INTELLIGENT ENERGY MANAGEMENT SYSTEM (IEMS) FOR SMART GRIDS

1. Introduction

The global shift towards renewable energy sources, such as solar and wind, has created new challenges in modern power systems. These resources are inherently variable and intermittent, while consumer load demand fluctuates throughout the day. Without intelligent coordination, this leads to over-dependence on the utility grid, higher operational costs, underutilization of renewable energy, and reliability concerns during peak demand hours. An Intelligent Energy Management System (IEMS) ensures optimized allocation of renewable sources, battery storage, and grid supply, thereby improving efficiency, reliability, and sustainability.

2. Objectives

The key objectives of the project are: - To design and implement an IEMS model using MATLAB/Simulink. - To supply a variable load using solar, wind, battery storage, and grid. - To prioritize renewable sources (solar and wind), then battery, and use the grid as a last resort. - To minimize grid dependency and electricity cost. - To demonstrate metrics such as renewable penetration, grid dependency, and system reliability.

3. Methodology

3.1 Input Profiles : A 24-hour dataset was generated for solar, wind, and load demand to mimic realistic daily variations. - Solar Profile: Zero during night, peaking during midday. - Wind Profile: Fluctuating values throughout the day. - Load Profile: Higher in morning and evening, lower during off-peak hours. Example MATLAB script for inputs:

Command Window

```
>> time = (0:23)';  % 24 hours, column vector

Solar = [0 0 0 0 0.5 1 2 3 4 5 5.5 6 6 5.5 5 4 3 2 1 0.5 0 0 0 0]';
Wind  = [2 2.5 3 3 2.5 2 1.5 1 1 1.5 2 2.5 3 3 2.5 2 1.5 1 1 1.5 2 2.5 3 3]';
Load  = [4 4 4 5 5 6 7 7 6 5 5 5 6 7 8 8 7 6 5 5 4 4 4 4]';

% Combine time and values
Solar_input = [time, Solar];
Wind_input  = [time, Wind];
Load_input  = [time, Load];

% Initial battery charge
Batt_init = 0;
fx >>
```

3.2 Energy Management Logic: The decision-making process follows a priority-based algorithm implemented in a MATLAB Function block: 1. Solar: First priority. Excess solar charges the battery. 2. Wind: Supplies demand when solar is insufficient. 3. Battery: Discharges to meet remaining demand. 4. Grid: Last priority, only when all other sources are insufficient.

4. Results and Observations

Simulation outputs were obtained using the Simulink Scope: - Solar Output (Yellow): Rises during the day, peaks at noon, falls in evening. - Wind Output (Blue): Fluctuates, available throughout the day. - Load Demand (Green): Peaks in morning and evening hours. - Battery Output (Purple): Discharges when demand > (solar + wind). - Grid Output (Red): Supplies energy only when demand cannot be met by renewable + battery. Observation: The IEMS effectively prioritizes renewable energy, minimizes grid reliance, and ensures reliable power supply at all times.

5. Conclusion

This project demonstrates that an Intelligent Energy Management System (IEMS) can efficiently integrate solar, wind, battery storage, and the grid to supply variable demand. By prioritizing renewables and optimizing resource allocation, the system reduces grid dependency, increases renewable energy utilization, and provides reliable and cost-effective power. Future enhancements can include forecasting algorithms, real-time data integration, and demand-side management for deployment in smart grid environments.

6. Appendix :

Figure 1: Simulation Block Diagram

Figure 2: MATLAB Function Code

Figure 3: Output of Solar, Wind, Battery, Grid, and Battery State

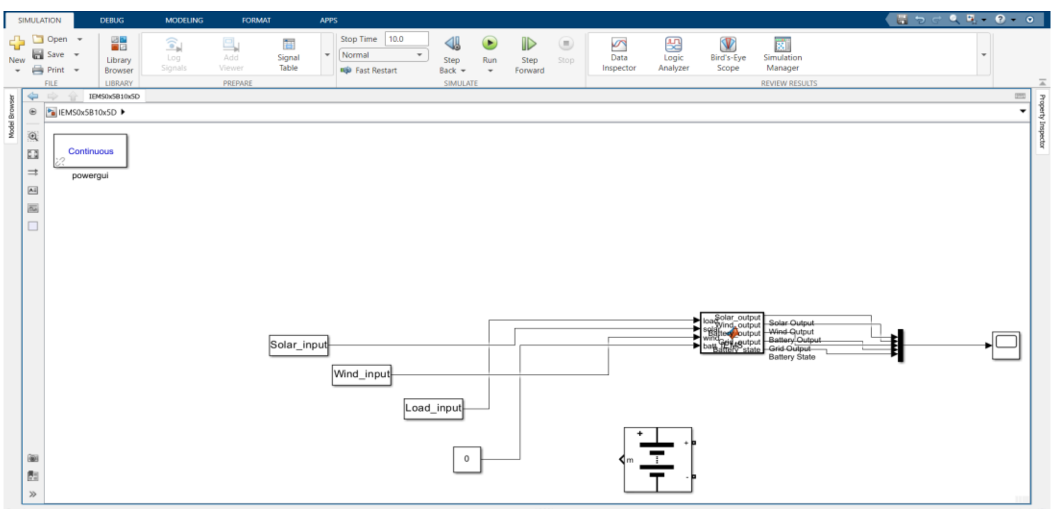

Figure 1

```
function [Solar_output, Wind_output, Battery_output, Grid_output, Battery_state] = IEMS(load, solar, wind, batt)
    % Battery maximum capacity
    batt_capacity = 10;    % kWh

    % Initialize outputs
    Solar_output = 0;
    Wind_output = 0;
    Battery_output = 0;
    Grid_output = 0;

    demand = load;

    % 1. Solar first
    if solar >= demand
        Solar_output = demand;
        batt = min(batt + (solar - demand), batt_capacity);
        demand = 0;
    else
        Solar_output = solar;
        demand = demand - solar;
    end

    % 2. Wind next
    if demand > 0
        if wind >= demand
            Wind_output = demand;
            demand = 0;
        else
            Wind_output = wind;
            demand = demand - wind;
        end
    end

    % 3. Battery next
    if demand > 0
        if batt >= demand
            Battery_output = demand;
            batt = batt - demand;
            demand = 0;
        else
            Battery_output = batt;
            demand = demand - batt;
            batt = 0;
        end
    end

    % 4. Grid last
    if demand > 0
        Grid_output = demand;
        demand = 0;
    end

    % Output updated battery state
    Battery_state = batt;
end
```

Figure 2

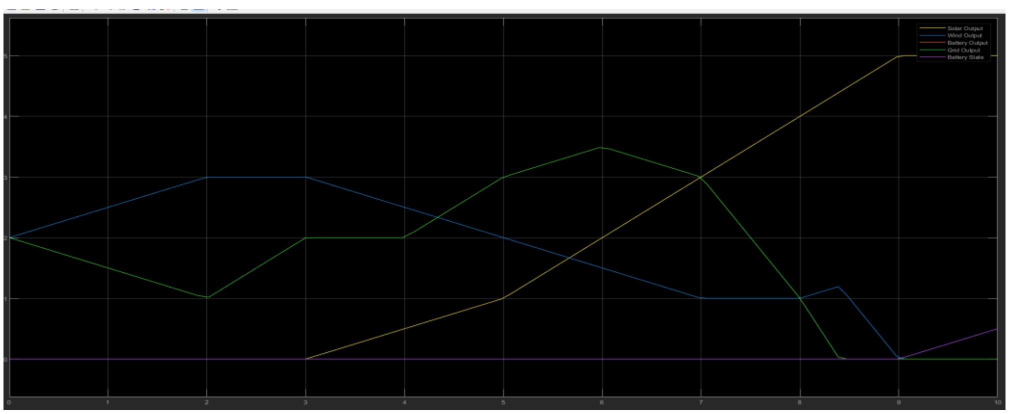

Figure 3

7. Conclusion:

This project simulated solar, wind, and load variations in MATLAB, showing realistic fluctuations and integration challenges. It highlights solar's daytime dependence, wind's variability, and the need for matching load with renewables, with future scope in real data, forecasting, and storage integration.

P. Pavani - 23WH1A0240

Y. Roshini - 23WH1A0248

K. Akshara - 23WH1A0213