Load Scheduling with Integration of RES and BESS System to Grid

EEE300 MINI PROJECT REPORT

submitted by

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towards partial fulfillment of the requirements for the award of the degree of

Bachelor of Technology
In
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School of Electrical & Electronics Engineering

SASTRA DEEMED TO BE UNIVERSITY

(A University established under section 3 of the UGC Act, 1956)

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This is to certify that the mini project work entitled "**Load Scheduling with Integration of RES and BESS System to Grid**" is a bonafide record of the work carried out by

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Examiner-I **Examiner-II**

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Declaration

We declare that the report titled "**Load Scheduling with Integration of RES and BESS system to grid**" submitted by us is an original work done by us under the guidance of **Dr. K. Narayanan, Sr. Asst. Professor, School of Electrical and Electronics Engineering, SASTRA Deemed to be University** during the academic year 2024-25, in the **School of Electrical and Electronics Engineering**. The work is original and wherever We have used materials from other sources, We have given due credit and cited them in the text of the report. This report has not formed the basis for the award of any degree, diploma, associate-ship, fellowship or other similar title to any candidate of any University.

Signature of the candidate(s) :

Name of the candidate(s) **: Maanasa N.S**

: Theresa Merlin.S

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Date **:** 09 / 11 / 2024

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ABSTRACT

Keywords: Renewable Energy Source, Distributed Generator, Time Tagged Price, Commercial loads, Residential loads

The work aims to explore the cost efficiency of the Distribution system with the integration of RES and BESS. Two bus systems, namely the IEEE 33 and 69 bus systems are considered, with two scenarios, each displaying a different loading scenario. The work aims to integrate two RES, namely wind and solar energy based on the load demands of the test systems. The total loads per hour are segregated into Fixed, Curtailable, and Controllable loads which are then scheduled to find the optimal solution considering the price and reliability of the grid. With the results obtained, the work aims to integrate a BESS to manage the intermittency of the RES integrated, for continuous, uninterrupted power supply.

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ABBREVIATIONS

RES	Renewable Energy Source
DG	Distributed Generator
BESS	Battery Energy Storage System
PV	Photo Voltaic
TTP	Time Tagged Price
GA	Genetic Algorithm
Comm	Commercial loads
Res	Residential loads
SoC	State of Charge
ADHDP	Action-Dependent Heuristic Dynamic Programming
HVAC	Heat Ventilation and Air Conditions
LOT	Lyapunov Optimization Technique
MIQCP	Mixed Integer Quadratically Constrained Programming
Sch	Scheduled loads

NOTATIONS

P_t	Real power generated out of bus t.
Q_t	Reactive power generated out of bus t
Q'_t	Reactive power initiating out of bus k after re-configuration.
P_{Lt+1}	Real load power at bus t+1.
Q_{Lt+1}	Reactive load power at bus t+1.
$P_{(Loss(t,t+1))}$	Loss in the line connecting buses t and t+1
R_t	Line resistance between buses t and t+1.
X_t	Line reactance between buses t and t+1.
V_t	Voltage at bus t.
Y_t	Shunt admittance at any bus t.

CHAPTER 1

INTRODUCTION

The increasing global demand for electricity, driven by population growth and industrial development, combined with concerns over climate change and energy security, has prompted a significant shift towards more sustainable energy solutions. Renewable Energy Sources (RES), particularly wind and solar energy, have become crucial in transitioning from fossil fuel-based power generation to cleaner, more sustainable alternatives. However, the intermittent nature of RES, such as fluctuations in solar irradiance and wind speed, poses challenges for ensuring a reliable and stable electricity supply.

Battery Energy Storage Systems (BESS) have emerged as a key enabling technology to address these challenges. BESS helps to store excess energy generated during periods of high RES availability and dispatch it during times of low generation or peak demand. This capability not only improves grid resilience but also enhances the economic efficiency of RES by enabling better load matching and reducing the reliance on conventional, carbon-intensive energy sources. The integration of RES and BESS is, therefore, crucial for optimizing energy distribution systems and achieving sustainability goals.

This work presents a comprehensive analysis of the cost efficiency of distribution systems integrated with both RES (wind and solar energy) and BESS. By developing an optimal load scheduling strategy, the study aims to minimize overall energy costs while ensuring grid reliability. Using the IEEE 33 and 69 bus systems as test cases, this research evaluates the performance of the proposed scheduling strategy under different operational scenarios, providing valuable insights into the economic and technical benefits of integrating RES and BESS into modern distribution systems. The findings of this research can inform the development of more sustainable, resilient, and cost-effective power distribution networks, contributing to the global transition towards clean energy.

CHAPTER 2

REVIEW OF LITERATURE

The analysis of the positions of Distributed Generator (DG) and the integration of transmission and distribution systems is done in [1]. [2] presents a new method to solve the network reconfiguration problem in the presence of DGs to minimize real power loss and improve the voltage profile in the distribution system. [3] explores the utilization of demand response and load shifting in hybrid microgrid systems. The load demand is predicted through Convolutional Neural Network (CNN) and the joint dispatch of energy and spinning reserve capacity performed with the integration of RES and BSS (Battery Storage System) to satisfy the expected load demand and penalize undesired outcomes in [4]. [5] explores the optimal arrangement of DG using Genetic Algorithm (GA) obtained based on fixed penetration level. The State of Charge (SoC) value for each hour before placing the battery based on the demand is estimated, and the battery is placed in the optimal location of the fixed capacity. When integrated with a RES, techniques of network optimization and network penetration of DGs are explored in [6] and [7]. These methods focus on optimizing the performance of the network. [8] explores using renewable energy to schedule residential loads considering the hour of the day and the price of power. Similar to this, the integration of renewable energy in a smart grid is explored in [9]. The work explained also emphasizes the importance of an algorithmic approach for the strategic scheduling of loads. The scheduling of micro-grid loads and the integration of RES is explored in [10]. [11] focuses on scheduling the loads such that maximum demand response is achieved. The integration of two different RES, microturbines, and EVs are explored in [12]. [13] explores the various sizes of BESS across various test cases, including the IEEE 33 and 69 Bus systems.

Furthermore, [14] focuses on scheduling algorithms for distribution systems incorporating Photo Voltaic (PV) and Battery Energy Systems (BES), aiming to minimize costs and manage renewable energy and storage systems. Joint load scheduling and voltage regulation integrating solar, wind, and hydropower are discussed in [15] and optimal scheduling incorporating Distributed Generators (DGs) with renewable energy and battery systems is explored in [16]. The integration of Renewable Energy Sources (RES), particularly solar energy, into smart grids poses significant challenges due to their inherent variability and intermittency, which is addressed in [17], by proposing an optimal scheduling mechanism aimed at enhancing the efficiency and reliability of smart grids. By advanced algorithms, the proposed method seeks to minimize operational costs and promote sustainable energy practices.

Integrating solar energy generation with load management strategies studied in [18], enhances their energy efficiency and reliability. It helps in reducing operational costs, minimizing the dependency on non-renewable energy sources, and contributing more to sustainable energy. [19] proposes a residential energy scheduling for solar energy in smart grids, which involves managing household loads, storage batteries, utility grids, and renewable resources. It introduces an Action-Dependent Heuristic Dynamic Programming (ADHDP) method for enhancing microgrid's efficiency. It reduces electricity costs and improves load balancing, performing the PSO algorithm. [20] presents a method to minimize overall cost and maintain home comfort by optimizing Heat Ventilation and Air Conditions (HVAC), Electric Vehicle (EV), and Energy Storage System (ESS) with the help of the Lyapunov Optimization Technique (LOT). Integration of RES and ESS is approached by using Demand Response (DR) [21] which gives a reduction in operational cost in microgrids. Mathematical methods like Mixed Integer Quadratically Constrained Programming (MIQCP) and CPLEX solver are used in General Algebraic Modeling System (GAMS) to optimize the investment cost and to enhance the lifespan of ESS. With the above in consideration, the objectives of the work include strategizing the scheduling of loads over the hours of the day to achieve the lowest price possible.

CHAPTER 3

SCOPE OF THE PRESENT WORK

The objectives of this work are:

- Minimization of energy costs through load scheduling.
- Integration of solar and wind-generated energy to reduce consumer bills.
- Optimal load scheduling for cost-effective energy utilization.
- Integration of BESS for improved system resilience.

CHAPTER 4

EXPERIMENTAL PROCEDURES

This chapter discusses the various strategies employed to schedule loads and integrate both solar and wind-generated energy as Renewable Energy Sources (RES). The integration of solar and wind energy allows for a more comprehensive approach to optimizing energy utilization while considering economic constraints. Initially, each RES is integrated separately to analyze their individual impacts on load scheduling and system efficiency. Subsequently, both solar and wind energy are combined to further enhance system performance and cost-effectiveness. Finally, the system is integrated with a Battery Energy Storage System (BESS), which enables better energy management by storing excess energy during periods of low demand and releasing it when needed. This combined approach ensures optimal load scheduling, improved energy utilization, and reduced overall operational costs.

4.1 Test Cases

Two different loading cases have been considered for the work done. In each of these, different time frames and system conditions have been taken into consideration, for more precise results. The positions of DGs are assumed to be the same as shown in the topology diagrams, for both the IEEE 33 and 69 buses. Two different scenarios are considered, along with two topologies of both bus systems.

4.1.1 Test Case 1

For this case, the IEEE 33 bus as shown in Fig 4.1 is considered. Here, two scenarios are considered and the peak load limit per hour is 3715 kW. The data for loads per hour is taken from [1] and the data for solar and wind energy generated per hour is taken from [2]. The load variations for the scenarios considered are as shown in Fig 4.2 and Fig 4.3.

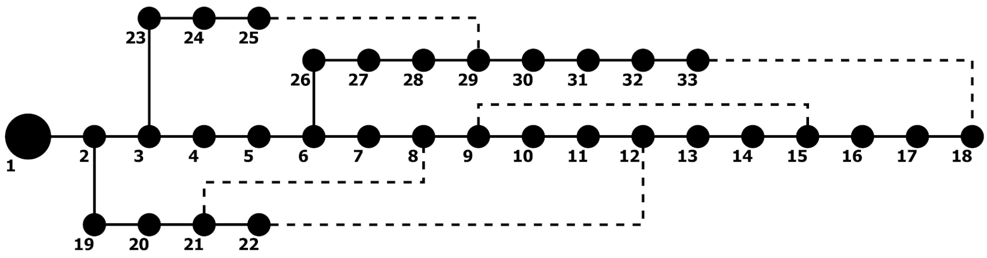

Figure 4.1: Single Line Diagram with Tie Lines of 33 bus system

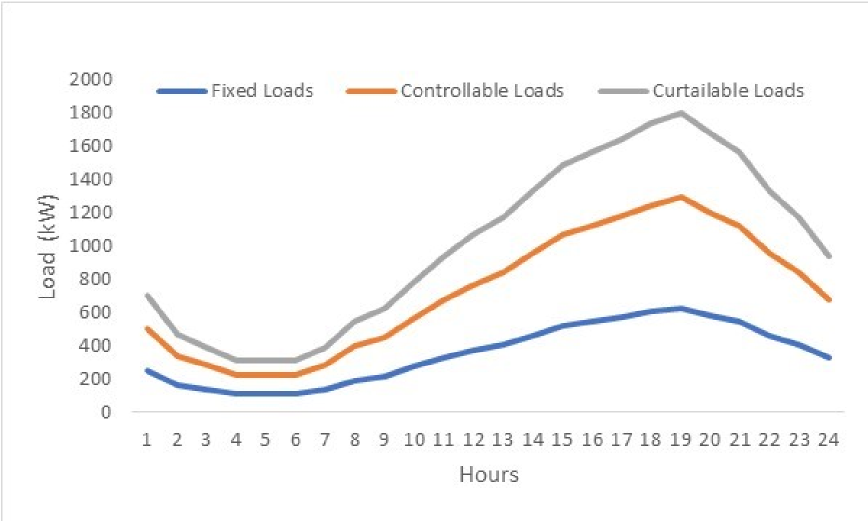

Figure 4.2: Load curve of IEEE 33 bus system Scenario-1

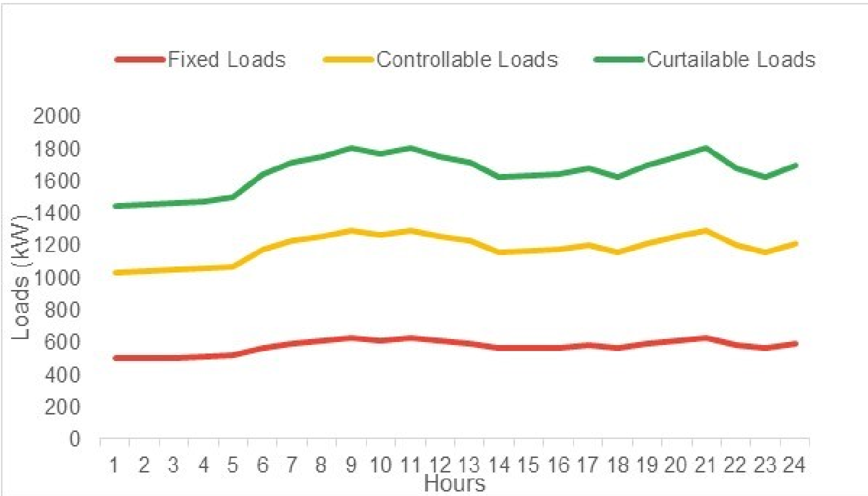

Figure 4.3: Load curve of IEEE 33 bus system Scenario-2

4.1.2 Test case 2

For this case, the IEEE 69 bus shown in Fig 4.4 with two different scenarios is considered. Here the peak load limit per hour is 3849.89 kW. The data for loads per hour is taken from [1] and the data for wind energy generated per hour are taken from [2]. The load variation for the scenarios considered is as follows in Fig 4.5 and 4.6 respectively.

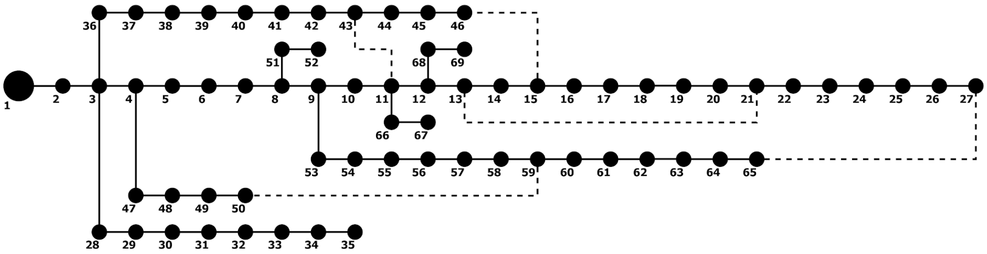

Figure 4.4: Single Line Diagram with Tie Lines of 69 bus system

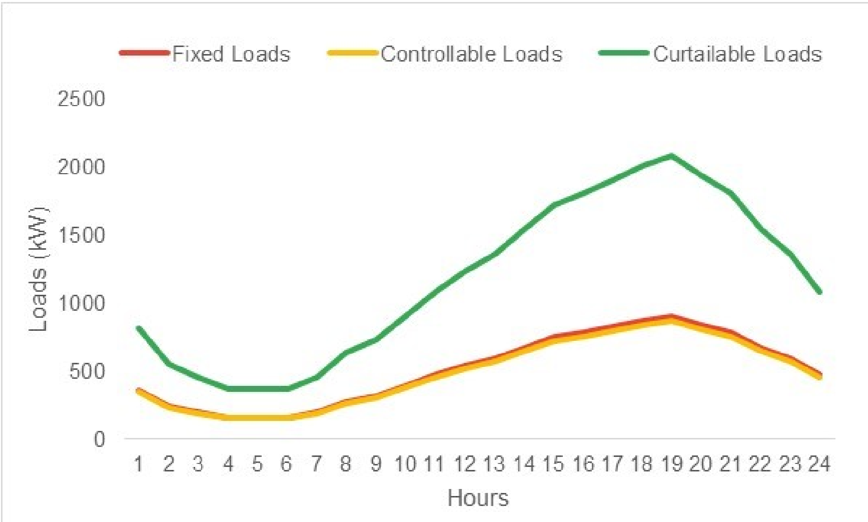

Figure 4.5: Load curve of IEEE 69 bus system Scenario-1

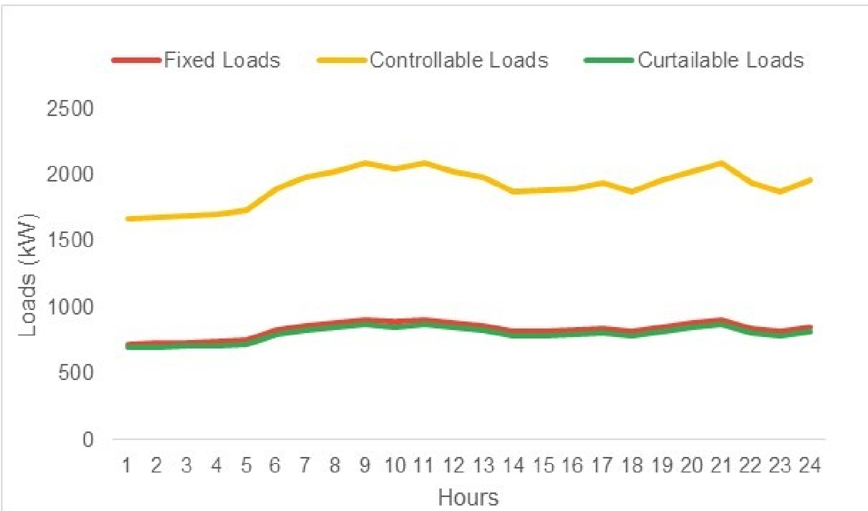

Figure 4.6: Load curve of IEEE 69 bus system Scenario-2

4.2 Time Tagged Pricing

According to the Time Tagged Pricing (TTP), the cost per kWh varies with respect to each hour. The main aim is to reduce total cost of operation. It is scheduled with a strategy where more loads are to be scheduled during hours with lower TTP. TTP data for an 24-hour period is provided in Table 3.1. This data sourced from [2], is used to schedule the loads in this work.

Table 4.1: TTP Data

Hour	Price($kWh)	Hour	Price($kWh)
1	0.033	13	0.215
2	0.027	14	0.572
3	0.02	15	0.286
4	0.017	16	0.279
5	0.017	17	0.086
6	0.029	18	0.059
7	0.033	19	0.05
8	0.054	20	0.061
9	0.215	21	0.181
10	0.572	22	0.077
11	0.572	23	0.043
12	0.572	24	0.037

4.3 Principle

When the cost of energy (TTP) is low, more load is scheduled, and when the cost of energy is high, less load is scheduled. This focuses mainly on minimizing the cost of a distribution system. The values of costs are taken from Table 4.1. The process of scheduling is shown as a flowchart in Fig 4.7 for multiple cases.

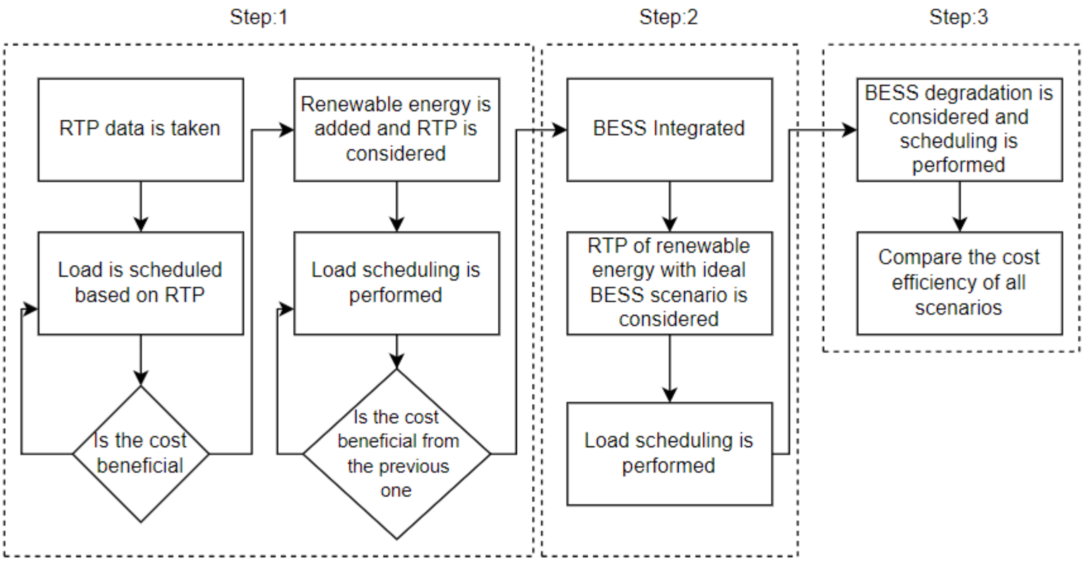

Figure 4.7: Flowchart for Proposed Algorithm

4.3.1 Case-1: Scheduling of Controllable loads

Step-1: The loads for three different utilities are collected for 24 hours, which include: Fixed loads – loads that cannot be altered throughout the day. These include small industries, agricultural utilities, etc. Controllable loads – loads that can be shifted over the hours of the day, but not cut down. These loads must be fulfilled but can be shifted through the hours of the day. These include commercial loads, such as businesses, storage units, etc. Curtailable loads – loads that can be shifted or reduced based on the demand of the hour. These include the residential loads of the day, which cover apartments and housing units. Based on this classification, the strategy to arrive at an economic solution for the scheduling has been devised as explained in further steps.

Step-2: This step deals with the organization of controllable loads. Here, the following strategy is utilized:

• The hours are compared with each other throughout the day. Hours that have the highest load are separated first.

• These loads are organized based on their respective Time Tagged Price (TTP), giving the hour with the highest price the most priority.

• After this, hours with the least TTPs are organized, with the hour having the least TTP when compared to giving the most priority.

• With this classification, the hours with the highest and lowest TTPs are zeroed in and compared with each other in terms of their loads.

• If the load of the hour with a higher TTP is larger than the hour with a lower TTP, the load values are subtracted to find the difference.

• This difference is taken and added to the hour with the lower TTP, hence reducing the load on the hour with high TTP.

This method of organization is followed until the loads are scheduled at the lowest possible price.

Step-3: This step focuses on keeping the total loads within the limit per hour, with a strategy as follows:

• Once the curtailable loads are shifted, the total load per hour is evaluated.

• At this step, the new total load for the entire day will be equal to the initial total load calculated.

• When comparing the per-hour total load, which is the sum of the three different loads considered, the newly obtained value of the load must not exceed the peak limit per hour.

In a situation where it does exceed the peak load limit, the new value of the total load is subtracted from the set peak load and the difference is shifted to a different hour that fulfills the set constraints.

Step-4: This step focuses on the scheduling of curtailable loads. The following strategy is utilized to schedule the loads:

• Once step 3 organization is completed, the total load per hour is calculated and the cost for the following is also calculated. The load prices are compared hour to hour with the initial price corresponding to the unhampered values of the data.

• Since the method focuses on obtaining a solution with the least price, the residential loads are curtailed when a particular case arises as follows:

– When the newly computed load exceeds the peak load limit at an hour, the new load is subtracted from the peak limit to find the difference.

– This difference is then curtailed from the residential load value at an hour where the price is higher than the other hours comparatively.

This method is not actively utilized in the work done, since curtailing the loads would lead to the grid. Though the method would yield a solution that has a considerably low price for the given period of 24 hours, it may not be the best method when real-life situations are considered.

Within the four steps of the organization explained above, the total price is expected to reduce, making a feasible method of organization that can be used in real-life situations.

4.3.2 Case-2: Integrating PV Energy

In this, two different methods have been analyzed, wherein, in the first method, PV is integrated into the system and loads are scheduled. In the second method, the controllable loads are shifted first for lower prices and PV is integrated.

Method I: Integration of PV with base controllable loads: PV energy is integrated into base commercial loads to achieve price reduction, resulting change in total load and price.

$$PV_{Commercial}(h) = L_{Commercial}(h) - PV(h) \tag{4.1}$$

where,

$PV_{Commercial}(h)$ is the commercial load obtained after integration solar energy,

$L_{Commercial}(h)$ is the initial commercial load considered before scheduling.

$PV(h)$ is the solar energy produced.

After the integration, the total load is calculated as follows:

$$L_{Total}(h) = PV_{Commercial}(h) + L_{Residential}(h) + L_{Industrial}(h) \tag{4.2}$$

where,

$L_{Total}(h)$ is the total load obtained after integration of PV,

$L_{Residential}(h)$ is the residential load present in h hour before scheduling,

$L_{Industrial}(h)$ is the industrial load present in h hour before scheduling.

$$L_{price}(h) = L_{Total}(h) * Price \tag{4.3}$$

$L_{Price}(h)$ is the total price calculated after integration of solar energy,

$Price$ is the cost of energy at 'h' hour.

Method II: Integration of PV with Scheduled Controllable Loads: In this method, the controllable loads are scheduled as per equations 4.1 to 4.3. However, the PV is integrated after the loads are scheduled considering the TTP.

4.3.3 Case-3: Integration of wind energy

in this, two different methods have been analyzed, wherein, in the first method, wind energy is integrated into the system and loads are scheduled. In the second method, the controllable loads are shifted first for lower prices and wind energy is integrated.

Method I: Integration of Wind energy with base Commercial loads: Wind energy is integrated into base commercial loads to achieve price reduction, resulting in a change in total load and price.

$$Wind_{Commercial}(h) = L_{Commercial}(h) - Wind(h) \tag{4.4}$$

where,

$Wind_{Commercial}(h)$ is the commercial load after the integration of wind energy,

$L_{Commercial}(h)$ is the initial commercial load considered before scheduling,

$Wind(h)$ is the wind energy produced during hour h.

After the integration, the total load is calculated as follows:

$$L_{Total}(h) = Wind_{Commercial}(h) + L_{Residential}(h) + L_{Industrial}(h) \tag{4.5}$$

where,

$L_{Total}(h)$ is the total load after wind energy integration,

$Wind_{Commercial}(h)$ is the result obtained from equation 4.1,

$L_{Residential}(h)$ is the residential load present in hour h before scheduling,

$L_{Industrial}(h)$ is the industrial load present in hour h before scheduling.

The price of energy consumption at hour h is calculated using the following equation 4.3.

$$L_{price}(h) = L_{Total}(h) * Price \tag{4.6}$$

where,

$L_{Price}(h)$ is the total price calculated after the integration of wind energy,

$L_{Total}(h)$ is obtained from equation 4.2,

$Price$ is the cost of energy at ‘h’ hour.

Method II: Integration of Wind Energy with Scheduled Commercial Loads: In this method, the controllable loads are scheduled as per equations 4.4 to 4.6. However, the wind energy is integrated after the loads are scheduled considering the TTP.

4.3.4 Case-4: Combining PV and Wind energy

To optimize cost reduction and efficient renewable energy utilization, this case proposes a hybrid approach combining Case-2 and Case-3. Specifically, wind energy is integrated with controllable loads, while PV energy is paired with curtailable loads. This integrated methodology leverages the strengths of both renewable energy sources and load types. Wind energy, with its variable output, is matched with controllable loads that can adjust to changing energy availability. Meanwhile, PV energy, with its predictable peak output, is aligned with curtailable loads that can be temporarily reduced or shifted during periods of high energy demand. By effectively combining these two approaches, the proposed methodology aims to minimize costs, maximize renewable energy utilization, and promote a more efficient and sustainable energy management system. In buses 6 and 31 of the IEEE 33 Bus System, Wind-based DG has been used. For bus 13 of the same bus system, PV-based DG has been used. For the IEEE 69 bus system, the Wind-based DG has been placed in positions 12 and 59. For bus 29 of the same system, PV-based DG has been used.

4.3.5 Case-5: Integrating Battery Energy Storage System (BESS)

In Case-5, a Battery Energy Storage System (BESS) is integrated with the Renewable Energy Source (RES) infrastructure to optimize energy utilization, mitigate intermittency, and reduce costs. The BESS stores excess energy generated by RES during off-peak hours, allowing for its subsequent utilization during peak hours or periods of reduced RES output due to climatic fluctuations or other disruptions. This integrated approach enables a more efficient, resilient, and cost-effective energy management system.
The incorporation of BESS yields significant benefits, including:

- Cost reduction by minimizing dependence on the grid during peak hours
- Enhanced RES utilization efficiency
- Reduced energy waste during off-peak periods
- Improved overall system reliability and stability

The position of BESS in IEEE 33 Bus System is at bus 28 [13] and for the IEEE 69 Bus System is at bus 61 [13]. Considering the intermittency of RES, the BESS system stores energy when demand is low, maintaining a stable total cost per day. Although the integration of BESS increases the initial capital cost, this investment can be recovered over the system's operational lifetime, ultimately reducing the overall cost. This integrated BESS-RES configuration forms a critical component of the proposed methodology, facilitating a more sustainable, efficient, and economically viable energy management framework.

4.3.6 Load Flow Analysis

As scheduling of the load starts, it has to be considered that the voltages between the bus nodes may change, as well as the losses in the buses. To calculate the value of loss, a technique called Backward - Forward Sweep Analysis (BFSA) is used. It is mandatory to estimate the losses found in the system for the new demand curve and compare it with the old demand curve and this aids to evaluate the efficacy of the proposed scheduling process. The process mainly has two parts namely forward sweep and backward sweep.

4.3.6.1 Backward Sweep Algorithm

It is used to find the current in each bus from the supply side to the demand side and add the values in such a way using Kirchoff's Current Law (KCL) that can determine the current supplied by the provider. This is used in the forthcoming steps.

$$I_{\text{bus}} = \frac{S}{\sqrt{3} \cdot V} \tag{4.7}$$

4.3.6.2 Forward Sweep Algorithm

It is used to calculate the voltages in every bus and store it in the respective node from the first bus on the supply side using the current found in the previous step. Now this gives us the bus voltage of each buses in the IEEE 33 bus Radial system.

$$V_{\text{curr}} = V_{\text{prev}} - \sqrt{3} \cdot I_{\text{prev branch}} \cdot Z \tag{4.8}$$

V_{curr} is the voltage in the current bus and V_{prev} is the voltage at the previous bus of the same iteration.

4.3.6.3 Power Loss Calculation

Figure. 4.8 represents a simple radial network as an example to show the power loss calculation between t^th and t+1^th bus. Here the term 't' represents the bus number.

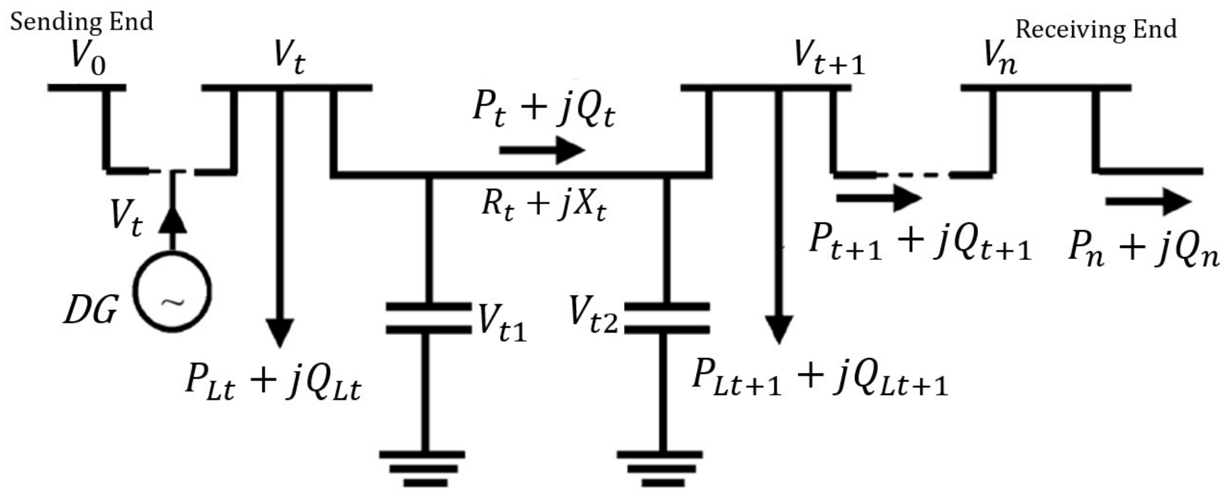

Figure 4.8: Single line diagram of a simple radial network

$$P_{t+1} = P_t - P_{\text{Loss},t} - P_{Lt+1} = P_t - \frac{R_t}{|V_t|^2}\left\{P_t^2 + \left(Q_t + Y_t|V_t|^2\right)^2\right\} - P_{Lt+1}$$

$$Q_{t+1} = Q_t - Q_{\text{Loss},t} - Q_{Lt+1} \tag{4.9}$$

$\mathrm{Q}_{t+1} = Q_t - \frac{X_t}{|V_t|^2}\left\{P_t^2 + Q_t + Y_{t1}|V_t|^2\right\} - Y_{t1}|V_t|^2$
$- Y_{t2}|V_{t+1}|^2 - Q_{Lt+1}$
(4.10)

$|V_{t+1}|^2 = |V_t|^2 + \frac{R_t^2+X_t^2}{|V_t|^2}\left(P_t^2 + Q_t\right) - 2(R_tP_t + X_tQ_t)$

$= |V_t|^2 + \frac{R_t^2+X_t^2}{|V_t|^2}\left(P_t^2 + (Q_t + Y_t|V_t|^2)^2\right)$

$- 2(R_tP_t + X_t(Q_t + Y_t|V_t|^2))$

(4.11)

The power loss between t^th^ and t+1^th^ bus is given by,

$$P_{\text{Loss}(t,t+1)} = R_t \cdot \frac{P_t^2 + Q_t^2}{|V_t|^2} \tag{4.12}$$

The sum of all these line losses gives the total power loss in i^th^ hour.

$$P_{Loss(i)} = \sum_{t=1}^{n} P_{Loss(t,t+1)} \tag{4.13}$$

CHAPTER 5

RESULTS AND DISCUSSION

In this chapter, the results of various cases, under different loading scenarios for IEEE 33 and 69 Bus systems are analyzed.

5.1 IEEE 33 BUS SYSTEM

The system has a peak load limit of 3715 kW per hour and a peak limit for wind and PV energy of 1046.2 kW.

5.1.1 Scenario-1

The PV and wind energy variation for scenario 1 is shown in Fig 5.1.

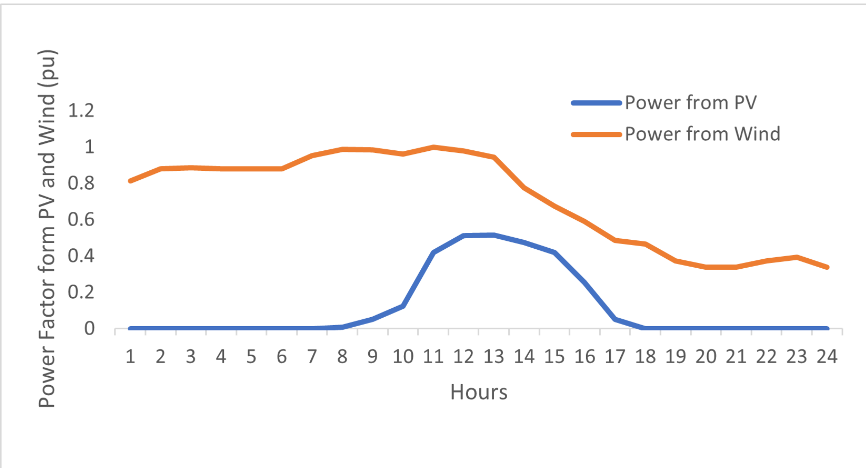

Figure 5.1: Energy variation observed in PV and Wind energy over 24 hours

Case-1: The base case scenario represents the initial condition without load scheduling or RES integration. Scheduling controllable loads alone yields a considerable 11.31% price reduction relative to the base case. Table 5.1 shows the cost reduction of the system.

Case-2: The base case is characterized by higher demand values and cost prices. Due to this,

Table 5.1: Cost comparison of 33 bus system after scheduling

Condition	Total Load (kW)	Price($)
Base case	50104.41	9528.14727
Scheduling Controllable loads	50104.41	8450.13

the grid may tend to lose its reliability and fluctuations may occur. The integration of PV energy gives a cost difference of 13.08%. PV energy helps mitigate the strain on the grid and promotes cost-effectiveness. Scheduled controllable load values are taken from case-1 and integrated with PV energy, with a reduction of 24.98%. This results in a higher percentage of cost reduction. Here, a maximum amount of PV energy can be utilized to supply loads. Table 5.2 shows the cost reduction after the integration of PV energy as a RES and Fig 5.2 shows the hourly power loss of the system after the integration of PV energy.

Table 5.2: Cost comparison of 33 bus system after integration of PV energy

Parameters	Total Load (kW)	Total Price ($)
Base	50104.41	9528.147
Base with PV	47148.85	8281.68
Sch. loads with PV	44847.415	7147.64

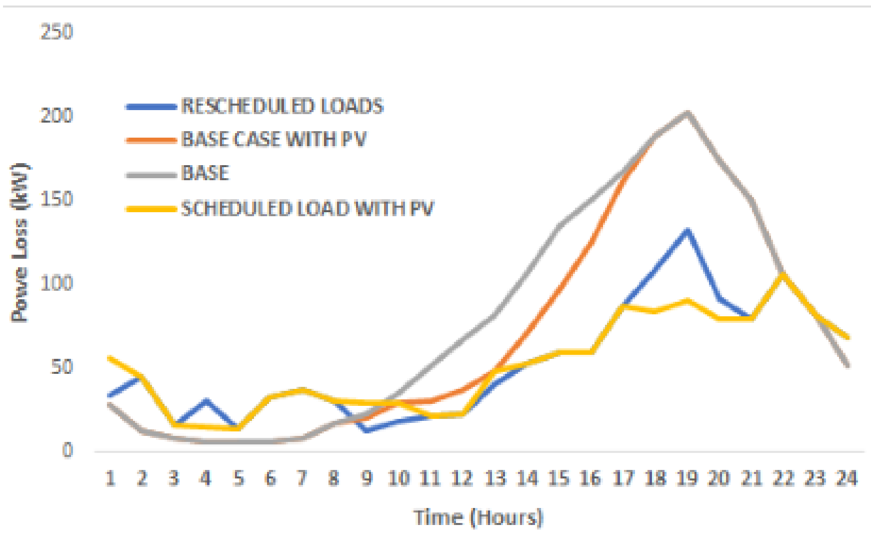

Figure 5.2: IEEE 33 bus system - Scenario-1 Hourly power loss after integration of PV energy.

Case-3: This case deals with the integration of wind energy with controllable loads for scenario -1. In this case, when wind energy is integrated into controllable or curtailable loads after shifting, the total reduction in price is 60.42 %. Here, the integration of wind energy in controllable and curtailable loads yields the same result. Compared to other cases, this case yields the most reduction in total cost due to the integration of RES after scheduling. In the very same case, when wind energy is integrated before the scheduling of controllable loads, a reduction of 49.11 % in price is observed as shown. Table 5.3 shows the reduction of cost and Fig 5.3 shows the hourly power loss after the integration of wind energy.

Table 5.3: Cost comparison of 33 bus system after integration of wind energy

Parameters	Total Load (kW)	Total Price ($)
Base	50104.41	9528.147
Base with wind	21001.916	4848.509
Sch. loads with wind	21001.916	3770.483

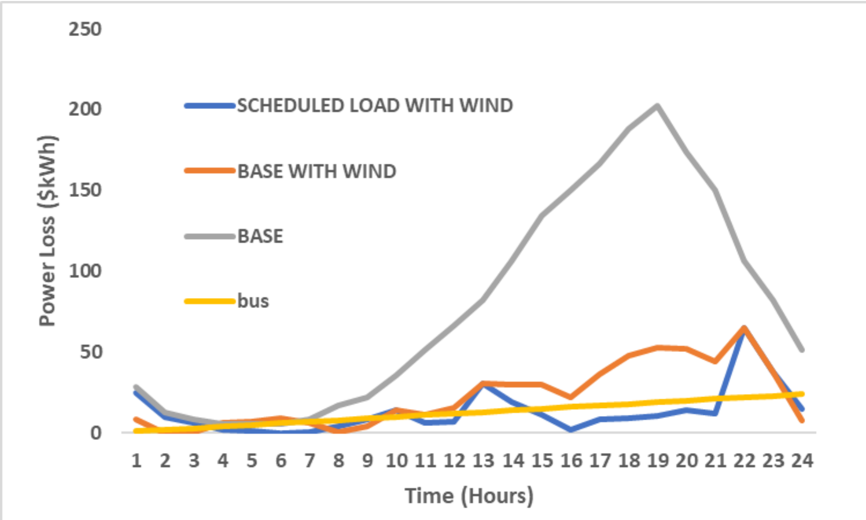

Figure 5.3: IEEE 33 bus system - Hourly power loss after integration of wind energy

Case-4: The integration of RES with controllable and curtailable loads yielded significant reductions in total price. Notably, combining wind and PV as an RES, and scheduling loads based on availability and demand, resulted in substantial cost savings. A comparative analysis of the results revealed that integrating RES after load scheduling produced the most optimal outcomes. Table 5.4 shows the cost reduction and Figure 5.4 shows the hourly power loss of the system. Specifically, this integrated approach yielded the highest total price reduction and promoted efficient energy utilization.

Table 5.4: Cost comparison of 33 bus system scenario 1 after integration of PV wind and scheduling

Parameters	Cost reduction (%)	Total load (kW)
Case-1	11.31	50104.41
Case-4	61.64	28208.86967

Figure 5.4: Power loss after combining PV and wind

Case-5: Here, a BESS is integrated along with the two RES to support their intermittent nature. By utilizing the same to store excess energy generated during low-demand hours, the intermittency of the RES integrated here can be managed, yielding higher reductions in price and energy loss as in Figure5.5 and Table5.5.

Table 5.5: Cost reduction after integration of BESS.

Total Loss (kW)	Total Loads (kW)	Price ($)	Price reduction (%)
827.35	21518.63	2575.44	72.97%

Figure 5.5: IEEE 33 bus system-Scenario-1 hourly power loss and price after integration of BESS

5.1.2 Scenario-2

The PV and wind energy variation for scenario 2 is shown in Fig 5.6.

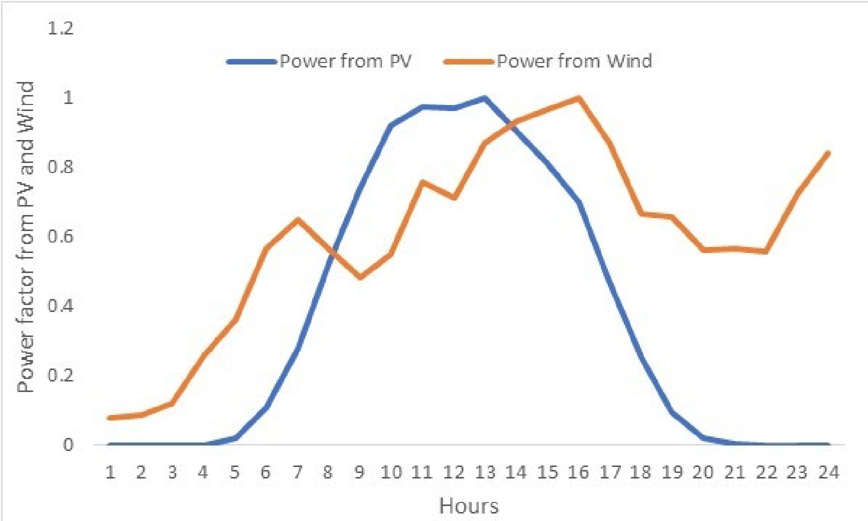

Figure 5.6: Energy variation observed in PV and Wind energy over 24 hours

Case-1: The base case scenario represents the initial condition without load scheduling or RES integration. Scheduling controllable loads alone yields a considerable price reduction of 2.25% compared to the base case. Table 5.6 shows the cost reduction of the system.

Table 5.6: Cost comparison of 33 bus system after scheduling

Condition	Total Load(kW)	Price($)
Base case	81796.87	14495.85942
Scheduling Controllable loads	81796.87	14169.19272

Case-2: The base case is considered, wherein unscheduled loads are integrated with PV energy, yielding a cost reduction of 22.06%. Whereas, when RES is integrated into scheduled loads difference concerning the case is 24.31%. The above case is re-scheduled for a reduction of cost, yielding 24.35%. Table 5.7 shows the cost reduction and Figure 5.7 shows the hourly power loss of the system.

Table 5.7: Cost comparison of 33 bus system after integration of PV energy

Parameters	Total Load (kW)	Total Price ($)
Base	81796.87	14495.85
Base with PV	72614.26	11297.6
Sch. loads with PV	72614.26	10970.94

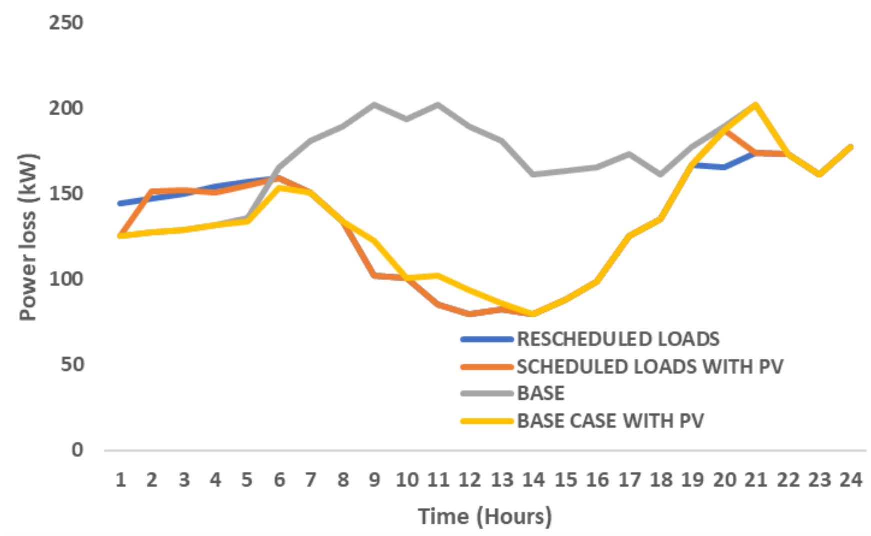

Figure 5.7: IEEE 33 bus system - Scenario-2 hourly power loss for PV energy.

Here, a slight variation in cost is observed compared to the previous condition. Maximum solar energy is consumed during this period, which gives a lower operational price.

Case-3: This case analyzes the integration of wind energy as a RES with controllable loads. The integration of wind energy produces much higher reductions in price as compared to the integration of PV energy, due to its availability across 24 hours of the day. Table 5.8 shows the cost reduction and Figure 5.8 shows the hourly power loss of the system after the integration of wind energy.

Table 5.8: Cost comparison of 33 bus system after integration of wind energy

Parameters	Total load (kW)	Total Price ($)
Base	81,796.87	14,495.85
Base with wind	66738.62	10717.54507
Base with wind sch.	66738.62	10717.54507

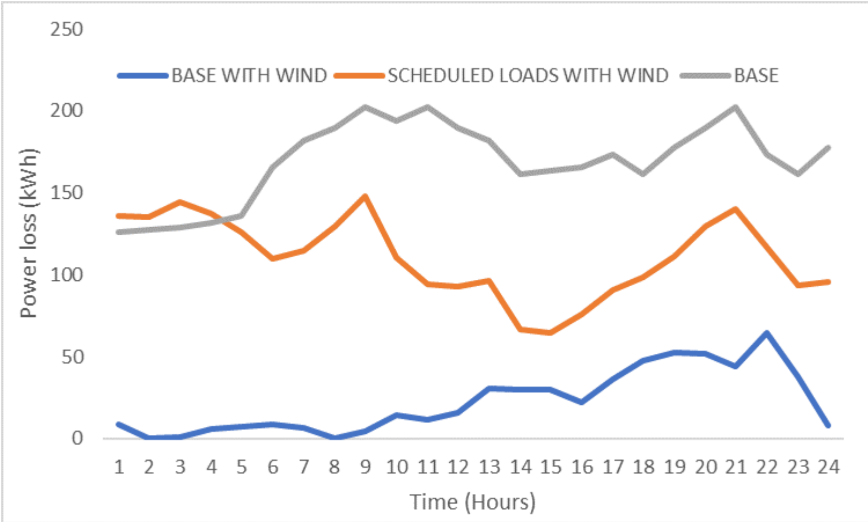

Figure 5.8: IEEE 33 bus system - Hourly power loss after integration of wind energy

Case-4: The integration of RES with controllable and curtailable loads yielded significant reductions in total price. Notably, combining wind and PV as an RES, and scheduling loads based on availability and demand, resulted in substantial cost savings. A comparative analysis of the results revealed that integrating RES after load scheduling produced the most optimal outcomes. Table 5.8 shows the cost reduction and Figure 5.9 shows the hourly power loss of the system after the integration of PV and wind energy.

Table 5.9: Comparison after integration of wind, PV and scheduling

Parameters	Cost reduction (%)	Total load (kW)
Case-1	2.25	81796.87
Case-4	45.95	7833.740977

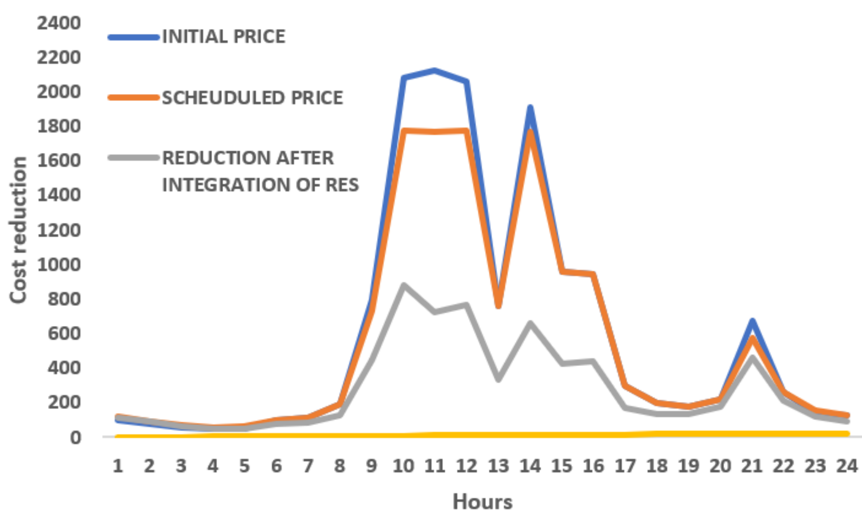

Figure 5.9: Power loss after combining PV and wind

Specifically, this integrated approach yielded the highest total price reduction and promoted efficient energy utilization.

Case-5: Here, a BESS is integrated along with the two RES to support their intermittent nature. By utilizing the same to store excess energy generated during low-demand hours, the intermittency of the RES can be managed, yielding higher reductions in price and energy loss. Table 5.10 shows the cost reduction and Figure 5.10 shows the hourly power loss of the system after integration of BESS with case-4.

Table 5.10: Cost reduction after integration of BESS.

Total Loss (kWh)	Total Loads (kW)	Price ($)	Price reduction (%)
1806.75	52231.88	7096.38	51.04%

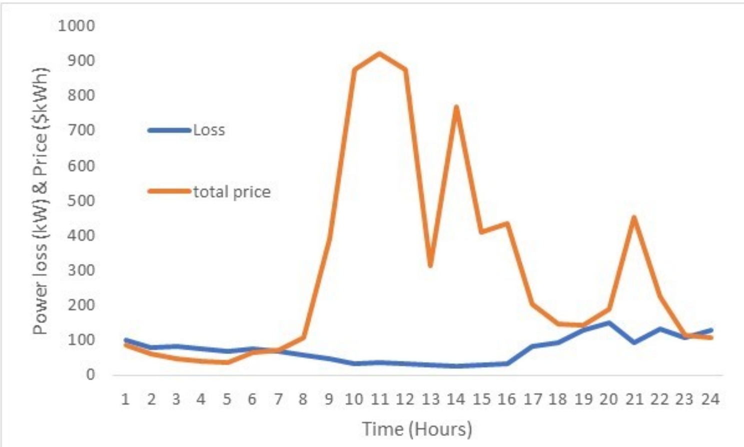

Figure 5.10: IEEE 33 bus system-Scenario-2 hourly power loss and price after integration of BESS

Comparing the two scenarios analyzed here, Scenario 2 yields better results for all the 5 cases used for analysis. Scenario 2 has a much better production profile with regards to Wind energy. Due to its consistency, the system has reduced dependency on the grid. Scenario 1 of the same system has loads that are concentrated on some hours of the day. This is due to scheduling of the loads considering the load demand and price across the day. This reduces the effectiveness of the RES integrated into the system.

5.2 IEEE 69 BUS SYSTEM

The IEEE 69 bus is considered, with a peak load limit of 3849.89 kW per hour and a peak limit of 1046.2 kW for wind energy. The data for loads per hour is taken from [1] and the data for wind energy generated per hour are taken from [3]. The figure below displays the loss recorded for controllable and curtailable loads for the 69 bus system for 24 hours. It is observed that losses occurring in controllable loads are much more unpredictable, as compared to the other loads. The single-line diagram with tie lines of the 69 bus system is shown in Figure 4.4.

5.2.1 Scenario-1

Case-1: The difference in price in controllable scheduling concerning the base case is 8.73%. The price variation is low because curtailable loads are not curtailed since it is not required. Also, the load value remains constant due to this cause. The below Table 5.11 shows a brief explanation.

Table 5.11: Cost comparison of 69 bus system after scheduling

Condition	Total Load(kW)	Price($kWh)
Base case	51923.02469	9873.952021
Scheduling Controllable loads	51923.02469	9011.045634

Case-2: Without load scheduling, the initial data shows high energy demand and costs, straining the grid. However, after the integration of RES and adjustments made in controllable loads, costs dropped by 8.73%. Load scheduling is key here because it helps reduce grid strain and lower overall costs. Table 5.12 shows the cost reduction and Figure 5.11 shows the hourly power loss of the system after the integration of PV energy.

Table 5.12: Cost comparison of 69 bus system after integration of PV energy

Parameters	Total Load (kW)	Total Price ($kWh)
Base	51923.02	9873.95
Base with PV	48967.5	8627.48
Sch. loads with PV	48967.5	7764.57

Case-3: The same method for integrating wind energy as an RES as utilized for the IEEE 33 bus system is followed here. The cost reduction is much higher here due to the availability of wind energy throughout the day. Table 5.13 shows the cost reduction and Figure 5.11 shows the hourly power loss after integrating wind energy into the system.

Case-4: The integration of RES with controllable and curtailable loads yields significant reductions in total price. Notably, combining wind and PV as an RES, and scheduling loads based on

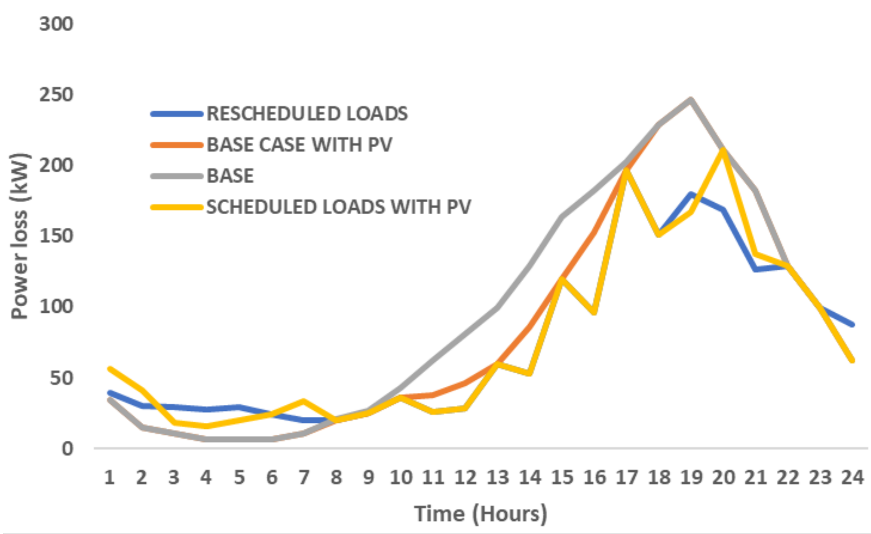

Figure 5.11: IEEE 69 bus system - Hourly power loss for PV energy.

Table 5.13: Cost comparison of 69 bus system scenario 1 after integration of wind energy

Parameters	Total load (kW)	Total Price ($)
Base	51,923.02	9,873.95
Base with wind	36,864.76	6,727.29
Base with wind sch.	36,864.76	5,864.39

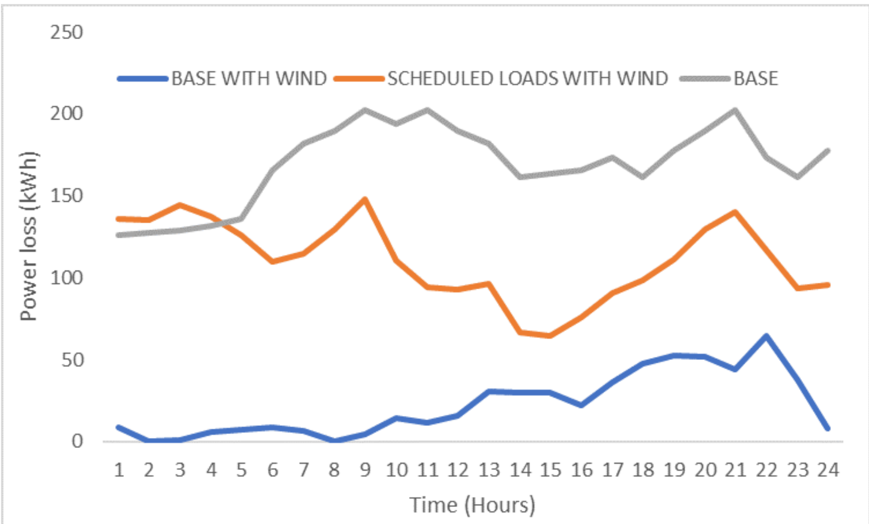

Figure 5.12: IEEE 69 bus system - Hourly power loss after integration of wind energy.

availability and demand, resulted in substantial cost savings. A comparative analysis of the results revealed that integrating RES after load scheduling produced the most optimal outcomes. Specifically, this integrated approach yielded the highest total price reduction and promoted efficient energy utilization. Table 5.12 shows the cost reduction and Figure 5.13 shows the hourly power loss after integrating solar and wind energy.

Table 5.14: Comparison after integration of wind, PV and scheduling

Parameters	Cost reduction (%)	Total load (kW)
Case-1	8.73	51923.02469
Case-4	24.17	38308.19728

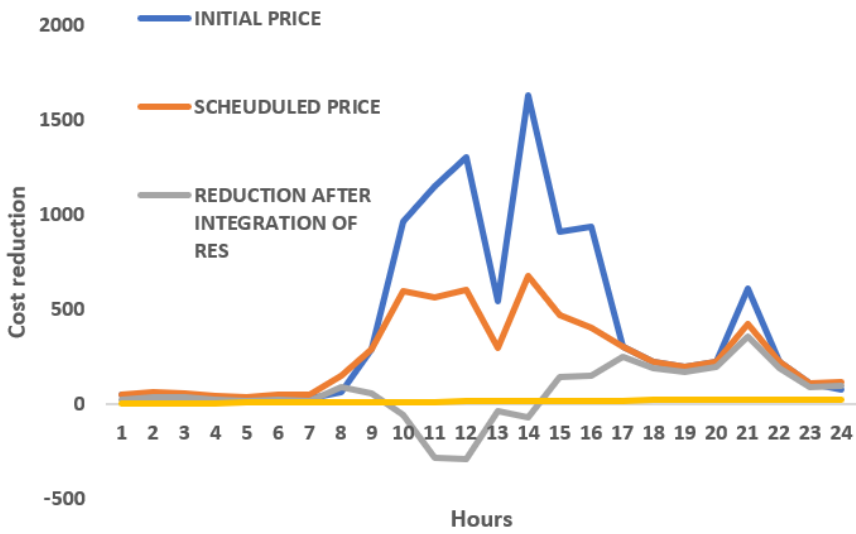

Figure 5.13: Power loss after combining PV and wind

Case-5: Here, BESS is integrated along with RES to support their intermittent nature. By utilizing the same to store excess energy generated during low-demand hours, the intermittency of RES can be managed, yielding higher reductions in price and energy loss and improving the overall reliability of the approach. Table 5.15 shows the cost reduction and Figure 5.14 shows the hourly power loss after integration of BESS in case-4.

Table 5.15: Cost reduction after the integration of BESS.

Total Loss (kWh)	Total Loads (kW)	Price ($)	Price reduction (%)
380.02	23784.59	4568.99	53.72%

5.2.2 Scenario-2

Case-1: The difference in price obtained after the scheduling of controllable loads in the base case is 2.05%. The price variation is low because curtailable loads are preserved to maintain grid stability. Due to this, the load value remains constant. Table 5.16 shows the cost reduction of the system after scheduling.

Figure 5.14: IEEE 69 bus system-Scenario-1 hourly power loss and price after integration of BESS

Table 5.16: Cost comparison of 69 bus system after scheduling

Conditions	Total Load (kW)	Price ($)
Base case	84766.87812	15022.19763
Scheduling Controllable loads	84766.87812	14714.16513

Case-2: The base case is integrated with PV energy, yielding a difference of 21.30% before scheduling. Scheduled loads are considered and integrated with PV, yielding a difference of 23.34%. Table 5.17 shows the cost reduction and Figure 5.15 shows the hourly power loss of the system after integrating PV energy.

Table 5.17: Cost comparison of 69 bus system after integration of PV energy

Parameters	Total Load (kW)	Total Price ($)
Base	84766.87	15022.1
Base with PV	75584.27	11823.9
Sch. loads with PV	75584.27	11515.9

Case-3: The same method for integrating wind energy as RES as utilized for the IEEE 33 bus system is followed here. Evidently, the integration of wind energy yields better price reduction, due to its availability across the day. Table 5.18 shows the cost reduction and Figure 5.15 shows the hourly power loss of the system after integrating wind energy.

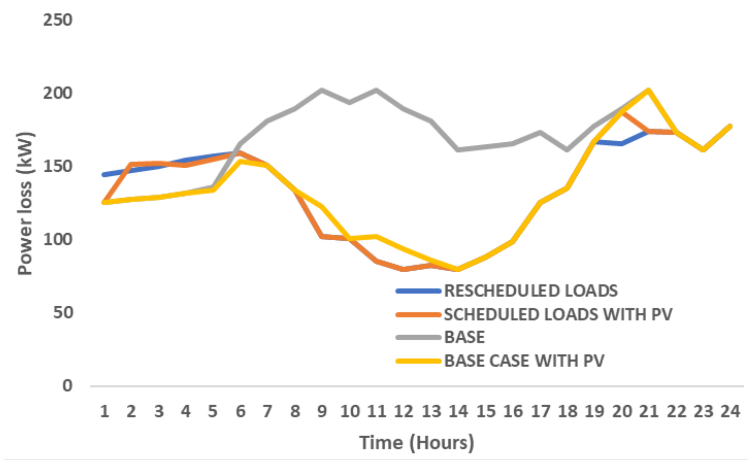

Figure 5.15: IEEE 69 bus system - Hourly power loss for PV energy.

Table 5.18: Cost comparison of 69 bus system scenario 2 after integration of wind energy

Parameters	Total load (kW)	Total Price ($)
Base	84,766.88	15,022.20
Base with wind	69,708.62	11,875.54
Base with wind sch.	69,708.62	11,875.54

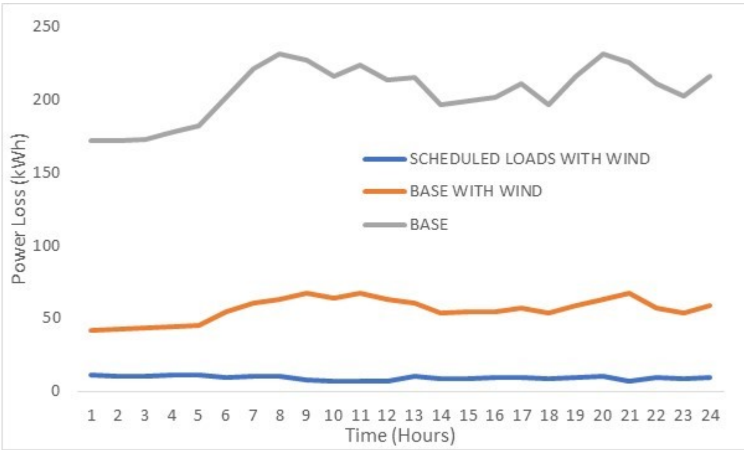

Figure 5.16: IEEE 69 bus system Hourly power loss after integration of wind energy

Case-4: The integration of RES with controllable and curtailable loads yielded significant reductions in total price. Notably, combining wind and solar RES, and scheduling loads based on availability and demand, resulting in substantial cost savings. A comparative analysis of the results revealed that integrating RES after load scheduling produced the most optimal outcomes. Specifically, this integrated approach yielded the highest total price reduction and promoted efficient energy utilization. Table 5.19 shows the cost reduction and Figure 5.17 shows the hourly power loss of the system after integrating PV and wind energy.

Case-5: Here, a BESS is integrated along with the two RES to support their intermittent nature

Table 5.19: Comparison after integration of wind, PV and scheduling

Parameters	Cost reduction (%)	Total load (kW)
Case-1	2.05	84766.87812
Case-4	30.64	64401.69908

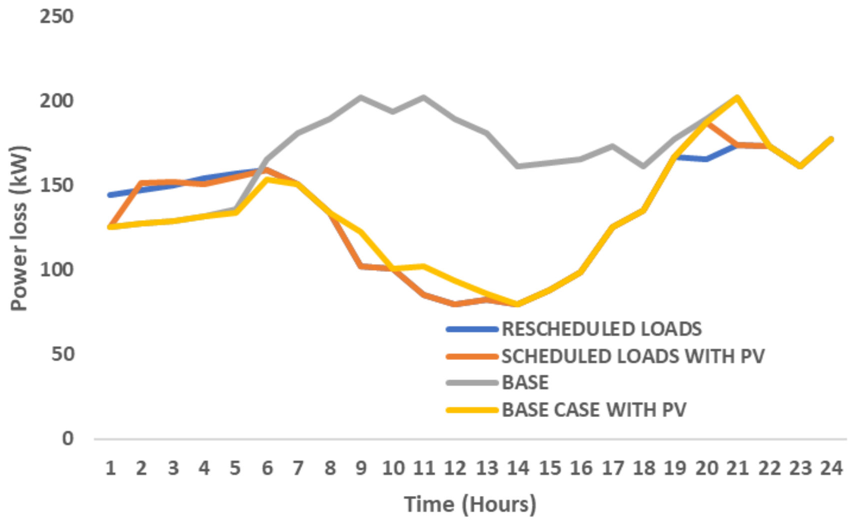

Figure 5.17: Power loss after combining PV and wind

as done in scenario 1. By utilizing the same to store excess energy generated during low-demand hours, the intermittency of the RES integrated here can be managed, yielding higher reductions in price and energy loss as follows. Table 5.20 shows the cost reduction and Figure 5.18 shows the hourly power loss of the system after integrating solar energy.

Table 5.20: Cost reduction after integration of BESS.

Total Loss (kWh)	Total Loads (kW)	Price ($)	Price reduction (%)
343.79	21774.42	3150.37	79.02%

Comparing the two scenarios analyzed here, Scenario 2 yields better results for all the 5 cases used for analysis. Scenario 2 has a much better production profile with regards to Wind energy. Due to its consistency, the system has reduced dependency on the grid. The loads across 24 hours are dispersed consistently, providing better cost and loss reductions. The load demand across the day is spread out, and combining this with the proposed technique makes the reduction across the scenario better.

Figure 5.18: IEEE 69 bus system-Scenario-2 hourly power loss and price after integration of BESS

CHAPTER 6

CONCLUSIONS

The work done above has made it clear that with organized scheduling, the overall costs concerning different loads throughout the day can be well maintained under control. Here, two scenarios in terms of system conditions are considered. The work done above utilizes an approach that prioritizes the consumers when the loads are scheduled, such that the final result is practically feasible. The DG and BESS positions for both the test systems are fixed. Following an attempt to vary the position of DGs, the prices and loads concerning the hour may differ, leading to a change in the expected price. Along with this, the renewable energy generated per day may also vary, causing changes to the final prices.

The presented work makes it clear that the integration of two RES along with the strategic scheduling of loads, comparing the peak prices and demand over 24 hours of the day creates a considerable reduction in the cost in both the scenarios of the systems taken into consideration.This has made the method highly cost-effective and energy-efficient. The integration of storage systems has proved useful in managing the intermittency of the RES and storing surplus energy generated during hours with lower power requirements, which can be utilized to fulfill a larger set of loads during peak hours, ultimately reducing the overall cost and increasing the effectiveness of scheduling.

The integration of electric vehicles may also provide a different scene with respect to load utilization since they can act as both charging and discharging loads. The integration of this method to a transmission system would help reduce losses considerably, along with efficient utilization of generated energy.

Signature of the Guide

Name of the Guide: Dr. Narayanan K (SAP/EEE/SEEE)

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APPENDIX A

FIRST SET DATA

A.1 IEEE 33-Bus System

The IEEE 33-Bus System consists of 33 buses, 32 normally closed branches, and 5 normally open tie lines. The total load present in the system is 3715 kW and 2300 kVAr. Its line data and original load data are given in Tables A.1, A.2 respectively. Fig. A.1 represent the system pictorially, with its buses, branches, and tie lines labeled.

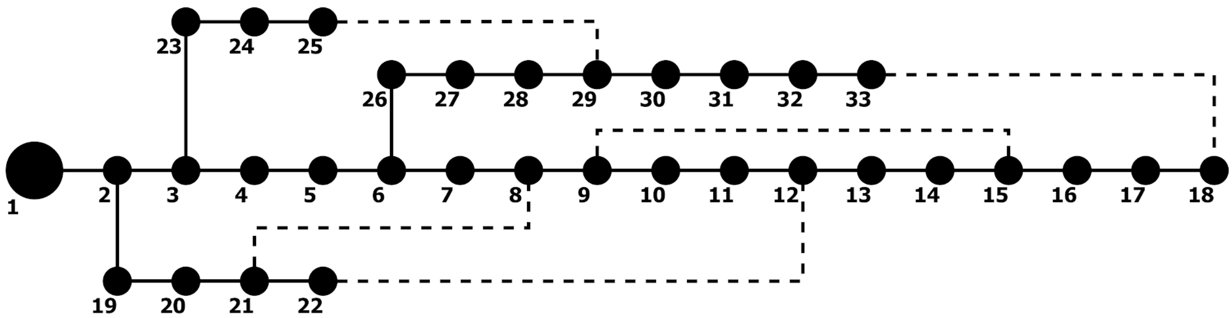

Figure A.1: IEEE 33-Bus System

Table A.1: Line Data of the IEEE 33-Bus System

Branch Parameters			Line parameters		Reliability Parameters	
Branch No.	**From Bus**	**To Bus**	**Resistance (Ω)**	**Reactance (Ω)**	**Failure Rate (f/yr)**	**Repair Time (hours)**
1	1	2	0.0922	0.047	0.05	1
2	2	3	0.493	0.2511	0.3	1
3	3	4	0.366	0.1864	0.22	1
4	4	5	0.3811	0.1941	0.23	1
5	5	6	0.819	0.707	0.51	1
6	6	7	0.1872	0.6188	0.11	1
7	7	8	0.7114	0.2351	0.44	1
8	8	9	1.03	0.74	0.64	1
9	9	10	1.044	0.74	0.65	1
10	10	11	0.1966	0.065	0.12	1
11	11	12	0.3744	0.1238	0.23	1
12	12	13	1.468	1.155	0.91	1
13	13	14	0.5416	0.7129	0.33	1
14	14	15	0.591	0.526	0.36	1
15	15	16	0.7463	0.545	0.46	1
16	16	17	1.289	1.721	0.8	1
17	17	18	0.732	0.574	0.45	1
18	2	19	0.164	0.1565	0.1	0.5
19	19	20	1.5042	1.3554	0.93	0.5
20	20	21	0.4095	0.4784	0.25	0.5
21	21	22	0.7089	0.9373	0.44	0.5
22	3	23	0.4512	0.3083	0.28	0.5
23	23	24	0.898	0.7091	0.56	0.5
24	24	25	0.896	0.7011	0.55	0.5
25	6	26	0.203	0.1034	0.12	0.5
26	26	27	0.2842	0.1447	0.17	0.5
27	27	28	1.059	0.9337	0.66	0.5
28	28	29	0.8042	0.7006	0.5	0.5
29	29	30	0.5075	0.2585	0.31	0.5
30	30	31	0.9744	0.963	0.6	0.5
31	31	32	0.3105	0.3619	0.19	0.5
32	32	33	0.341	0.5302	0.21	0.5
33*	8	21	2.000	2.000	1.24	0.5
34*	9	15	2.000	2.000	1.24	0.5
35*	12	22	2.000	2.000	1.24	0.5
36*	18	33	0.500	0.500	0.31	0.5
37*	25	29	0.500	0.500	0.31	0.5

* - Tie Lines

Table A.2: Load Data of the IEEE 33-Bus System

Bus No.	**Real Power Load**	**Reactive Power Load**	**No. of Customers**
	kW	**kVAr**	
2	100	60	148
3	90	40	148
4	120	80	148
5	60	30	110
6	60	20	118
7	200	100	10
8	200	100	10
9	60	20	132
10	60	20	132
11	45	30	132
12	60	35	110
13	60	35	110
14	120	80	110
15	60	10	2
16	60	20	118
17	60	20	118
18	90	40	118
19	90	40	118
20	90	40	126
21	90	40	126
22	90	40	126
23	90	50	126
24	420	200	126
25	420	200	126
26	60	25	108
27	60	25	108
28	60	20	108
29	120	70	108
30	200	600	108
31	150	70	58
32	210	100	58
33	60	40	58

A.2 IEEE 69-Bus System

The IEEE 69-Bus System is a standard test system. It has 3.802 MW and 2.695 MVAr of total load connected to it and consists of 69 buses, 68 normally closed branches, and 5 normally open tie lines. Its line data and original load data are given in Tables A.3 and A.4 respectively. Fig. A.2 represents the system pictorially, with its buses, branches, and tie lines labeled.

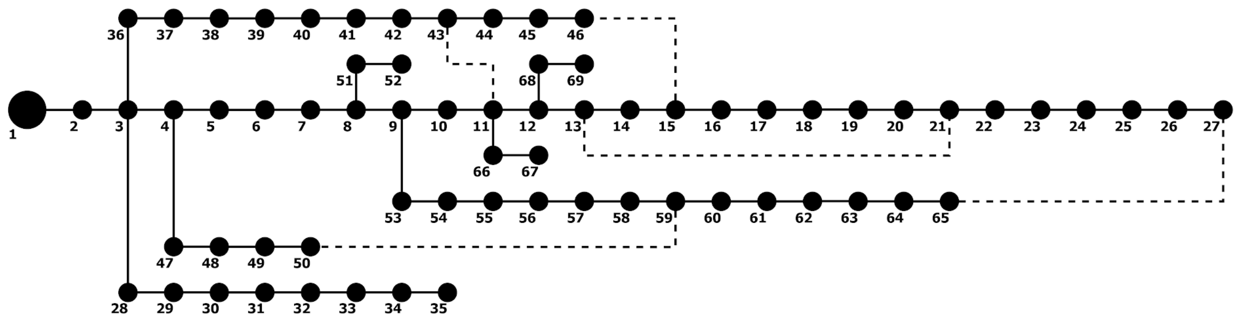

Figure A.2: IEEE 69-Bus System

Table A.3: Line Data of the IEEE 69-Bus System

Branch Parameters			Line parameters		Reliability Parameters	
Branch No.	From Bus	To Bus	Resistance (Ω)	Reactance (Ω)	Failure Rate (f/yr)	Repair Time (hours)
1	1	2	0.0005	0.0012	0.0003	0.5
2	2	3	0.0005	0.0012	0.0003	0.5
3	3	4	0.0015	0.0036	0.0009	0.5
4	4	5	0.0251	0.0294	0.0156	0.5
5	5	6	0.366	0.1864	0.2269	0.5
6	6	7	0.3811	0.1941	0.2363	0.5
7	7	8	0.0922	0.047	0.0572	0.5
8	8	9	0.0493	0.0251	0.0306	0.5
9	9	10	0.819	0.2707	0.5078	0.5
10	10	11	0.1872	0.0691	0.1161	0.5
11	11	12	0.7114	0.2351	0.4411	0.5
12	12	13	1.03	0.34	0.6386	0.5
13	13	14	1.044	0.345	0.6473	0.5
14	14	15	1.058	0.3496	0.6560	0.5
15	15	16	0.1966	0.065	0.1219	0.5
16	16	17	0.3744	0.1238	0.2321	0.5
17	17	18	0.0047	0.0016	0.0029	0.5
18	18	19	0.3276	0.1083	0.2031	0.5
19	19	20	0.2106	0.069	0.1306	0.5
20	20	21	0.3416	0.1129	0.2118	0.5
21	21	22	0.014	0.0046	0.0087	0.5
22	22	23	0.1591	0.0526	0.0986	0.5
23	23	24	0.3463	0.1145	0.2147	0.5
24	24	25	0.7488	0.2745	0.4643	0.5
25	25	26	0.3089	0.1021	0.1915	0.5
26	26	27	0.1732	0.0572	0.1074	0.5

Branch Parameters			Line parameters		Reliability Parameters	
Branch No.	From Bus	To Bus	Resistance (Ω)	Reactance (Ω)	Failure Rate (f/yr)	Repair Time (hours)
27	3	28	0.0044	0.0108	0.0027	1
28	28	29	0.064	0.1565	0.0397	1
29	29	30	0.3978	0.1315	0.2466	1
30	30	31	0.0702	0.0232	0.0435	1
31	31	32	0.351	0.116	0.2176	1
32	32	33	0.839	0.2816	0.5202	1
33	33	34	1.708	0.5646	1.0590	1
34	34	35	1.474	0.4673	0.9139	1
35	3	36	0.0044	0.0108	0.0270	1
36	36	37	0.064	0.1565	0.0397	1
37	37	38	0.1053	0.123	0.0653	1
38	38	39	0.0304	0.0355	0.0188	1
39	39	40	0.0018	0.0021	0.0011	1
40	40	41	0.7283	0.8509	0.4515	1
41	41	42	0.31	0.3623	0.1922	1
42	42	43	0.041	0.0478	0.0254	1
43	43	44	0.0092	0.0116	0.0057	1
44	44	45	0.1089	0.1373	0.0675	1
45	45	46	0.0009	0.0012	0.0006	1
46	4	47	0.0034	0.0084	0.0021	1
47	47	48	0.0851	0.2083	0.0528	1
48	48	49	0.2898	0.7091	0.1797	1
49	49	50	0.0822	0.2011	0.5100	1
50	8	51	0.0928	0.0473	0.0575	1
51	51	52	0.3319	0.1114	0.2058	1
52	9	53	0.174	0.0886	0.1079	1
53	53	54	0.203	0.1034	0.1259	1
54	54	55	0.2842	0.1447	0.1762	1

Branch Parameters			Line parameters		Reliability Parameters	
Branch No.	**From Bus**	**To Bus**	**Resistance (Ω)**	**Reactance (Ω)**	**Failure Rate (f/yr)**	**Repair Time (hours)**
55	55	56	0.2813	0.1433	0.1744	1
56	56	57	1.59	0.5337	0.9858	1
57	57	58	0.7837	0.263	0.4859	1
58	58	59	0.3042	0.1006	0.1886	1
59	59	60	0.3861	0.1172	0.2394	1
60	60	61	0.5075	0.2585	0.3146	1
61	61	62	0.0974	0.0496	0.6040	1
62	62	63	0.145	0.0738	0.0899	1
63	63	64	0.7105	0.3619	0.4405	1
64	64	65	1.041	0.5302	0.6454	1
65	11	66	0.2012	0.0611	0.1247	1
66	66	67	0.0047	0.0014	0.0029	1
67	12	68	0.7394	0.2444	0.4584	1
68	68	69	0.0047	0.0016	0.0029	1
69*	11	43	0.5000	0.5000	0.3100	1
70*	13	21	0.5000	0.5000	0.3100	1
71*	15	46	1.0000	1.0000	0.6200	1
72*	50	59	2.0000	2.0000	1.2100	1
73*	27	65	1.0000	1.0000	0.6200	1

* - Tie Lines

Table A.4: Load Data of the IEEE 69-Bus System

Bus No.	Real Power Load	Reactive Power Load	No. of Customers
	kW	kVAr	
2	0.00	0.00	0
3	0.00	0.00	0
4	0.00	0.00	0
5	0.00	0.00	0
6	2.60	2.20	148
7	40.40	30.00	148
8	75.00	54.00	10
9	30.00	22.00	10
10	28.00	19.00	10
11	145.00	104.00	132
12	145.00	104.00	132
13	8.00	5.50	110
14	8.00	5.50	110
15	0.00	0.00	0
16	45.50	30.00	112
17	60.00	35.00	118
18	60.00	35.00	118
19	0.00	0.00	0
20	1.00	0.60	118
21	114.00	81.00	126
22	5.00	3.50	126
23	0.00	0.00	0
24	28.00	20.00	126
25	0.00	0.00	0
26	14.00	10.00	126
27	14.00	10.00	108
28	26.00	18.60	108

Bus No.	Real Power Load	Reactive Power Load	Customers
	kW	kVAr	
29	26.00	18.60	108
30	0.00	0.00	0
31	0.00	0.00	0
32	0.00	0.00	0
33	14.00	10.00	58
34	19.50	14.00	58
35	6.00	4.00	126
36	26.00	18.55	126
37	26.00	18.55	126
38	0.00	0.00	0
39	24.00	17.00	126
40	24.00	17.00	126
41	1.20	1.00	126
42	0.00	0.00	0
43	6.00	4.30	126
44	0.00	0.00	0
45	39.20	26.30	126
46	39.20	26.30	126
47	0.00	0.00	0
48	79.00	56.40	126
49	384.70	274.50	108
50	384.70	274.50	118
51	40.50	28.30	58
52	3.60	2.70	148
53	4.35	3.50	148
54	26.40	19.00	148
55	24.00	17.20	148
56	0.00	0.00	0
57	0.00	0.00	0

Bus No.	Real Power Load	Reactive Power Load	Customers
	kW	kVAr	
58	0.00	0.00	0
59	100.00	72.00	10
60	0.00	0.00	0
61	1244.00	888.00	12
62	32.00	23.00	132
63	0.00	0.00	0
64	227.00	162.00	132
65	59.00	42.00	132
66	18.00	13.00	132
67	18.00	13.00	132
68	28.00	20.00	132
69	28.00	20.00	110

SIMILARITY CHECK REPORT