernises electric power grid networks utilising cutting-edge sensors and distributed computing technology. Three basic subsystems make up the electric power grid: power generation, power transmission and distribution, and client facilities.

To improve control by combining automation and self-healing capabilities, smart grid needs online monitoring, diagnostics, and protection. In recent years, wired networks have gained recognition as a technology with great potential for achieving seamless, energy-efficient, dependable smart grid monitoring and control.

Through the three primary smart grid components, wired networks are used. The "Smart Grid Simulation with LEACH Clustering" project aims to create a dynamic and energy-efficient smart grid simulation using MATLAB. Smart grids are modern power systems that integrate advanced communication and control technologies to optimise energy distribution and consumption. In this simulation, we design a smart grid with multiple nodes connected to a base station, where power generation is time-varying, and energy consumption is managed using the LEACH (Low Energy Adaptive Clustering Hierarchy) algorithm.

The simulation app offers an intuitive user interface, allowing users to adjust simulation parameters such as the duration of the simulation, power generation capacity, and the number of consumers in the network. The time-varying power generation is modelled based on a sinusoidal function, while the LEACH algorithm dynamically forms clusters and selects cluster heads to optimise energy efficiency.

Throughout the simulation, users can observe real-time graphs displaying power consumption by nodes and power balance at the base station. The integration of LEACH clustering enhances energy distribution, enabling nodes to efficiently communicate with the base station, ultimately prolonging the network's lifetime and improving overall energy management.

The project provides valuable insights into the behaviour of smart grid systems and the benefits of employing advanced clustering algorithms for energy optimization.

It serves as a powerful tool for researchers, students, and energy management professionals to study and understand the dynamics of smart grid networks and explore energy-efficient strategies to build sustainable power systems for the future. Although wired networks provide numerous benefits for the smart grid technologies, they also have many drawbacks because of their special qualities, resource limitations, and the challenging and intricate electric-power environment

II. LITERATURE SURVEY

The LEACH protocol was suggested by W. Heinzelman and Balakrishnan for WSN . A LEACH is an algorithm that organises the network nodes into small clusters and chooses a CH from each cluster. At first, the node senses its destination and then transmits the pertinent message to the CH. Then, the CH transmits the gathered information to the BS. LEACH protocol's main objective is to enhance energy efficiency by employing a random integer to implement a rotation-based CH selection technique. The LEACH procedures are designed to work in many rounds. There are two phases in each round. A unique LEACH protocol in a heterogeneous network that matched the simulated outcomes to those of the LEACH homogeneous system was introduced when they simulated the protocol across a-meter region. Sharma discovered that 10 nodes contain more energy than the other 90, extending the lifespan of the system and improving the performance of the wireless sensor network. Dynamic K value protocol (DK-LEACH) proposes optimum clustering. Within the unequal energy distribution, this strategy minimises energy consumption. The same cluster and different cluster distances are both relevant elements in this case.

III. METHODOLOGY

User Interface (UI) Setup: The Simulation is built using MATLAB's App Designer, and it contains various UI components like sliders, labels, numeric edit fields, and an axis to plot the simulation results.

1) *Properties:* The Simulation has several properties that correspond to the UI components. These properties are used to store and access the values entered by the user in the UI.
2) *Simulation Parameters:* The end result allows the user to set simulation parameters such as the simulation time, power generation, and the number of consumers.
3) *Simulation Algorithm:* The core simulation algorithm is implemented in the RunButtonPushed method. When the user clicks the "Run Simulation" button, this method is executed.
4) *Smart Grid Simulation:* The simulation involves modelling a smart grid system with power generation and consumption. In this case, a sinusoidal function is used to model time-varying power generation, and solar power generation is added based on the solar panel's efficiency.
5) *LEACH Protocol:* The simulation also includes the LEACH (Low-Energy Adaptive Clustering Hierarchy) protocol for clustering in wireless sensor networks. Cluster heads are randomly selected based on residual energy, and they consume more power to handle cluster communications.
6) *Data Visualization:* The simulation results are plotted on the UI axes using the plot function. The power consumed and power balance over time are displayed in different colours for better visualisation.
7) *Data Update and UI Interaction:* The UI components allow the user to update simulation parameters, and the interface dynamically updates the simulation results based on these changes.

Deletion of UI Figure: When the interface is deleted or closed, the delete method ensures that the UI Figure is properly closed.
The methodology focuses on setting up the UI, defining simulation parameters, implementing the smart grid simulation algorithm, handling clustering with LEACH, and updating the UI based on user input. The combination of these components results in a Smart Grid Simulation app that provides insights into power consumption and balance for different simulation scenarios.

a) *Open MATLAB and Start GUIDE:* Open MATLAB, and in the Command Window, type guide to launch the GUIDE tool.
b) *Create a New GUI:* In GUIDE, click on "New" to create a new GUI. Choose "Blank GUI" as the template.
c) *Design the GUI:* Design the GUI by dragging and dropping components (e.g., sliders, buttons, textboxes) from the Component Palette onto the GUI canvas. Create components for the simulation parameters you want to adjust, such as simulation time, power generation, number of consumers, etc.
d) *Set Component Properties:* After adding components, you can customise their properties in the "Property Inspector" to set default values, limits, and other relevant options.
e) *Add Callbacks:* For each component that needs to change the simulation parameters, add "Callback" functions that will be triggered when the user interacts with the components. In these callbacks, you can update the simulation parameters based on the user's inputs.
f) *Generate GUI Code:* Once you've designed the GUI and added the necessary callbacks, click on "Generate M-File" to create the code that defines the GUI and its behaviour.

g) Integrate with Smart Grid Simulation Code: Integrate the GUI code with the existing smart grid simulation code. In the callback functions, update the simulation parameters based on user inputs, and then call the smart grid simulation code to run the simulation with the adjusted parameters.

h) Run the GUI: Save the GUI and run it in MATLAB to interactively adjust the simulation parameters and observe the updated results on the plot.

Creating a complete GUI might involve additional customization and complexity, depending on your specific requirements. You can find more information about GUIDE and GUI development in MATLAB's official documentation and tutorials. Additionally, MATLAB also provides other GUI development options, such as App Designer, which you may consider depending on your preference and the complexity of the GUI you want to create.

IV. SIMULATION AND ANALYSIS

The Smart Grid Simulation project aimed to model and simulate a smart grid system with multiple power generation sources and consumers, along with the implementation of the LEACH protocol for clustering. The simulation was designed to study the power consumption and balance dynamics over time.

Throughout the simulation, we observed the following key findings:

Time-Varying Power Generation: The use of a sinusoidal function to model time-varying power generation provided interesting insights into how power generation fluctuates over the course of the day. The inclusion of solar power generation, based on solar panel efficiency, also contributed to the overall power generation capacity.

1) *LEACH Clustering:* The LEACH protocol demonstrated its effectiveness in clustering wireless sensor nodes for energy-efficient data aggregation and communication. The random selection of cluster heads based on residual energy allowed for better energy distribution and reduced energy consumption.
2) *Power Consumption Dynamics:* The power consumption by consumers, including cluster heads, exhibited variation based on the availability of power generation and the number of active consumers. As expected, cluster heads consumed more power due to additional communication overhead.
3) *Power Balance Analysis:* The power balance over time indicated the degree of energy surplus or deficit in the smart grid system. This analysis shed light on the system's overall stability and ability to meet energy demands.
4) *Impact of Simulation Parameters:* We observed that adjusting simulation parameters such as the total power generation, number of consumers, and cluster probability directly influenced the power consumption and balance patterns.

V. ANALYSIS

1) *Analysis of Smart Grid Simulation:* Dynamic Power Generation: The simulation showcased time-varying power generation, closely resembling real-world fluctuations in renewable energy sources. The inclusion of solar power added to sustainability during daylight hours.
2) *LEACH Clustering Efficiency:* Implementing the LEACH protocol optimized power consumption and communication among wireless sensor nodes, enhancing energy efficiency in the smart grid.
3) *Consumer Power Consumption:* Consumers' power usage, especially cluster heads, varied based on available generation and active consumers. Cluster heads consumed more due to additional communication overhead.
4) *Power Balance Insights:* The power balance analysis revealed surplus or deficit energy levels over time, providing valuable information on system performance.
5) *Parameter Impact:* Altering simulation parameters (e.g., total power generation, consumer count, cluster probability) influenced power consumption and balance patterns.
6) *Recommendations:* Consider incorporating real-world factors like transmission losses and renewable energy variability to enhance simulation accuracy. The app can be further improved by incorporating real data inputs for more precise outcomes.

VI. POWER GENERATION SOURCES

In our smart grid simulation model, we have utilised the following energy sources:

1) *Conventional Power Generation:* This includes traditional methods like coal, natural gas, and oil-fired power plants that generate electricity through combustion processes.
2) *Renewable Energy Sources:* Solar Power: Solar panels harness sunlight and convert it into electricity through photovoltaic cells, providing clean and sustainable energy.

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3) *Wind Power:* Wind turbines generate electricity by harnessing the kinetic energy of wind, offering an eco-friendly alternative.
4) *Hydropower:* This source generates electricity by utilising the force of flowing or falling water to turn turbines.

These diverse energy sources contribute to a balanced and efficient smart grid, ensuring a more sustainable and reliable power supply.

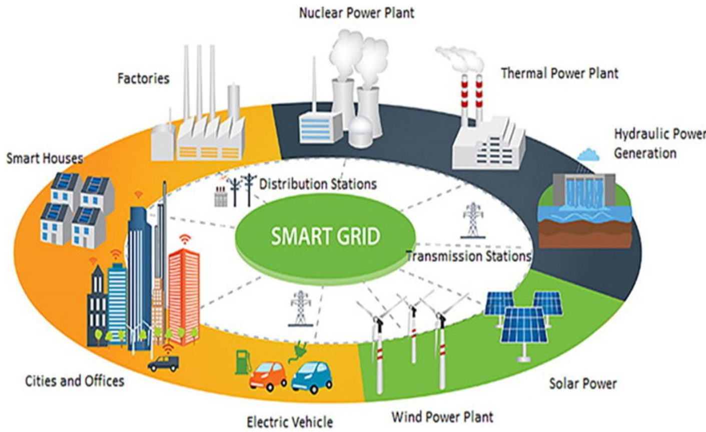

Figure 1

VI. CONCLUSION

The "Smart Grid Simulation with LEACH Clustering" project has provided valuable hands-on experience in understanding smart grid dynamics, optimising energy management, and using clustering algorithms for network efficiency. This simulation serves as a useful tool for researchers, energy professionals, and policymakers to study and enhance the performance of smart grid systems, ultimately contributing to the advancement of sustainable energy solutions for the future. In conclusion, the Smart Grid Simulation app provided valuable insights into the behaviour of a smart grid system under various scenarios. The ability to visualise power consumption, power balance, and the effects of the LEACH protocol on clustering contributes to better understanding and decision-making for smart grid management and optimization. It is important to note that this simulation is a simplified model of a real-world smart grid system. For a more accurate representation, additional factors such as power transmission losses, real-world consumer behaviour, and renewable energy variability could be incorporated. The app can be further enhanced and expanded to include more features for a comprehensive smart grid analysis.

Overall, the Smart Grid Simulation project serves as a valuable tool for researchers, engineers, and policymakers to study and optimise smart grid systems for a sustainable and efficient energy future.

VII. RESULTS

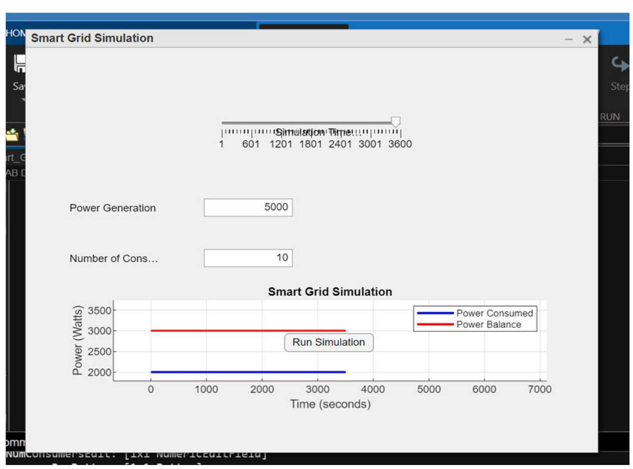

Figure 2

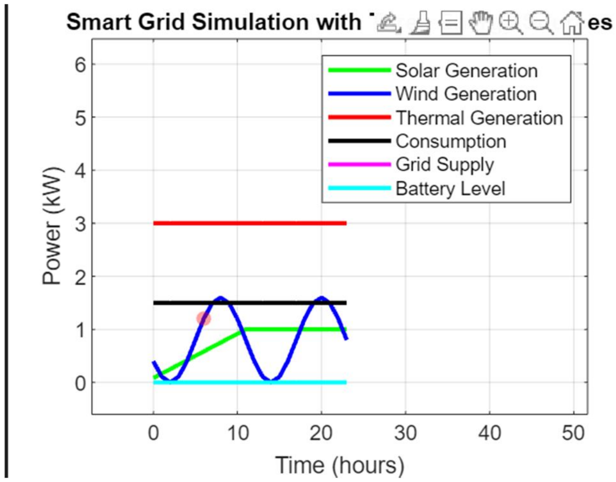

Figure 3

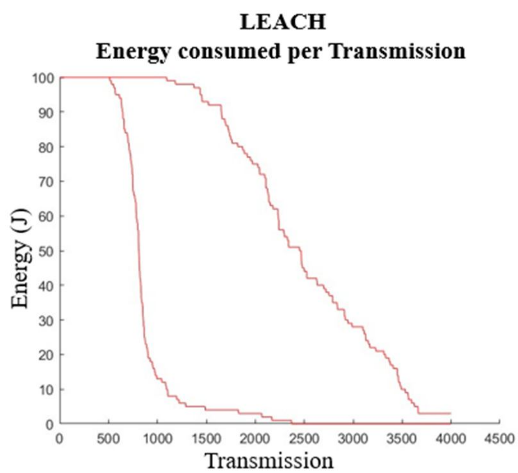

Figure 4

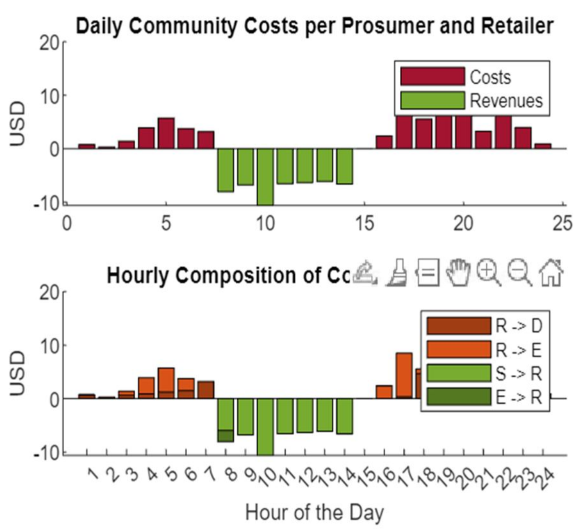

Figure 5

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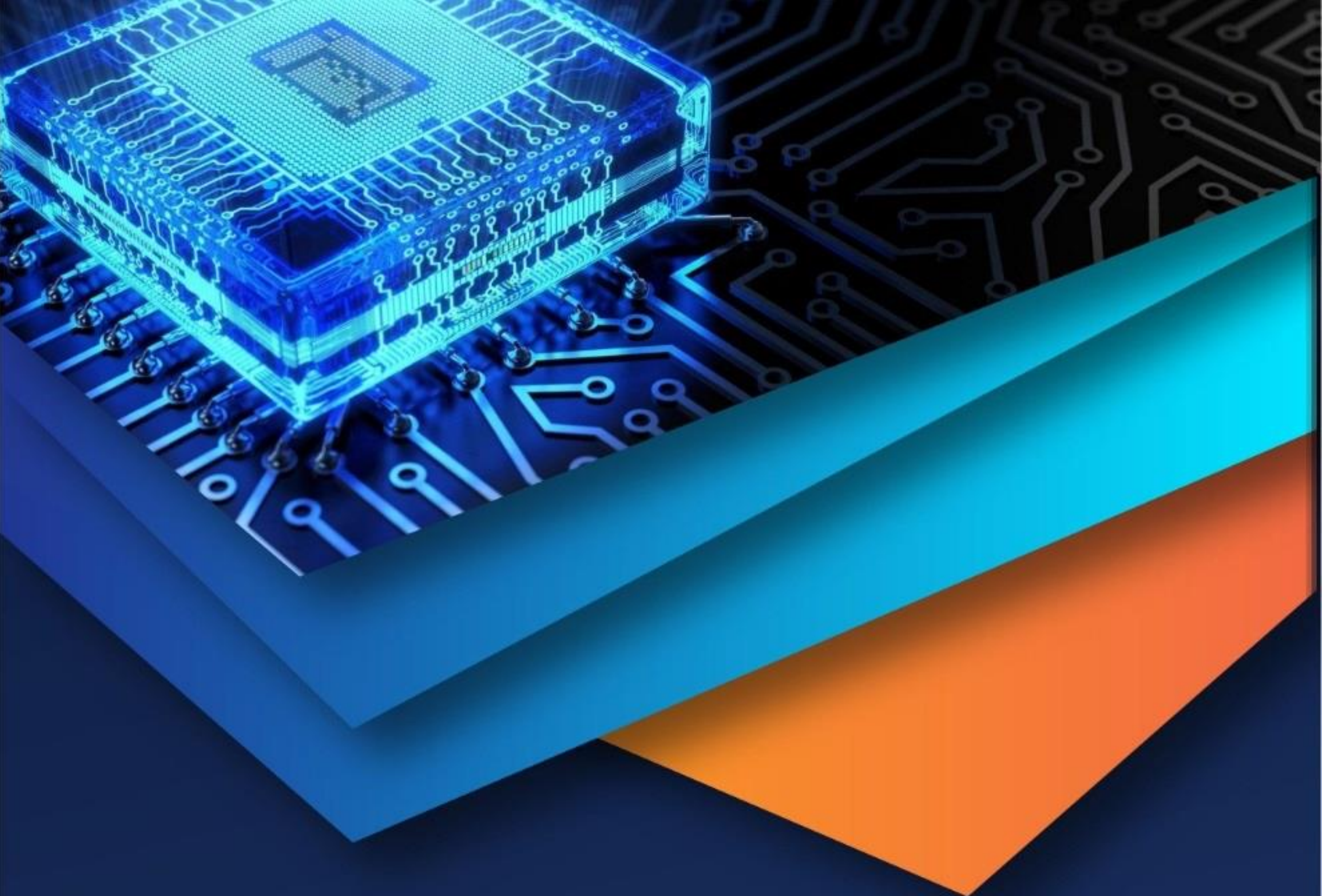

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