NEURAL NETWORK BASED MICROGRID VOLTAGE CONTROL

by

Chun-Ju Huang

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ABSTRACT

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Chun-Ju Huang

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Under the Supervision of Professor David Yu

The primary purpose of this study is to improve the voltage profile of Microgrid using the neural network algorithm. Neural networks have been successfully used for character recognition, image compression, and stock market prediction, but there is no directly application related to controlling distributed generations of Microgrid. For this reason the author decided to investigate further applications, with the aim of controlling diesel generator outputs.

Firstly, this thesis examines the neural network algorithm that can be utilized for alleviating voltage issues of Microgrid and presents the results. MATLAT and PSCAD are used for training neural network and simulating the Microgrid model respectively. The Feedforward Back-propagation algorithm is used in this study and the Microgrid consists of wind, solar, and diesel power generations, and battery storage. Neural network will indicate how much real and reactive power is needed from each generator. In the second stage, several scenarios are proposed to verify that the monitoring points are very

important for training neural networks. Finally, the comparison of results is shown for further discussion of critical points.

In conclusion, the results of the study show that neural network algorithm is well suited for the application, and it was effectively certified for the purpose of improving the voltage profile of Microgrid.

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PV	Photovoltaic
CSP	Concentrated solar power
MPPT	Maximum power point tracking
HAWT	Horizontal axis wind turbines
VAWT	Vertical axis wind turbines
AC	Alternating current
DC	Direct current
MSE	Mean Squared Error

CHAPTER I

INTRODOUCTION

Background

New energy technologies and scientific discoveries are being made every day. These extraordinary technologies and discoveries have improved and changed humans living conditions.

Most well known technologies are wind for sailing, insolation for grain drying and falling water for milling purposes. Electricity was the most important discovery of science. It is a basic feature of everything in the universe, and it brings convenience in many ways to humans' life. Fossil fuels are very old. Oil deposits are around 150 million years old. Although humans probably used it in ancient times, it was the industrial revolution that led to their wide-scale extraction. The industrial revolution was a key turning point in Earth's ecology and humans' relationship with their environment and the era of fossil fuels was the product of it. The most obvious evidence of the industrial revolution's impact on the world is human population growth that has rapidly increased energy consumption. Human beings have relied on finite sources over centuries and the CO2 production dramatically rising along with energy consumption. The results of major depletion of fossil fuel reserves cause global warming, financial instability, and political turmoil in the world. Scientists indicate that human will run out of fossil fuel reserves in the near future, world is facing an impending energy crisis. It is truly urgent to find energy alternatives that are reliable, sustainable and environment friendly.

Renewable energy sources will be a significant role to supply global energy demand in the future.

Renewable energy could supply for almost 80% of the world's energy demand within four decades and shift global dependence away from fossil fuels [1]. Renewable energy sources will also provide environmental benefits such as reduced pollution, land restoration, and slow down global warming. Renewable energy technologies development will excite global economy and it also offers more job opportunities.

Energy is one of the important needs for humans. The fundamental of global economic stability and growth are secure, reliable, and affordable energy. The world economic growth depends on global supply, and oil accounts for about 40% of the world energy consumption and almost all of the transportation fuels [2]. Humans have consumed an incredible amount of fossil fuels in a very short period of time since the industrial revolution. Crude oil reserves are vanishing at the rate of 4 billion tons a year. If humans carry on at this rate without any increase of our growing population, oil deposits will be gone by 2052. There still have gas and coal left but the increasing of gas production fills the energy gap left by oil, those reserves will only last an additional eight years. The coal will provide world energy till 2088 after oil and gas are vanished. Since the world's population is still rising, fossil fuels will run out earlier. Figure 1.1 shows that how many years the fossil fuels reserves will last.

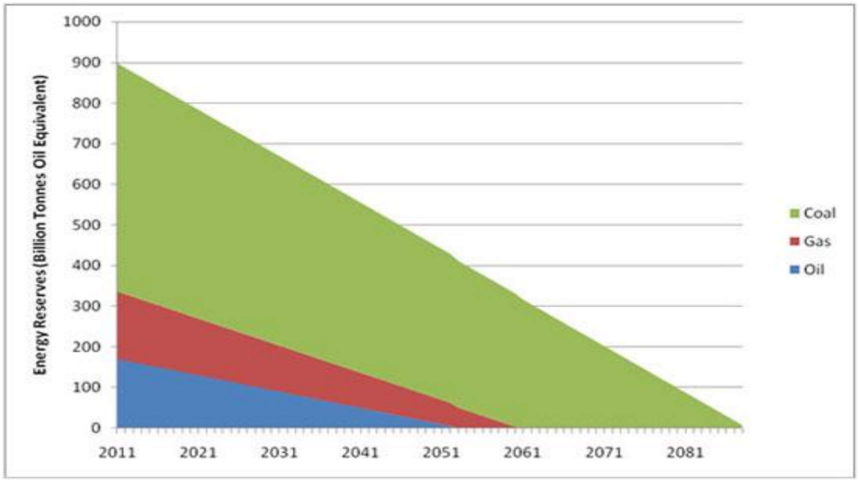


Figure 1.1: Years of production left for fossil fuels [3]

Literature review

Fossil fuel reserves are going to be vanished in the near future, so human beings will need to find alternative energy sources to avoid this disaster. The use of renewable energy sources is becoming popular along with fossil fuels depletion. Microgrid concept was quickly becoming a popular topic within the power community. It has been found that in terms of energy security, multiple small generators are more efficient than relying on a single large generator [4]. Microgrid systems can be integrated with renewable energy sources and meet the needs of a wide range of application in commercial, industrial and other critical applications such as running at hospitals and military bases. Microgrid will also be increasingly deployed in rural communities to meet their electricity needs. Independence is one of the advantages of Microgrid. It offers more reliability and stability over a traditional central generation. Faults and load imbalances are a reality within electrical distribution systems. There is a need of a controller to help maintain stability.

The paper investigated a control strategy for distributed generation systems to mitigate imbalances due to load conditions [5]. It presented a controller that regulates the terminal voltage of sensitive loads in the island mode and real and reactive power flow in the grid-connected mode. The controller has multiple loops containing regulators for filter inductor current, filter capacitor voltage and real and reactive powers. Simulation results are presented in the paper to verify the performance of the controller. Frequency regulation was not investigated in the paper and the controller operates at a single frequency.

The analysis of droop based generation control schemes for distributed generation inverters comprising of active power-frequency and reactive power-voltage controllers are presented in [6]. The author built small-signal models for microgrids that consisting of several distributed generations in a chain topology. It is a radial network with several generators and an infinite bus at one end and loads connected at each distributed resource bus. Microgrid has a system matrix that is portioned into submatrices referring to the active and reactive power flows [7]. An eigenvalue analysis and sufficient conditions were developed to guarantee their small signal stability, and guidelines are provided for design of the active power-frequency and reactive power-voltage controllers. The authors also used IEEE 1547 standards in the design process in order to follow the established regulations. The droop-based controllers that allow decentralized operation of the Microgrid system without communication between the distributed generations.

Objective of Study

Microgrid deployments will increase significantly in decades. Power system planning is very important and voltage is one of the key objects of power systems. This thesis pursues the same idea as the paper that was mentioned previously there is no communication system or central controller between generations, but this study provided a different method to accomplish it. The neural network algorithm is used for Microgrid voltage control. When the load demand changes significantly it might cause problems such as low and high voltage issues at the terminal of sensitive loads. The diesel generators should smooth these disturbances by controlling its real and reactive power. Microgrid has multiple power generations, and there is no central controller and no communication system between them in this study. It is difficult to solve the problems without a controller or by regulating only one generation's real and reactive power outputs. There are two diesel generators presented in this study, and their real and reactive powers are regulated. It will optimize Microgrid reliability. Diesel generators will sustain the load demand and renewable sources are mainly used for charging battery. Since there is no direct relationship between two generators, neural network is one of the best solutions to solve non-linear problems. There are many different types of neural networks; the abilities of different networks can be related to their structure, dynamics and learning methods. It offers improved performance over conventional technologies in areas which include: signal filtering, data segmentation, optimization and scheduling [8].

CHAPTER II

RENEWABLE ENERGY SYSTEMS INTEGRATION-MICROGRID

Overview

Renewable energy comes from sources that can be replaced or replenished. Nowadays, this type of energy is growing in popularity. It is a combination of various renewable energy sources such as solar, wind, biomass, and geothermal. These renewable energy sources are clean and have nominal environmental impacts. In contrast, fossil fuels are a finite resource. Eventually, it will become very expensive, and the world will run out of fossil fuels. However, renewable resources offer the alternative of fossil fuels; these are distributed all over the world and are available at no cost. Even the renewable energy demand is regularly increasing but the world still relies on fossil fuel energy the most. The percentage of annual energy consumption by source in the US and in the world is shown in the Table 2.1. Statistics has shown that there is an ongoing increase in the use of renewable energy. By the end of 2011, approximately 8% of the total global energy consumption came from renewable sources [9]. In the United States alone, 9% of the total energy production came from renewable energy sources [10]. The potential of renewable energy sources is enormous.

Source	World	US
petroleum	33%	36%
Natural Gas	24%	26%
Coal	30%	20%
Renewable Energy	8%	9%
Nuclear Electric Power	5%	8%

Table 2.1: Energy use in U.S and World in 2011

Even though the rapid growth of renewable sources, it has many challenges could affect wider deployment of these resources, for instance, intermittency, lack of large scale energy storage, and restriction of locations. These technical challenges must be overcome to make it growing maturity.

Components of Microgrid

There are some main components in a Microgrid power system such as protection, monitoring, immediate storage, local loads, and distributed generations. Distributed generations and energy storage will be introduced in this chapter.

Solar Energy

Solar power is considering an unlimited energy resource. One day of the insolation onto Earth is more than enough energy to satisfy global needs each day. The drawback of the solar energy is its intermittency. Solar power system needs to have a storage device such as a battery during the night. The cloudy weather would make the solar energy unreliable during the day.

Solar energy technologies are growing very fast in recent decades. The solar radiation can be used in many ways such as water heating-solar thermal, directly electricity generation-solar Photovoltaic (PV), and electricity generation-solar thermal power systems.

Photovoltaic Technology

Solar Photovoltaic devices convert sunlight into electrical energy and it is used very common in public. For instance, directly light traffic signs and providing house electricity. PV modules are wired in series and in parallel to meet voltage and current requirements. It can be applied to the grid or with storage for off-grid applications. It needs a power inverter to convert direct current (DC) to alternating current (AC). One of the advantages of PV technology is its high reliability, and warranties of 20 years or more. Figure 2.1 show a photovoltaic cell structure.

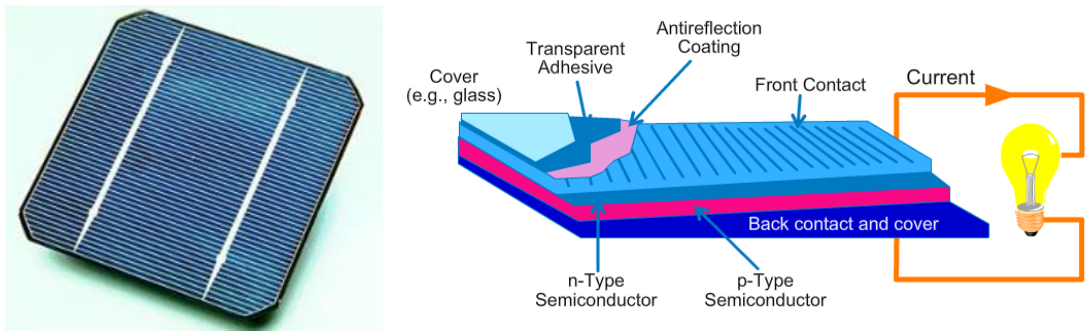


Figure 2.1: Photovoltaic cell structure [11]

The number of PV installations have a dramatically amount of growth in recent years. The growth is because of government supporting policies, cost reductions and technology improvements. For example, Solyndra was a manufacturer of photovoltaic (PV) systems and the company received a $535million U.S. Energy Department loan guarantee [12]; the PV system price was $9 per Watt-DC by system component for completed systems in 2009. The price dropped to $5.9 per Watt-DC in 2012[13]. The world annual solar photovoltaic production is shown in Figure 2.2.

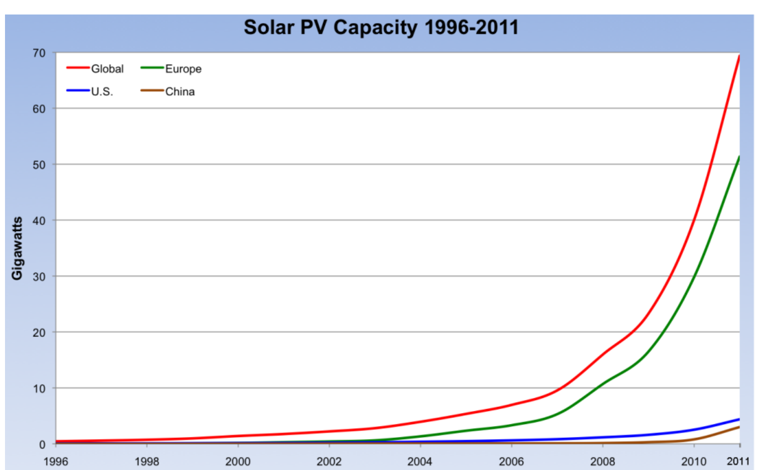


Figure 2.2: World annual solar photovoltaic production [9]

Photovoltaic cells have a complex relationship. The power delivered by a PV system is dependent on the temperature, solar irradiance, and incidence angle. As the operating conditions differ, the voltage and current that leads to maximum power vary. Maximum power tracking is widely used in a power electronic converter in order to produce as much power as possible from a PV system [14]. It also benefits some applications as putting power on the grid, charging batteries, and powering an electric motor. There are several methods such as constant voltage, open circuit voltage, short circuit current, and perturb and observe. Figure 2.3 shows the I-V and power characteristics of solar panel [14]. The certain resistance value at the maximum power point is called characteristic resistance of the cell; this value draws the maximum power from the device. If the resistance is lower or higher than this value, the system will not be used efficiently and drawn less power than the maximum available.

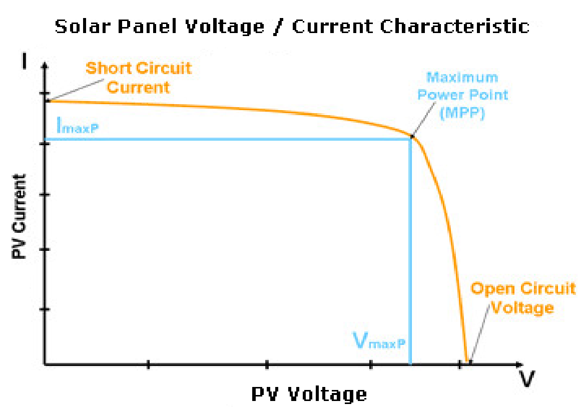


Figure 2.3: I-V curve [14]

Wind Energy

Wind energy comes from air current flowing across the earth’s surface. A wind turbine is a device that converts wind energy from the wind into mechanical energy. The mechanical energy can be used to drive machinery such as for grinding grain or pumping water. Similarly, it can be used to produce electricity. The first known wind turbine for producing electricity was a battery charging machine in 1887. Wind generators for electricity were common on farms in the past. Nowadays, the wind energy is widely used for many applications such as telecom towers, offshore platforms, and rural schools.

Wind Technology

Wind turbines convert wind energy into usable power that can provide electricity for home, school or business applications on residential or utility scales. It can be horizontal axis wind turbines (HAWT) or vertical axis wind turbines (VAWT). The two wind turbines are shown in Figure 2.4 and Figure 2.5.

Figure 2.4: VAWT [15]

Figure 2.5: HAWT [16]

Power from the wind can be calculated by the equation.

$$P = 0.5\rho A v^3 C_p$$

Where P: power, watt, ρ: density of air, kg/m^3, v: wind speed, m/s, C_p: wind turbine power efficiency, A: πr^2 swept area of wind turbine. Figure 2.6 shows a sketch of how the power output from a wind turbine varies with steady wind speed [17].

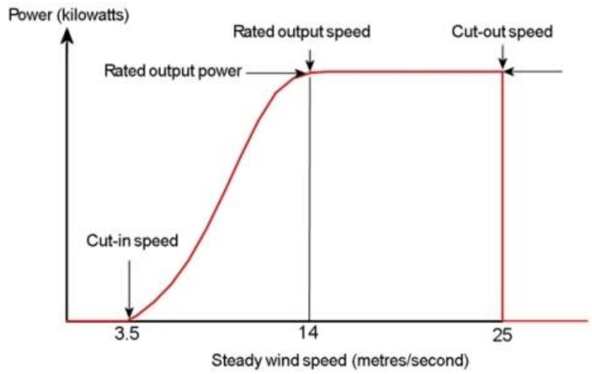


Figure 2.6: Wind turbine power output with steady wind speed [17]

The cut-in speed is at very low wind speeds. The wind turbines will begin to spin and generate electrical power when the wind speed is above 3.5 meters per second. Every turbine has a rated output power. When the wind speed reach the rated output speed the wind turbine will only generate rated output power. There is no further rise in the output power. If the wind speed is above the cut-out speed there is a risk of damage to the rotor. As a result, a braking system is employed to stop the wind turbine. There are several different technologies are used for wind turbine generators such as variable frequency synchronous generators, squirrel cage induction generators, and doubly fed induction generators. Most of modern wind turbines have two or three blades. A wind farm is numbers of wind turbines in the same area for production of electricity. The wind technologies have excellent environmental credential and avoidance of long distance transmission costs. Wind energy is one of the fastest growing markets in the world today. Figure 2.7 shows the world wind power capacity from 1997-2011.

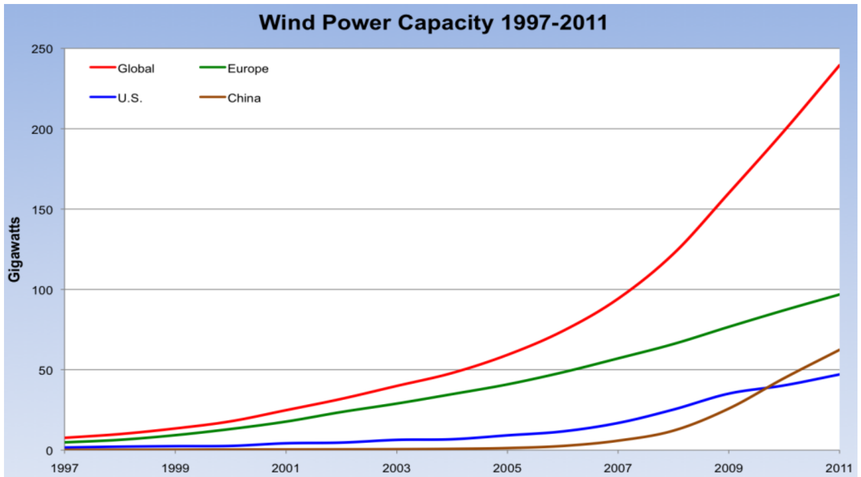


Figure 2.7: World annual wind energy production [9]

Energy Storage

Energy storage plays an important role in a utility disconnected power system. A conventional generation system is large enough not to be affected by load changes. Renewable energy must be stored in order to make power system reliable if it is not grid-connected. For example, energy storage is required to compensate for no wind periods; solar energy is not available on cloudy days and during the night time, so stored energy must be available to pick up the loads for the loss of sunlight. Storage batteries are generally used as energy backup. When the load voltages fluctuating along with load profile changing, energy storage has to have the ability of smoothing out load changes. There are several types of batteries such as Lithium ion, lead acid, and fuel cell. There are some other storage methods: for instance, thermal storage, mechanical storage, and biological storage. Figure 2.8 illustrates the emerging energy storage technologies. The storage battery is a bidirectional converter to the system. It is necessary to charge and discharge energy.

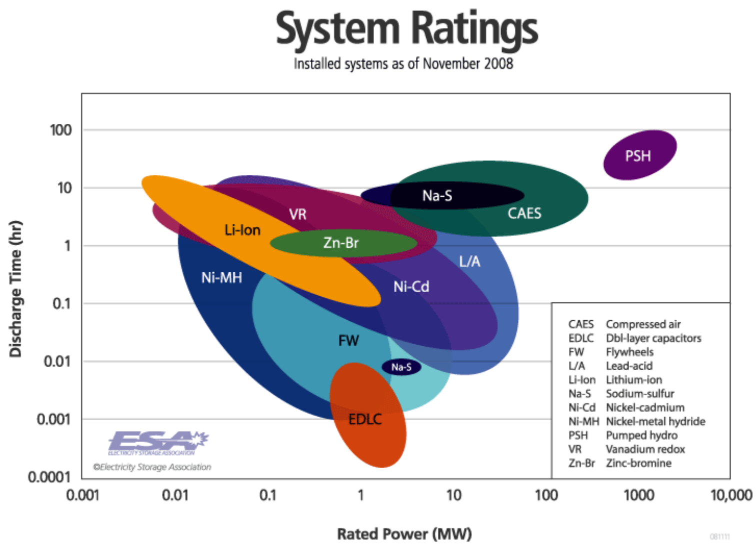


Figure 2.8: Energy storage rated power versus discharge time [18]

Diesel Generator

A diesel generator consists of a diesel engine with an electrical generator to generate electrical energy. Diesel generators are the most commonly used generators because of the diesel's unique features: powerful, portable, and highly dependable for a wide variety of uses. They also require minimal maintenance work and costs due to the absence of carburetors and spark plugs [19]. They are cheaper compared to gas generators because of the low fuel costs. Diesel has a higher energy density and more energy can be extracted from when compared to the same volume of gas. Despite the advantages of diesel generators, it could be way more expensive in terms of their setting up. However, the statistics shows that the savings derived from the investment in generators that run on diesel are worth on outweigh the disadvantages [20]. It is still the top rated choice among commercial users. Diesel generators are widely used in places where grid is not available or as emergency power source if the grid fails. One or more diesel generators could be supplying energy for residents, schools, and business buildings without a connection to an electrical grid. It is one of the main components in Microgrid. Figure 2.9 shows a diesel generator.

Figure 2.9: Diesel generator [21]

Cost Optimization

Microgrid power system is a local version of a centralized electricity system that provides cheap and reliable power in remote areas. The capital cost of electric power transmission is very high to certain regions such as mountains and sparsely populated areas. The conventional power plant has a huge amount of power loss in a long distance transmission line. Power loss is a waste of energy. In addition, renewable energy resources are considered to be an unlimited power supply. Microgrid is the best solution to provide power to these areas.

Microgrid Power System

Microgrid power system is a small-scale power supply network that is designed to provide power for a small community. Microgrid technology has been in a research and development phase for the last decade. A major advantage of Microgrid is its ability to work alone during the utility grid disturbance or outage. The main components of Microgrid contain multiple distributed energy resources, local loads, and energy storages.

These technologies are in different stages of maturity. The challenges are to integrate them all and to operate in a stable and reliable condition, and to manage the imbalance between loads and generations. Interconnection standards need to be developed to ensure consistency. For example, ANSI C84 is the American National Standard for Electric Power Systems and Equipment; the IEEE 1547 Standard for interconnecting distributed resources with electric power systems is proposed by the Institute of Electrical and Electronic Engineers. These standards include voltage, frequency, harmonics regulations, and synchronous interconnection requirements for distributed resources and utility grid. Figure 2.10 shows a typical Microgrid power system.

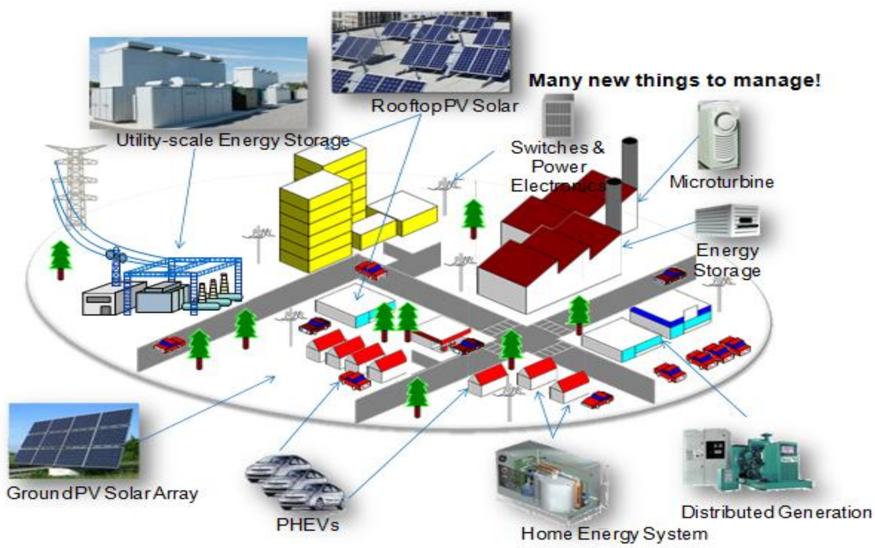


Figure 2.10: Microgrid [22]

There are two operating modes of a Microgrid power system. Grid Connected Mode: When it is connected to the utility grid, the static switch is closed. All the feeders are being supplied by the utility grid, and Microgrid can be sending excess power to the utility gird. Islanding Mode: The utility grid does not supply power when the static switch is open. Microgrid can be working alone preventing power outages when the utility grid is not available. Figures 2.11 and 2.12 illustrate the configurations of the two modes. The point of common coupling is the point where a Microgrid system is connected to the utility grid. Islanding mode includes two operating conditions: intentional islanding and unintentional islanding. The intentional islanding is expected to disconnect from the utility grid. The benefits of the intentional islanding mode is allowing for maintenance, resolving power quality issues, and relieving overload problems on the utility grid. The unintentional islanding is when the faults happen at the utility grid side, according to the ANSI C84 and IEEE 1547 Standards; Microgrid should be disconnected from the utility grid if its voltages or frequencies violate either the lower or upper bound limits.

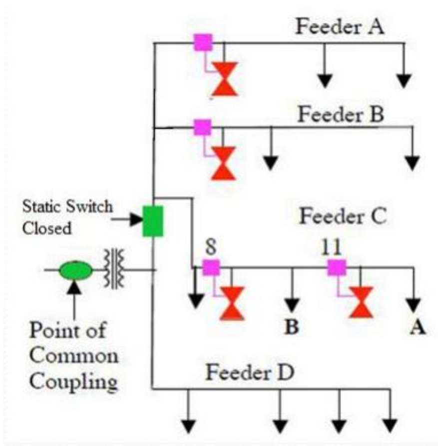


Figure 2.11: Grid connected mode [23]

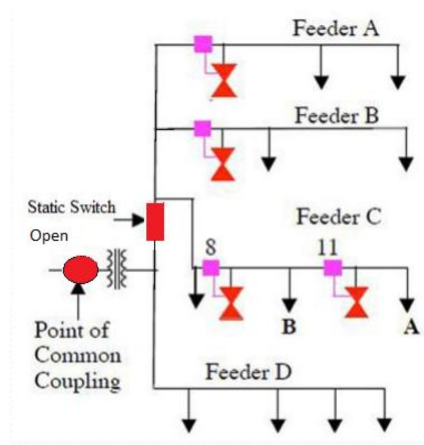


Figure 2.12: Islanding mode [23]

CHAPTER III

NEURAL NETWORK BASED MICROGRID VOLTAGE CONTROL

Microgrid Topology

A Microgrid system is presented on PSCAD. It represents a small community that consists of solar, wind, and diesel generations, battery storage and 10 variable loads. The system is a three phase balanced power system disconnected from the utility grid. As time progresses, the load demand changes. When the total load demand changes significantly, it might cause problems such as low and high voltage issues at the critical buses. The purpose of this study is to improve the voltage profile of Microgrid. The diesel generations should smooth out these disturbances by controlling their real and reactive power outputs using a neural network algorithm. Neural network will provide how much real and reactive power is needed from each generator supplying power to the system. This study included low voltage issue, high voltage issue, and low and high voltage issue at the same time at the terminal of sensitive loads. The lower bound and higher bound voltage are 0.978 and 1.027 per unit respectively. The power factors of diesel generators were also considered; the desired range was from 0.85 to 0.89 per unit. The system voltage is at a distribution level with rated line to line voltage-480 V. The locations of the power generation are given in this study. Figure 3.1 demonstrates the Microgrid topology.

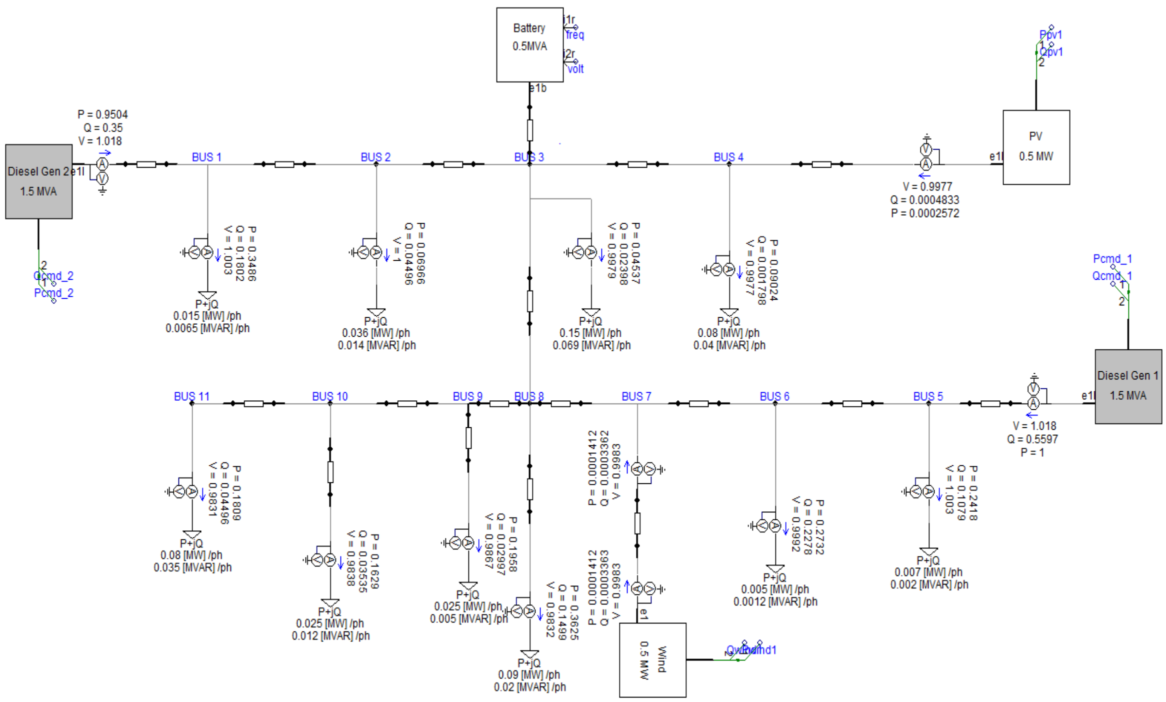


Figure 3.1: Microgrid topology

Table 3.1 shows the capacity of each power generation.

Power Generations	capacity
Wind Power	0.5MW
Solar Power	0.5MW
Diesel Generators	3.0MVA(PQ control)
Battery Storage	0.5MVA(voltage control)

Table 3.1: Electricity generating capacity

The transmission line parameters are the same but the distance may vary between bus to bus. Table 3.2 shows the transmission line parameters.

Resistance	0.3418 ohm
Reactance	1.0335 ohm
Mutual resistance	0.1558 ohm
Mutual reactance	0.4367 ohm
Capacitance(A, B, C)	5.9990 uF
Capacitance(A-B, A-C, B-C)	-1.3300 uF

Table 3.2: Transmission line parameters

Table 3.3 illustrates the length of the transmission line between bus and bus in mile.

Bus	Bus	Length/mile	Bus	Bus	Length/mile
1	2	0.0035	1	Diesel 2	0.0090
2	3	0.0035	3	Battery	0.0070
3	4	0.0025	3	8	0.0070
5	6	0.0020	4	PV	0.0070
6	7	0.0010	5	Diesel 1	0.0070
7	8	0.0050	7	Wind	0.0010
8	9	0.0075	8	Load 8	0.0150
9	10	0.0064	9	Load 9	0.0055
10	11	0.0063	10	Load 10	0.0043

Table 3.3: Length of transmission line

The diesel generator model is shown in Figure 3.2. The diesel generator model consists of a synchronous generator, exciter, IC engine, and governor. The diesel generator model is P-Q controlled to provide desired output in order to sustain the system's voltage profile.

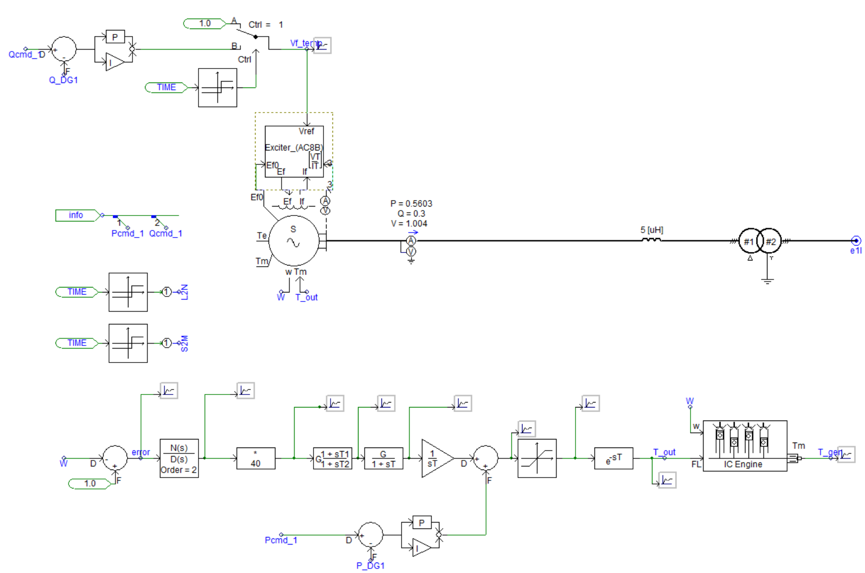


Figure 3.2: Diesel generator model

Figure 3.3 demonstrates the inverter average model for wind and solar power. Three current control current sources were used to model the inverter. It does not supply reactive power to the system, it only provides real power.

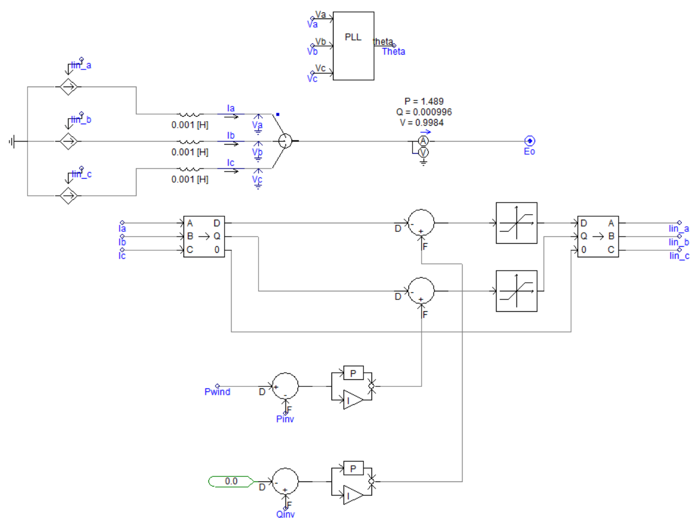


Figure 3.3: Inverter average model for wind and solar power

Artificial Neural Network

Neural network is a data processing system that is inspired by the biological neurons. It can be derived from the neurophysiologist Warren McCulloch and mathematician Walter Pitts; they modeled a simple neural network using electrical circuits in 1943 [24], but the technology was limited at that time. Neural network has significant progress that has been made since then. It has an outstanding ability to derive meaning from complicated data. It also can be used to detect data trends and patterns that are too complex to be classified by neither humans nor computer techniques. A trained neural network can analyze information that has been given and providing projections and answers to further problems. Neural networks take a different approach to problem solving than the conventional computers. Neural networks are like human beings' brain. They are suited to situations that have no clear algorithmic solutions and are able to manage imprecise data. Neural networks are used in several applications that have irrelevant data such as robotics, signal processing, pattern recognition, and financial applications. This advantage allows neural networks to excel in some areas that conventional computers often find difficult [25]. In contrast to neural networks, conventional computers' instructions are fetched from memory. Its process is repeated the instructions are completed. This kind of process is suited to solving problems using an algorithm such as searching for an item on a database [25]. Conventional computers are not able to manage the variability of data obtained in the real word.

Architecture of Neural Networks

Mathematically, neural networks can be represented as weighted directed graphs. Feed-forward network was the first type of neural network. The data moves in only one direction, there are no cycles or loops in the network. The two common neural network architectures are:

- Single Layer Feed-forward Neural Networks
- Multi Layer Feed-forward Neural Networks

The single layer feed-forward network consists of a single layer, where the inputs are directly connected to the outputs, via a series of weights. It is the simplest type of feedforward network and can only classify separable cases with a binary target [26]. Figure 3.4 shows the structure of single layer neural network.

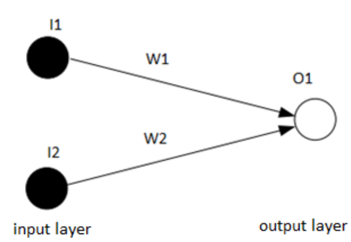


Figure 3.4: Single layer neural network

A multilayer feed-forward neural network has the same structure of a single layer network with one or more hidden layers. Network data and calculations flow in a single direction, from the input data to outputs [27]. The hidden layers sit in between the input and output layers. Figure 3.5 demonstrates the structure of multiple layers neural network

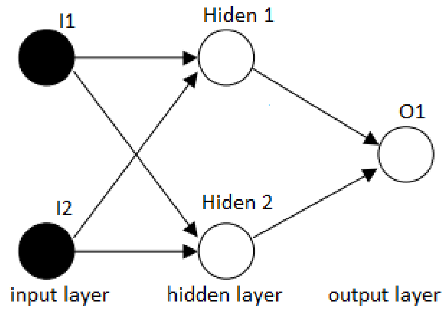


Figure 3.5: Multiple layers neural network

The Back-Propagation Algorithm

The back-propagation is used to learn the examples. Input data and output target are very important in the algorithm that needs to be given to train the network. When training is done, it will provide the required output for a particular input. The back-propagation networks are widely used for pattern recognition and mapping tasks. Figure 3.6 demonstrates the back-propagation algorithm.

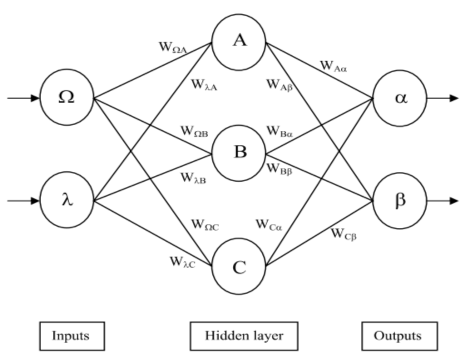


Figure 3.6: The back-propagation algorithm [28]

Activation Functions

The activation function translates the input signals to output signals. The sigmoid transfer function is commonly used in back-propagation networks, because it is differentiable. It can reduce the computation burden for training. Figure 3.7 shows the sigmoid transfer function.

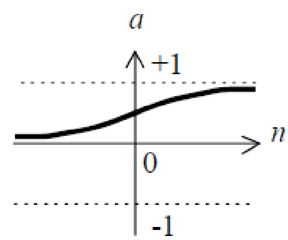


Figure 3.7: Sigmoid transfer function [29]

The calculation of the algorithm is shown below.

1. Calculate errors of output neurons

$$E_\alpha = out_\alpha(1-out_\alpha)(\text{Target}_\alpha - out_\alpha)$$

$$E_\beta = out_\beta(1-out_\beta)(\text{Target}_\beta - out_\beta)$$

2. Change output layer weights

$$W^+_{A\alpha} = W_{A\alpha} + \eta E_\alpha out_A \qquad W^+_{A\beta} = W_{A\beta} + \eta E_\beta out_A$$

$$W^+_{B\alpha} = W_{B\alpha} + \eta E_\alpha out_B \qquad W^+_{B\beta} = W_{B\beta} + \eta E_\beta out_B$$

$$W^+_{C\alpha} = W_{C\alpha} + \eta E_\alpha out_C \qquad W^+_{C\beta} = W_{C\beta} + \eta E_\beta out_C$$

3. Calculate errors of hidden layer neurons

$$E_A = out_A(1-out_A)(E_\alpha W_{A\alpha} + E_\beta W_{A\beta})$$

$$E_B = out_B(1-out_B)(E_\alpha W_{B\alpha} + E_\beta W_{B\beta})$$

$$E_C = out_C(1-out_C)(E_\alpha W_{C\alpha} + E_\beta W_{C\beta})$$

4. Change hidden layer weights

$$W^+_{\lambda A} = W_{\lambda A} + \eta E_A \text{in}_\lambda \qquad W^+_{\Omega A} = W_{\Omega A} + \eta E_A \text{in}_\Omega$$

$$W^+_{\lambda B} = W_{\lambda B} + \eta E_B \text{in}_\lambda \qquad W^+_{\Omega B} = W_{\Omega B} + \eta E_B \text{in}_\Omega$$

$$W^+_{\lambda C} = W_{\lambda C} + \eta E_C \text{in}_\lambda \qquad W^+_{\Omega C} = W_{\Omega C} + \eta E_C \text{in}_\Omega$$

Where η is the learning rate, E is the errors of neurons, *out* represents each neuron's output, W and W^+ are the initial weight and adjusted weight respectively.

When the Mean Squared Error (MSE) ceases to decrease, the neural network training will stop.

$$\mathrm{MSE} = \frac{1}{\mathrm{n}}\sum_{i=1}^{n}(Y_i^{'} - Y_i)^2$$

Where $Y_i^{'}$ is the neural network output, and Y_i is the output target value.

Neural Network Training

The input data cases with their corresponding output targets for training neural networks were generated on PSCAD. Possible circumstances were included, such as high and low voltages at critical buses. Table 3.4 illustrates 5 of the 112 training cases.

	Case 1	Case 2	Case 3	Case 4	Case 5
Diesel 1 P	0.9500	1.0200	0.4000	0.2600	0.8000
Diesel 1 Q	0.5600	0.5800	0.2200	0.1000	0.4500
Diesel 2 P	0.5160	0.7000	0.7000	1.2300	0.7800
Diesel 2 Q	0.3100	0.4000	0.4000	0.6400	0.4600
Wind P	0	0	0	0.1300	0
PV P	0.2000	0	0	0.0600	0
Vd1	1.0330	1.0350	0.9926	0.9760	1.0280
Vd2	1.0180	1.0270	1.0150	1.0310	1.0300
V load 1	1.0070	1.0120	1.0010	1.0080	1.0140
V load 2	1.0050	1.0080	0.9965	1.0010	1.0090
V load 3	1.0040	1.0040	0.9929	0.9943	1.0050
V load 4	1.0040	1.0030	0.9924	0.9941	1.0050
V load 5	1.0170	1.0190	0.9863	0.9726	1.0150
V load 6	1.0130	1.0150	0.9849	0.9732	1.0120
V load 8	1.0040	0.9979	0.9741	0.974	1.0020
V load 9	0.9976	0.9987	0.9757	0.9732	0.9961
V load 10	0.9933	0.9965	0.9737	0.9699	0.9922
V load 11	0.9931	0.9969	0.9703	0.9692	0.9912

Table 3.4: 5 of the 112 training cases

The output targets were determined by manually adjusting diesel generators' output power to alleviate voltage issues. The table 3.5 indicates the corresponding output target to the input cases. When each generator provides a certain amount of power, the issues will be eliminated.

	Case 1	Case 2	Case 3	Case 4	Case 5
Diesel 1 P	0.65	0.80	0.85	0.95	0.68
Diesel 1 Q	0.39	0.47	0.46	0.56	0.38
Diesel 2 P	0.65	0.65	0.65	0.65	0.60
Diesel 2 Q	0.39	0.36	0.38	0.38	0.34

Table 3.5: 5 of the 112 output targets

Table 3.6 shows the test cases for verifying the neural network performance after training was finished. These test cases were different from the input training cases.

	Case 1	Case 2	Case 3	Case 4	Case 5
Diesel 1 P	0.3200	0.5000	0.9800	0.8500	0.6500
Diesel 1 Q	0.1900	0.2800	0.5824	0.5000	0.3500
Diesel 2 P	1.0500	1.1000	0.2000	0.3000	0.6500
Diesel 2 Q	0.6500	0.6100	0.1188	0.1600	0.3500
Wind P	0.0500	0	0.1000	0	0
PV P	0.0100	0	0.0600	0	0
Vd1	1.0020	1.0010	1.0350	1.0130	1.0130
Vd2	1.0370	1.0280	1.0040	1.0040	1.0220
V load 1	1.0150	1.0070	1.0000	0.9977	1.0090
V load 2	1.0070	1.0010	0.9993	0.9956	1.0040
V load 3	1.0000	0.9965	0.9997	0.9937	0.9999
V load 4	0.9994	0.9962	0.9996	0.9933	0.9997
V load 5	0.9966	0.9930	1.0200	0.9994	1.0030
V load 6	0.9953	0.9916	1.0160	0.9963	0.9999
V load 8	0.9869	0.9817	1.0010	0.9754	0.9803
V load 9	0.9819	0.9774	0.9986	0.9762	0.9807
V load 10	0.9744	0.9719	0.9958	0.9705	0.9753
V load 11	0.9760	0.9719	0.9957	0.9696	0.9745

Table 3.6: 5 of the 16 test cases

System Optimization Scenarios

There are seven scenarios to alleviate voltage issues in this thesis. The monitoring points are different in each scenario so there were seven neural networks. Their results are presented in this chapter respectively.

1. Monitor all the loads
2. Monitor four critical loads
3. Monitor three critical loads
4. Monitor two critical loads
5. Monitor one critical load
6. Monitor four irrelevant loads
7. Monitor one critical load and one irrelevant load

First Scenario – Monitoring All the Loads

The first scenario was to monitor 10 loads. The goal of this scenario was to determine that the neural network could be used for improving the voltage profile of Microgrid. There were 15 neurons in the hidden layer. Figure 3.8 demonstrates that the network training stopped at epoch 6 because it had the best vaildation performace. Regression values measure the correlation between neural outputs and output targets. An R value 1 means a close relationship, and 0 means a random relationship.

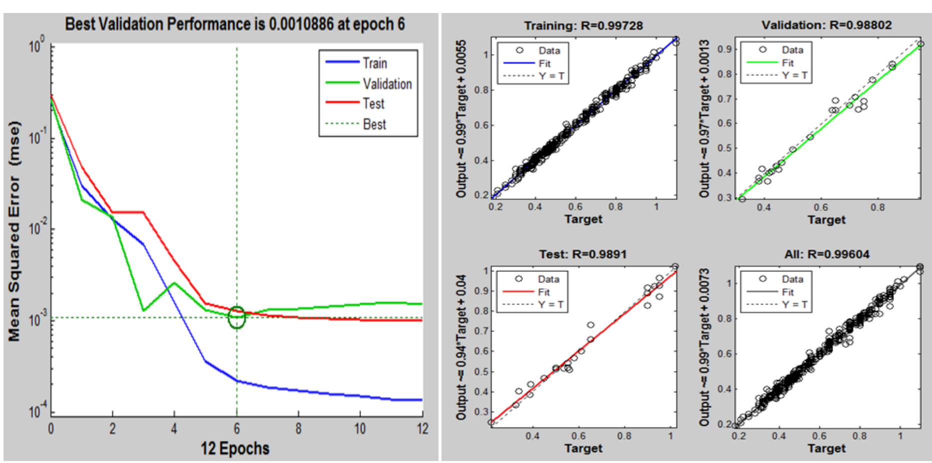


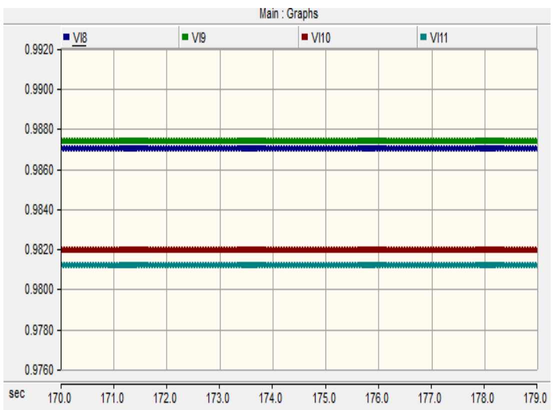
Figure 3.8: First scenario training information

First Scenario Simulation Result

	Case 1	Case 2	Case 3	Case 4	Case 5
Diesel 1 P	0.6922	0.9130	0.6844	0.9748	0.8097
Diesel 1 Q	0.3806	0.5304	0.3366	0.5586	0.4731
Diesel 2 P	0.6833	0.8839	0.5286	0.6803	0.6591
Diesel 2 Q	0.3506	0.4909	0.2914	0.3977	0.3887

Table 3.7: Neural network output of first network

Figure 3.9 shows the simulation plot of voltages at bus 8,9,10, and 11 before adjusting the diesel generators' power commands of case 5. Figure 3.10 shows the improved load voltages using the neural network outputs on diesel generators of case 5. The simulation results indicated that low voltage issues at critical buses were eliminated in case 5.



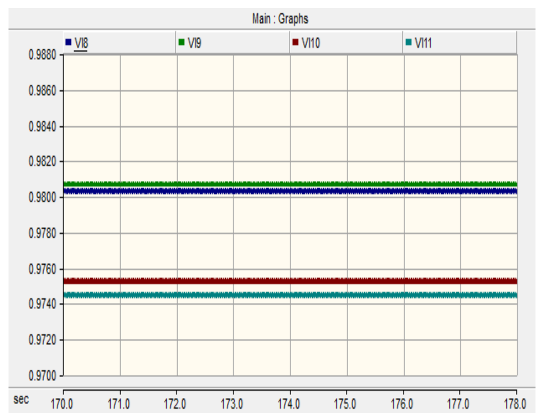


Figure 3.9: Load voltages of case 5 **Figure 3.10: Improved load voltages of case 5**

Table 3.8 demonstrates that the voltage profile and the neural network outputs for the diesel generators' commands were able to solve the problems for all the test cases. The power factors of diesel generators are also calculated and are within the desired range. The results proved that the neural network algorithm can be implemented for improving the voltage profile of Microgrid.

	Case 1	Case 2	Case 3	Case 4	Case 5
Diesel 1 P	0.6922	0.91303	0.6844	0.9748	0.8097
Diesel 1 Q	0.3806	0.5304	0.3366	0.5586	0.4731
Diesel 2 P	0.6833	0.8839	0.5286	0.6803	0.6591
Diesel 2 Q	0.3506	0.4909	0.2914	0.3977	0.3887
Wind P	0.0500	0	0.1000	0	0
PV P	0.0100	0	0.0600	0	0
Vd1	1.0200	1.0250	1.0160	1.026	1.0260
Vd 2	1.0210	1.0250	1.0150	1.026	1.0260
V load 1	1.0080	1.0070	1.0040	1.012	1.0130
V load 2	1.0030	1.0030	1.0010	1.0070	1.0080
V load 3	1.0000	1.0000	0.9990	1.0020	1.0040
V load 4	0.9991	0.9998	0.9988	1.0010	1.0030
V load 5	1.0090	1.0110	1.0060	1.0110	1.0130
V load 6	1.0060	1.0080	1.0050	1.0070	1.0090
V load 8	0.9933	0.9920	0.9941	0.9851	0.9870
V load 9	0.9894	0.9879	0.9922	0.9859	0.9874
V load 10	0.9847	0.9823	0.9892	0.9803	0.9820
V load 11	0.9840	0.9823	0.9892	0.9796	0.9813
PF D1	0.8762	0.8646	0.8973	0.8676	0.8634
PF D2	0.8896	0.8742	0.8757	0.8632	0.8613

Table 3.8: Simulation results for the first scenario

Second Scenario – Monitoring Four Critical Loads

In this scenario, the four critical buses were selected as monitoring points. The four buses were far away from the power generations. The lowest load voltages always happened on these buses, so they could be considered the most critical buses. They were bus 8, 9, 10, and 11. There were 10 Neurons in the hidden layer. The simulation results of voltage profile are shown in table 3.9. This scenario successfully resolved the voltage issues by monitoring four critical loads. The monitoring points narrowed down to four loads.

	Case 1	Case 2	Case 3	Case 4	Case 5
Diesel 1 P	0.8289	0.9097	0.7177	1.0248	0.8241
Diesel 1 Q	0.4587	0.5147	0.3686	0.5866	0.4802
Diesel 2 P	0.6146	0.8329	0.4750	0.600	0.5765
Diesel 2 Q	0.3482	0.45965	0.2756	0.3315	0.3213
Wind P	0.0500	0	0.1000	0	0
PV P	0.0100	0	0.0600	0	0
Vd1	1.0260	1.0230	1.0190	1.0260	1.0250
Vd2	1.0210	1.0220	1.0140	1.0210	1.0220
V load 1	1.0090	1.0050	1.0040	1.0090	1.0110
V load 2	1.0050	1.0020	1.0010	1.0050	1.0070
V load 3	1.0020	0.9991	0.9991	1.0010	1.0020
V load 4	1.0010	0.9989	0.9990	1.0000	1.0020
V load 5	1.0150	1.0090	1.0080	1.0110	1.0120
V load 6	1.0110	1.0060	1.0060	1.0080	1.0080
V load 8	0.9970	0.9906	0.9951	0.9850	0.9860
V load 9	0.9931	0.9866	0.9930	0.9857	0.9864
V load 10	0.9882	0.9809	0.9902	0.9802	0.9810
V load 11	0.9877	0.9810	0.9903	0.9793	0.9802
PF D1	0.8749	0.8703	0.8895	0.8678	0.8640
PF D2	0.8700	0.8755	0.8649	0.8753	0.8734

Table 3.9: Simulation results for the second scenario

Third Scenario – Monitoring Three Critical loads

The three monitoring points were bus 9, 10, and 11 in this scenario. There were 7 neurons in the hidden layer. Table 3.10 shows the voltage profile of the simulation results. This scenario also successfully resolved the voltage issues. In the next scenario, the number of monitoring points could be reduced to examine if the neural network would still perform its function.

	Case 1	Case 2	Case 3	Case 4	Case 5
Diesel 1 P	0.6922	0.91303	0.6470	0.9748	0.8097
Diesel 1 Q	0.3806	0.5304	0.3577	0.5586	0.4731
Diesel 2 P	0.6833	0.8839	0.5879	0.6803	0.6591
Diesel 2 Q	0.3506	0.4909	0.3192	0.3977	0.3887
Wind P	0.0500	0	0.1000	0	0
PV P	0.0100	0	0.0600	0	0
Vd1	1.0240	1.024	1.0180	1.0240	1.0230
Vd 2	1.0250	1.025	1.0180	1.0230	1.0250
V load 1	1.0110	1.0070	1.0060	1.0100	1.0120
V load 2	1.0060	1.0030	1.0020	1.0050	1.0070
V load 3	1.0020	0.9999	1.0000	1.001	1.0030
V load 4	1.0010	0.9995	0.9998	1.0000	1.0020
V load 5	1.0130	1.0100	1.0080	1.0090	1.0100
V load 6	1.0100	1.0070	1.0060	1.0060	1.0070
V load 8	0.9961	0.9915	0.9953	0.9840	0.9856
V load 9	0.9922	0.9872	0.9933	0.9848	0.9860
V load 10	0.9874	0.9816	0.9904	0.9792	0.9804
V load 11	0.9868	0.9817	0.9905	0.9783	0.9797
PF D1	0.8762	0.8646	0.8751	0.8676	0.8634
PF D2	0.8897	0.8742	0.8788	0.8633	0.8613

Table 3.10: Simulation Results for the third scenario

Fourth Scenario – Monitoring Two Critical Loads

The monitoring points could be gradually reduced since the previous scenario effectively resolved the voltage issues of the test cases. Based on the observation, bus 10 and 11 were the most critical points due to it always had the lowest voltages at these two buses. There were 10 neurons in the hidden layer. Table 3.11 shows the results. The issues could be resolved by monitoring only two critical loads.

	Case 1	Case 2	Case 3	Case 4	Case 5
Diesel 1 P	0.7282	0.8962	0.6966	0.8470	0.8068
Diesel 1 Q	0.4170	0.5191	0.3805	0.4946	0.4555
Diesel 2 P	0.6211	0.8203	0.5164	0.7405	0.5923
Diesel 2 Q	0.3466	0.4652	0.2834	0.4327	0.3303
Wind P	0.0500	0	0.1000	0	0
PV P	0.0100	0	0.0600	0	0
Vd1	1.0220	1.0230	1.0190	1.0200	1.0230
Vd2	1.0200	1.0220	1.0150	1.0260	1.0220
V load 1	1.0070	1.0050	1.0040	1.0120	1.0100
V load 2	1.0030	1.0020	1.0010	1.0060	1.0060
V load 3	1.0000	0.9990	0.9995	1.0010	1.0020
V load 4	0.9995	0.9987	0.9993	1.0000	1.0020
V load 5	1.0110	1.0090	1.0090	1.0060	1.0100
V load 6	1.0080	1.0060	1.0070	1.0030	1.0070
V load 8	0.9944	0.9907	0.9954	0.9826	0.9850
V load 9	0.9906	0.9864	0.9935	0.9831	0.9854
V load 10	0.9858	0.9811	0.9906	0.9786	0.9800
V load 11	0.9853	0.9812	0.9908	0.9780	0.9792
PF D1	0.8677	0.8653	0.8776	0.8635	0.8708
PF D2	0.8732	0.8698	0.8766	0.8634	0.8733

Table 3.11: Simulation Results for the fourth scenario

Fifth Scenario – Monitoring One Critical Load

The intention of reducing monitoring points was to find the most critical buses that need to be monitored for the purpose of training neural network. Bus 11 was monitored in this scenario. There were 6 neurons in the hidden layer. In this scenario, some of the cases were resolved but case 5 still has the low voltage issue. The neural network was not able to provide precise outputs for the two generators.

	Case 1	Case 2	Case 3	Case 4	Case 5
Diesel 1 P	0.6678	0.8931	0.6209	0.9545	0.7187
Diesel 1 Q	0.4031	0.5065	0.3512	0.5559	0.4230
Diesel 2 P	0.6627	0.7949	0.5525	0.6397	0.5656
Diesel 2 Q	0.3823	0.4551	0.3047	0.3731	0.3244
Wind P	0.0500	0	0.1000	0	0
PV P	0.0100	0	0.0600	0	0
Vd1	1.0210	1.0210	1.0160	1.0250	1.0180
Vd 2	1.0220	1.0220	1.0160	1.0230	1.0200
V load 1	1.0090	1.0090	1.0050	1.0100	1.0090
V load 2	1.0040	1.0040	1.0010	1.0050	1.0050
V load 3	1.0010	1.0010	0.9993	1.0010	1.0010
V load 4	0.9999	0.9999	0.9991	1.0000	1.0000
V load 5	1.0100	1.0100	1.0070	1.0100	1.0070
V load 6	1.0070	1.0070	1.0050	1.0060	1.0040
V load 8	0.9943	0.9943	0.9944	0.9841	0.9828
V load 9	0.9904	0.9904	0.9923	0.9850	0.9832
V load 10	0.9857	0.9857	0.9895	0.9793	0.9777
V load 11	0.9850	0.9850	0.9896	0.9786	0.9768
PF D1	0.8561	0.8698	0.8704	0.8641	0.8618
PF D2	0.8662	0.8678	0.8756	0.8638	0.8674

Table 3.12: Simulation Results for the fifth scenario

Sixth Scenario – Monitoring Four Irrelevant Loads

The four irrelevant loads were bus 1, 2, 3, and 6. The low and high voltage issues would not happen at these buses. The objective of this scenario was to indicate that monitoring point is very important. There were 8 neurons in the hidden layer. Since the critical loads were not included in the training cases, the low voltage issues still exist in cases 4 and 5. This network failed to resolve the problems. Table 3.13 shows the results.

	Case 1	Case 2	Case 3	Case 4	Case 5
Diesel 1 P	0.6593	0.8538	0.6555	0.9484	0.6774
Diesel 1 Q	0.3968	0.5004	0.3542	0.5271	0.3956
Diesel 2 P	0.6041	0.8253	0.5578	0.5993	0.4831
Diesel 2 Q	0.3652	0.4858	0.3120	0.3352	0.2752
Wind P	0.05	0	0.1000	0	0
PV P	0.01	0	0.0600	0	0
Vd1	1.02	1.022	1.0180	1.022	1.014
Vd 2	1.02	1.023	1.0170	1.02	1.016
V load 1	1.007	1.006	1.0050	1.008	1.006
V load 2	1.003	1.002	1.0020	1.004	1.002
V load 3	1	0.9989	0.9997	0.9993	0.9986
V load 4	0.9991	0.9986	0.9994	0.9991	0.9986
V load 5	1.009	1.008	1.0080	1.007	1.003
V load 6	1.006	1.005	1.0060	1.004	1
V load 8	0.9933	0.9901	0.9949	0.9822	0.9801
V load 9	0.9894	0.9857	0.9930	0.983	0.9805
V load 10	0.9848	0.9802	0.9901	0.9774	0.975
V load 11	0.9841	0.9804	0.9901	0.9766	0.9742
PF D1	0.856793	0.862744	0.8797	0.874075	0.863529
PF D2	0.855776	0.861784	0.8727	0.872759	0.868906

Table 3.13: Simulation results for the sixth scenario

Seventh Scenario – Monitoring One Critical Load and One Irrelevant Load

The monitoring buses were bus 9, and 10 in this scenario. In view of the fact that the fourth scenario was successful, bus 9 could be considered as an irrelevant load. There were 8 neurons in the hidden layer. According to the simulation results, some cases still have low or high voltage issues, and this neural network was not able to accomplish the task.

	Case 1	Case 2	Case 3	Case 4	Case 5
Diesel 1 P	0.6843	0.9333	0.5832	0.9450	0.8058
Diesel 1 Q	0.4039	0.5360	0.3481	0.5486	0.4249
Diesel 2 P	0.6946	0.8592	0.6203	0.6992	0.5759
Diesel 2 Q	0.3974	0.4735	0.3583	0.4182	0.3238
Wind P	0.0500	0	0.1000	0	0
PV P	0.0100	0	0.0600	0	0
Vd1	1.0270	1.0260	1.0170	1.0250	1.0200
Vd 2	1.0260	1.0240	1.0200	1.0270	1.0210
V load 1	1.0120	1.0060	1.0070	1.0120	1.0090
V load 2	1.0080	1.0030	1.0030	1.0070	1.0050
V load 3	1.0040	0.9999	1.0000	1.0020	1.0010
V load 4	1.0030	0.9996	1.0000	1.0010	1.0010
V load 5	1.0170	1.0110	1.0070	1.0100	1.0080
V load 6	1.0140	1.0080	1.0050	1.0070	1.0050
V load 8	1.0000	0.9921	0.9950	0.9849	0.9836
V load 9	0.9997	0.9879	0.9931	0.9856	0.9838
V load 10	0.9985	0.9824	0.9901	0.9800	0.9782
V load 11	0.9978	0.9825	0.9903	0.9794	0.9774
PF D1	0.8611	0.8671	0.8586	0.8648	0.8845
PF D2	0.8679	0.8758	0.8659	0.8582	0.8716

Table 3.14: Simulation results for the seventh scenario

Comparison of the Results

The results show that the first four scenarios have met the request to balance the load demand and generations to sustain the voltage profile at a certain range in case 5 and some other test cases. Figure 3.11 is shown the voltages at bus 10 and 11 of test case 5. In contrast the last three scenarios violated the lower bound and it could not deal with all the test cases. Evidently, the first four networks can provide accurate information compared to the last three networks. According to the simulation results, when the most critical points are included in the training cases, the neural network outputs will be able to improve the voltage profile. Consequently, this study also indicates that the critical points are very important when using the neural network algorithm. The monitoring points were reduced in the second scenario, the voltage issues were solved in every case. If the majority critical points can be determined it will be easier to alleviate the voltage issues for Microgrid.

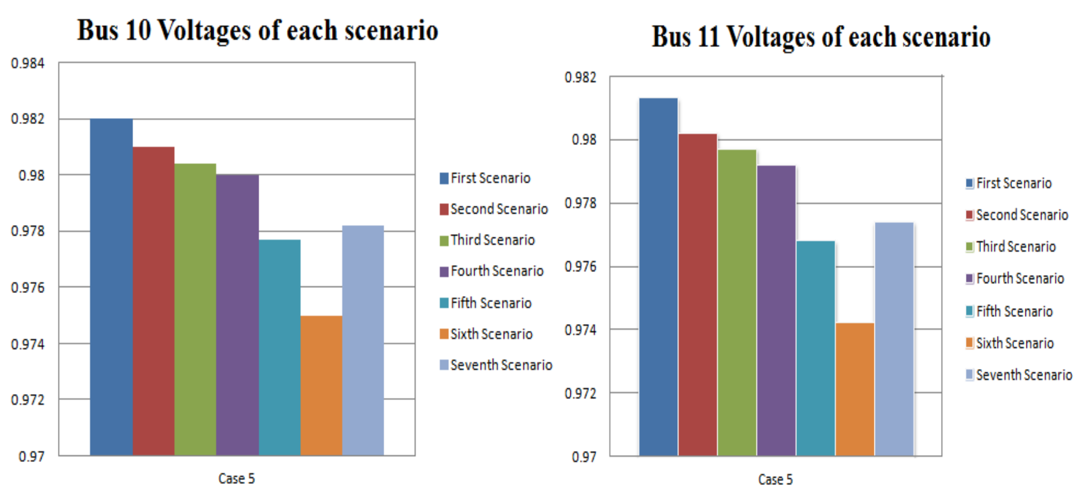


Figure 3.11: Bus 10 and 11 voltages of test case 5

CHATPER IV

CONCLUSIONS

Microgrid is very flexible in applications to different geographic conditions with several distributed generations. Management of imbalance between loads and generations is one of the Microgrid challenges. On the basis of the results of this research, it can be concluded that neural network is an effective and efficient tool that can be employed for Microgrid protection. Thus, neural network chip could be implemented in diesel generators to optimize Microgrid reliability. In addition, this study also indicates that the monitoring point is very important. Once monitoring points are determined, it allows neural network to perform its function. Furthermore, the neural network algorithm can be used for power systems planning and design due to its predictive ability. It is a very trustworthy approach in terms of power systems security. However, the neural network output and the system simulation are performed separately in this thesis. The work can be done in real time with simulation-interfacing of MATLAB and PSCAD software. When the voltage issues are detected on MATLAB, neural network will give new power outputs for diesel generators and the data will be transmitted from MATLAB to PSCAD immediately. The Microgrid topology for a small community with 10 loads is presented in this study. Ultimately, the neural network algorithm can even be implemented on a larger system, such as IEEE 34 bus, to maintain its voltage profile.

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APPENDIX A: Training Cases

Training Cases	case 1	case 2	case 3	case 4	case 5	case 6	case 7	case 8	case 9	case 10
Diesel 1 P	0.9500	0.6500	0.3000	0.3000	0.5500	0.8000	1.0000	0.7500	1.2000	0.6000
Diesel 1 Q	0.5600	0.3856	0.1800	0.1800	0.3263	0.4742	0.5900	0.4450	0.7200	0.3559
Diesel 2 P	0.5160	0.6500	1.0000	0.3000	0.4000	0.7000	0.2000	0.3000	0.2000	0.8300
Diesel 2 Q	0.3062	0.3856	0.5900	0.1800	0.2371	0.4154	0.1188	0.1800	0.1188	0.4925
Wind P	0.0000	0.2000	0.1200	0.2000	0.2000	0.0000	0.1200	0.2500	0.1000	0.0000
PV P	0.2000	0.2000	0.0000	0.1000	0.2000	0.3000	0.1500	0.0000	0.1000	0.1000
Vd1	1.0330	1.0090	0.9990	0.9952	1.0030	1.0170	1.0290	1.0120	1.0310	1.0050
Vd2	1.0180	1.0160	1.0300	1.0020	1.0010	1.0180	1.0000	1.0010	0.9936	1.0170
V 1	1.0070	1.0020	1.0100	0.9956	0.9927	1.0030	0.9959	0.9948	0.9892	0.9998
V 2	1.0050	0.9989	1.0040	0.9939	0.9919	0.9990	0.9949	0.9928	0.9902	0.9961
V 3	1.0040	0.9962	0.9984	0.9925	0.9914	0.9964	0.9956	0.9923	0.9924	0.9939
V 4	1.0040	0.9963	0.9981	0.9926	0.9907	0.9959	0.9948	0.9911	0.9913	0.9931
V 5	1.0170	0.9981	0.9940	0.9902	0.9937	1.0040	1.0130	0.9999	1.0110	0.9947
V 6	1.0130	0.9952	0.9927	0.9888	0.9919	1.0000	1.0090	0.9971	1.0070	0.9928
V 8	1.0040	0.9797	0.9859	0.9817	0.9824	0.9877	0.9934	0.9869	0.9910	0.9855
V 9	0.9976	0.9822	0.9815	0.9784	0.9780	0.9792	0.9903	0.9796	0.9803	0.9795
V 10	0.9933	0.9779	0.9761	0.9742	0.9732	0.9756	0.9843	0.9764	0.9786	0.9757
V 11	0.9931	0.9777	0.9749	0.9737	0.9736	0.9754	0.9843	0.9759	0.9781	0.9751
Training Cases	case 11	case 12	case 13	case 14	case 15	case 16	case 17	case 18	case 19	case 20
Diesel 1 P	0.2800	0.6500	0.4000	1.1500	0.3000	1.1500	0.7000	0.3000	0.6500	0.9000
Diesel 1 Q	0.1662	0.3856	0.2371	0.6824	0.1800	0.6824	0.4154	0.1800	0.3856	0.5340
Diesel 2 P	1.1500	0.8200	1.2000	0.4000	0.5500	0.2000	0.5500	1.2000	0.7000	0.6500
Diesel 2 Q	0.6824	0.4866	0.7200	0.2371	0.3263	0.1188	0.3263	0.7200	0.4450	0.3856
Wind P	0.1100	0.0000	0.0300	0.1500	0.0500	0.1000	0.2500	0.3000	0.1900	0.3000
PV P	0.1300	0.0000	0.4000	0.2000	0.0500	0.2000	0.2000	0.0000	0.2600	0.2600
Vd1	0.9898	1.0090	0.9961	1.0300	0.9920	1.0290	1.0060	0.9858	1.0020	1.0170
Vd2	1.0290	1.0190	1.0340	1.0070	1.0120	0.9956	1.0070	1.0320	1.0140	1.0140
V 1	1.0050	1.0020	1.0090	0.9986	1.0000	0.9914	0.9953	1.0070	0.9988	1.0000
V 2	0.9990	0.9978	1.0020	0.9961	0.9963	0.9914	0.9924	0.9991	0.9946	0.9968
V 3	0.9943	0.9952	0.9965	0.9952	0.9929	0.9927	0.9910	0.9926	0.9920	0.9949
V 4	0.9930	0.9940	0.9962	0.9945	0.9920	0.9920	0.9903	0.9916	0.9913	0.9946
V 5	0.9850	0.9984	0.9894	1.0110	0.9870	1.0100	0.9942	0.9808	0.9915	1.0020
V 6	0.9844	0.9960	0.9884	1.0070	0.9866	1.0060	0.9918	0.9804	0.9896	0.9989
V 8	0.9811	0.9874	0.9837	0.9847	0.9856	0.9878	0.9766	0.9712	0.9761	0.9820
V 9	0.9750	0.9804	0.9762	0.9840	0.9786	0.9840	0.9748	0.9694	0.9742	0.9802
V 10	0.9712	0.9753	0.9707	0.9783	0.9777	0.9793	0.9698	0.9643	0.9705	0.9770
V 11	0.9707	0.9754	0.9703	0.9779	0.9755	0.9785	0.9690	0.9635	0.9700	0.9764

Training Cases	case 21	case 22	case 23	case 24	case 25	case 26	case 27	case 28	case 29	case 30
Diesel 1 P	0.6000	0.8000	1.0000	0.6500	0.3600	0.6000	0.8000	0.6500	0.6200	0.8600
Diesel 1 Q	0.3558	0.4742	0.4800	0.4000	0.1800	0.3500	0.4000	0.3800	0.3100	0.4900
Diesel 2 P	1.1500	0.9000	0.8200	0.5000	0.6000	0.9000	0.6000	0.7500	0.7500	0.3300
Diesel 2 Q	0.6824	0.5340	0.4500	0.2800	0.3200	0.6000	0.3600	0.4500	0.4500	0.1800
Wind P	0.0500	0.1000	0.1000	0.0000	0.0000	0.3000	0.0800	0.3000	0.0000	0.1000
PV P	0.0600	0.1100	0.0250	0.0900	0.3000	0.2000	0.0400	0.2100	0.2100	0.3000
Vd1	0.9999	1.0330	1.0240	1.0350	0.9912	1.0250	1.0120	1.0080	0.9969	1.0320
Vd2	1.0300	1.0380	1.0100	1.0180	1.0100	1.0350	1.0130	1.0190	1.0200	1.0110
V 1	1.0070	1.0200	1.0070	1.0080	0.9986	1.0150	1.0000	1.0030	1.0040	1.0040
V 2	0.9999	1.0130	1.0020	1.0050	0.9955	1.0090	0.9970	0.9991	0.9992	1.0030
V 3	0.9948	1.0070	0.9961	1.0050	0.9932	1.0040	0.9953	0.9956	0.9947	1.0030
V 4	0.9941	1.0070	0.9945	1.0030	0.9935	1.0030	0.9951	0.9948	0.9950	1.0030
V 5	0.9904	1.0200	0.9954	1.0240	0.9859	1.0150	1.0010	0.9976	0.9876	1.0180
V 6	0.9887	1.0170	0.9927	1.0210	0.9849	1.0130	0.9977	0.9953	0.9863	1.0150
V 8	0.9794	1.0020	0.9784	1.0120	0.9756	1.0030	0.9886	0.9874	0.9759	1.0010
V 9	0.9766	1.0030	0.9754	1.0110	0.9791	1.0000	0.9827	0.9789	0.9724	1.0010
V 10	0.9733	1.0010	0.9708	1.0100	0.9765	0.9951	0.9754	0.9766	0.9700	0.9998
V 11	0.9715	1.0010	0.9696	1.0100	0.9745	0.9970	0.9740	0.9778	0.9712	0.9978
Training Cases	case 31	case 32	case 33	case 34	case 35	case 36	case 37	case 38	case 39	case 40
Diesel 1 P	0.6600	1.2000	0.2900	1.0900	0.3500	0.2300	0.7000	1.0000	0.5000	0.2600
Diesel 1 Q	0.3600	0.6800	0.1300	0.6500	0.1400	0.0800	0.4400	0.6000	0.2500	0.1000
Diesel 2 P	0.8200	0.3900	0.9600	0.2600	0.6400	0.8700	0.5100	0.1200	0.8600	1.2300
Diesel 2 Q	0.4400	0.2000	0.6300	0.0500	0.3200	0.6000	0.2300	0.0500	0.4800	0.6400
Wind P	0.0600	0.1000	0.0000	0.1500	0.1900	0.0300	0.0000	0.1200	0.0000	0.1300
PV P	0.2100	0.0500	0.1800	0.0500	0.3200	0.0500	0.0000	0.2200	0.0000	0.0600
Vd1	1.0000	1.0340	0.9866	1.0320	0.9874	0.9875	1.0080	1.0320	0.9912	0.9760
Vd2	1.0210	1.0040	1.0270	1.0000	1.0070	1.0230	1.0090	1.0010	1.0180	1.0310
V 1	1.0050	0.9967	1.0060	0.9973	0.9951	1.0030	0.9997	0.9991	1.0010	1.0080
V 2	0.9998	0.9948	0.9980	0.9968	0.9923	0.9983	0.9973	0.9993	0.9972	1.0010
V 3	0.9964	0.9945	0.9928	0.9978	0.9911	0.9943	0.9948	0.9995	0.9938	0.9943
V 4	0.9945	0.9925	0.9923	0.9970	0.9913	0.9933	0.9938	0.9989	0.9935	0.9941
V 5	1.0000	1.0160	0.9825	1.0150	0.9828	0.9847	0.9963	1.0160	0.9837	0.9726
V 6	0.9979	1.0110	0.9821	1.0110	0.9819	0.9843	0.9934	1.0120	0.9825	0.9732
V 8	0.9869	0.9934	0.9765	0.9936	0.9731	0.9792	0.9823	0.9959	0.9786	0.9740
V 9	0.9825	0.9890	0.9704	0.9962	0.9703	0.9756	0.9804	0.9970	0.9769	0.9732
V 10	0.9757	0.9824	0.9667	0.9945	0.9692	0.9731	0.9779	0.9971	0.9739	0.9699
V 11	0.9745	0.9811	0.9653	0.9940	0.9676	0.9709	0.9758	0.9974	0.9732	0.9692

Training Cases	case 41	case 42	case 43	case 44	case 45	case 46	case 47	case 48	case 49	case 50
Diesel 1 P	0.3800	0.3400	0.4200	0.7100	1.2300	0.6000	1.2500	0.2600	0.9500	0.4600
Diesel 1 Q	0.2000	0.1400	0.2100	0.3600	0.6500	0.3300	0.6800	0.1200	0.5600	0.2900
Diesel 2 P	0.6800	1.2200	0.4800	0.6600	0.5600	1.2600	0.3300	0.5000	0.2100	0.6800
Diesel 2 Q	0.3800	0.6400	0.2100	0.3200	0.3500	0.6200	0.1800	0.2800	0.1200	0.3800
Wind P	0.0800	0.0450	0.1200	0.2200	0.1000	0.0000	0.0000	0.1000	0.1100	0.1300
PV P	0.2700	0.0690	0.0800	0.1200	0.0000	0.3000	0.0000	0.1300	0.1600	0.0900
Vd1	0.9905	0.9945	0.9959	1.0070	1.0320	0.9939	1.0290	0.9943	1.0330	1.0040
Vd2	1.0120	1.0380	1.0030	1.0080	1.0140	1.0290	1.0010	1.0070	1.0020	1.0140
V 1	0.9987	1.0150	0.9945	0.9955	1.0010	1.0060	0.9947	0.9963	0.9979	1.0000
V 2	0.9955	1.0060	0.9970	0.9925	0.9986	0.9992	0.9934	0.9936	0.9974	0.9960
V 3	0.9927	0.9986	0.9909	0.9917	0.9970	0.9935	0.9936	0.9924	0.9984	0.9936
V 4	0.9930	0.9972	0.9908	0.9908	0.9961	0.9932	0.9922	0.9925	0.9986	0.9927
V 5	0.9846	0.9900	0.9896	0.9967	1.0140	0.9845	1.0100	0.9903	1.0180	0.9956
V 6	0.9836	0.9892	0.9883	0.9945	1.0090	0.9830	1.0050	0.9894	1.0130	0.9936
V 8	0.9705	0.9829	0.9802	0.9823	0.9853	0.9697	0.9913	0.9820	0.9980	0.9804
V 9	0.9742	0.9766	0.9776	0.9811	0.9867	0.9722	0.9862	0.9769	0.9926	0.9802
V 10	0.9705	0.9725	0.9746	0.9781	0.9831	0.9692	0.9816	0.9722	0.9904	0.9781
V 11	0.9682	0.9731	0.9743	0.9778	0.9823	0.9692	0.9810	0.9716	0.9919	0.9761
Training Cases	case 51	case 52	case 53	case 54	case 55	case 56	case 57	case 58	case 59	case 60
Diesel 1 P	0.9800	0.6500	1.1000	1.3000	0.6000	0.7200	0.5000	0.9300	0.8000	0.3000
Diesel 1 Q	0.4300	0.3800	0.5400	0.5900	0.3500	0.4500	0.2000	0.6000	0.4000	0.1800
Diesel 2 P	0.3500	0.2900	0.4500	0.2600	0.6500	0.9000	0.6000	0.4500	0.2900	1.2000
Diesel 2 Q	0.2000	0.1800	0.3200	0.0900	0.3000	0.6000	0.2400	0.2500	0.1200	0.6400
Wind P	0.3600	0.1000	0.1000	0.3000	0.0300	0.0000	0.2000	0.1300	0.0600	0.2000
PV P	0.1200	0.1000	0.1300	0.0500	0.0500	0.0000	0.1000	0.1200	0.0500	0.1300
Vd1	1.0150	1.0070	1.0290	1.0340	1.0090	1.0220	1.0020	1.0340	1.0130	0.9909
Vd2	0.9995	1.0020	1.0160	1.0010	1.0130	1.0390	1.0050	1.0110	0.9954	1.0290
V 1	0.9922	0.9954	1.0050	0.9975	1.0010	1.0190	0.9953	1.0010	0.9904	1.0060
V 2	0.9913	0.9941	1.0020	0.9973	0.9981	1.0120	0.9930	0.9997	0.9904	0.9994
V 3	0.9919	0.9933	0.9998	0.9979	0.9959	1.0060	0.9921	0.9992	0.9915	0.9943
V 4	0.9908	0.9932	0.9991	0.9975	0.9954	1.0050	0.9908	0.9986	0.9907	0.9936
V 5	1.0020	0.9967	1.0140	1.0170	0.9997	1.0100	0.9951	1.0180	1.0020	0.9859
V 6	0.9993	0.9944	1.0100	1.0130	0.9978	1.0080	0.9937	1.0150	0.9989	0.9851
V 8	0.9908	0.9749	0.9953	0.9965	0.9903	1.0000	0.9870	0.9990	0.9872	0.9781
V 9	0.9818	0.9777	0.9943	0.9944	0.9828	0.9948	0.9838	0.9938	0.9833	0.9746
V 10	0.9773	0.9718	0.9892	0.9927	0.9756	0.9887	0.9790	0.9911	0.9788	0.9686
V 11	0.9766	0.9707	0.9895	0.9917	0.9741	0.9882	0.9808	0.9909	0.9780	0.9675

Training Cases	case 61	case 62	case 63	case 64	case 65	case 66	case 67	case 68	case 69	case 70
Diesel 1 P	0.3000	0.2000	0.2500	0.4000	1.1500	0.3000	1.1500	0.7000	0.3000	0.6500
Diesel 1 Q	0.1800	0.1188	0.1500	0.2371	0.6824	0.1800	0.6824	0.4154	0.1800	0.3856
Diesel 2 P	0.9200	1.1500	1.0500	1.2000	0.4000	0.5500	0.2000	0.5500	1.2000	0.7000
Diesel 2 Q	0.5460	0.6824	0.6230	0.7200	0.2371	0.3263	0.1188	0.3263	0.7200	0.4450
Wind P	0.0000	0.0000	0.2000	0.0300	0.1500	0.0500	0.1000	0.2500	0.3000	0.1900
PV P	0.0000	0.0000	0.0500	0.4000	0.2000	0.0500	0.2000	0.2000	0.0000	0.2600
Vd1	1.0140	0.9895	0.9947	0.9961	1.0300	0.9920	1.0290	1.0060	0.9858	1.0020
Vd2	1.0370	1.0330	1.0300	1.0340	1.0070	1.0120	0.9956	1.0070	1.0320	1.0140
V 1	1.0180	1.0090	1.0080	1.0090	0.9986	1.0000	0.9914	0.9953	1.0070	0.9988
V 2	1.0110	1.0010	1.0010	1.0020	0.9961	0.9963	0.9914	0.9924	0.9991	0.9946
V 3	1.0050	0.9956	0.9962	0.9965	0.9952	0.9929	0.9927	0.9910	0.9926	0.9920
V 4	1.0040	0.9943	0.9959	0.9962	0.9945	0.9920	0.9920	0.9903	0.9916	0.9913
V 5	1.0090	0.9861	0.9906	0.9894	1.0110	0.9870	1.0100	0.9942	0.9808	0.9915
V 6	1.0080	0.9855	0.9898	0.9884	1.0070	0.9866	1.0060	0.9918	0.9804	0.9896
V 8	0.9979	0.9797	0.9824	0.9837	0.9847	0.9856	0.9878	0.9766	0.9712	0.9761
V 9	0.9997	0.9766	0.9792	0.9762	0.9840	0.9786	0.9840	0.9748	0.9694	0.9742
V 10	0.9973	0.9726	0.9753	0.9707	0.9783	0.9777	0.9793	0.9698	0.9643	0.9705
V 11	0.9967	0.9730	0.9756	0.9703	0.9779	0.9755	0.9785	0.9690	0.9635	0.9700
Training Cases	case 71	case 72	case 73	case 74	case 75	case 76	case 77	case 78	case 79	case 80
Diesel 1 P	0.9000	0.6000	0.8000	1.0000	0.3000	1.2000	0.2600	0.6500	0.7800	1.2000
Diesel 1 Q	0.5340	0.3558	0.4742	0.4800	0.1800	0.7200	0.1000	0.3600	0.4600	0.6500
Diesel 2 P	0.6500	1.1500	0.9000	0.8200	1.0000	0.2000	1.2300	0.5000	0.8500	0.2500
Diesel 2 Q	0.3856	0.6824	0.5340	0.4500	0.5900	0.1188	0.6400	0.2800	0.4500	0.1400
Wind P	0.3000	0.0500	0.1000	0.1000	0.1200	0.1000	0.1300	0.0000	0.0000	0.0000
PV P	0.2600	0.0600	0.1100	0.0250	0.0000	0.1000	0.0600	0.0000	0.0000	0.0000
Vd1	1.0170	0.9999	1.0330	1.0240	0.9990	1.0310	0.9760	1.0060	1.0180	1.0310
Vd2	1.0140	1.0300	1.0380	1.0100	1.0300	0.9936	1.0310	1.0070	1.0230	0.9984
V 1	1.0000	1.0070	1.0200	1.0070	1.0100	0.9892	1.0080	0.9963	1.0070	0.9934
V 2	0.9968	0.9999	1.0130	1.0020	1.0040	0.9902	1.0010	0.9936	1.0020	0.9928
V 3	0.9949	0.9948	1.0070	0.9961	0.9984	0.9924	0.9943	0.9920	0.9979	0.9930
V 4	0.9946	0.9941	1.0070	0.9945	0.9981	0.9913	0.9941	0.9911	0.9970	0.9910
V 5	1.0020	0.9904	1.0200	0.9954	0.9940	1.0110	0.9726	0.9959	1.0060	1.0130
V 6	0.9989	0.9887	1.0170	0.9927	0.9927	1.0070	0.9732	0.9936	1.0030	1.0080
V 8	0.9820	0.9794	1.0020	0.9784	0.9859	0.9910	0.9740	0.9810	0.9885	0.9932
V 9	0.9802	0.9766	1.0030	0.9754	0.9815	0.9803	0.9732	0.9764	0.9824	0.9817
V 10	0.9770	0.9733	1.0010	0.9708	0.9761	0.9786	0.9699	0.9725	0.9772	0.9773
V 11	0.9764	0.9715	1.0010	0.9696	0.9749	0.9781	0.9692	0.9723	0.9762	0.9763

Training Cases	case 81	case 82	case 83	case 84	case 85	case 86	case 87	case 88	case 89	case 90
Diesel 1 P	0.6800	0.8000	0.8900	0.6500	0.3000	1.0200	1.3000	1.0200	0.6000	0.6500
Diesel 1 Q	0.3800	0.4500	0.4700	0.3600	0.1600	0.5800	0.6500	0.5800	0.3300	0.3400
Diesel 2 P	0.6000	0.7800	0.6500	0.6500	1.1000	0.7000	0.2000	0.2200	0.6000	0.9800
Diesel 2 Q	0.3400	0.4600	0.3600	0.3600	0.5800	0.4000	0.1100	0.1200	0.3300	0.5700
Wind P	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
PV P	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Vd1	1.0120	1.0280	1.0150	1.0040	0.9930	1.0350	1.0290	1.0150	0.9973	1.0120
Vd2	1.0120	1.0300	1.0120	1.0100	1.0330	1.0270	1.0010	0.9949	1.0120	1.0380
V 1	1.0000	1.0140	0.9989	0.9967	1.0120	1.0120	0.9965	0.9905	0.9996	1.0180
V 2	0.9964	1.0090	0.9959	0.9936	1.0040	1.0080	0.9954	0.9894	0.9957	1.0100
V 3	0.9939	1.0050	0.9935	0.9912	0.9973	1.0040	0.9949	0.9903	0.9922	1.0030
V 4	0.9920	1.0050	0.9919	0.9897	0.9967	1.0030	0.9942	0.9892	0.9910	1.0030
V 5	1.0010	1.0150	1.0020	0.9940	0.9885	1.0190	1.0110	0.9993	0.9879	1.0020
V 6	0.9984	1.0120	0.9986	0.9916	0.9876	1.0150	1.0060	0.9958	0.9862	1.0010
V 8	0.9893	1.0020	0.9793	0.9773	0.9781	0.9979	0.9866	0.9839	0.9796	0.9936
V 9	0.9819	0.9961	0.9815	0.9771	0.9777	0.9987	0.9808	0.9783	0.9825	0.9885
V 10	0.9766	0.9922	0.9776	0.9732	0.9740	0.9965	0.9782	0.9714	0.9700	0.9887
V 11	0.9762	0.9912	0.9766	0.9722	0.9728	0.9969	0.9767	0.9712	0.9695	0.9872
Training Cases	case 91	case 92	case 93	case 94	case 95	case 96	case 97	case 98	case 99	case 100
Diesel 1 P	0.5000	0.4000	0.6500	0.4000	0.7000	0.8900	1.1000	0.7000	0.9900	0.6500
Diesel 1 Q	0.2800	0.2200	0.3800	0.2200	0.4200	0.4700	0.6400	0.4000	0.5300	0.3400
Diesel 2 P	0.5000	0.7000	0.5500	0.5800	0.9500	0.7500	0.4300	0.4500	0.8500	0.7400
Diesel 2 Q	0.2800	0.4000	0.3100	0.3400	0.5000	0.4200	0.2500	0.2400	0.4600	0.4300
Wind P	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
PV P	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Vd1	1.0010	0.9926	1.0070	0.9973	1.0250	1.0300	1.1000	1.0070	1.0290	1.0030
Vd2	1.0120	1.0150	1.0110	1.0100	1.0320	1.0260	1.0050	1.0040	1.0270	1.0150
V 1	1.0020	1.0010	1.0000	0.9982	1.0140	1.0110	0.9965	0.9952	1.0110	0.9994
V 2	0.9978	0.9965	0.9971	0.9948	1.0090	1.0070	0.9943	0.9931	1.0060	0.9948
V 3	0.9944	0.9929	0.9948	0.9924	1.0040	1.0030	0.9944	0.9916	1.0010	0.9923
V 4	0.9939	0.9924	0.9946	0.9914	1.0040	1.0030	0.9935	0.9905	1.0000	0.9914
V 5	0.9934	0.9863	0.9970	0.9910	1.0140	1.0170	1.0120	0.9962	1.0140	0.9933
V 6	0.9912	0.9849	0.9948	0.9896	1.0110	1.0140	1.0070	0.9935	1.0100	0.9913
V 8	0.9794	0.9741	0.9818	0.9805	0.9975	0.9985	0.9891	0.9767	0.9904	0.9804
V 9	0.9771	0.9757	0.9811	0.9801	0.9971	0.9981	0.9827	0.9756	0.9892	0.9774
V 10	0.9710	0.9737	0.9760	0.9759	0.9941	0.9951	0.9770	0.9722	0.9858	0.9732
V 11	0.9716	0.9703	0.9788	0.9768	0.9922	0.9933	0.9766	0.9708	0.9846	0.9719

Training Cases	case 101	case 102	case 103	case 104	case 105	case 106	case 107	case 108	case 109	case 110
Diesel 1 P	0.6500	0.6200	1.3000	0.7600	0.9500	0.3400	0.3400	1.3000	0.6500	0.5500
Diesel 1 Q	0.3856	0.3500	0.6800	0.4500	0.5300	0.2000	0.2000	0.6800	0.3500	0.3263
Diesel 2 P	1.1500	0.8500	0.3000	0.6800	0.8200	1.2000	1.2000	0.3000	0.5800	0.4000
Diesel 2 Q	0.6000	0.4500	0.1700	0.3500	0.5000	0.6400	0.6400	0.1700	0.3200	0.2371
Wind P	0.0000	0.1000	0.2000	0.0000	0.0000	0.0000	0.0000	0.2000	0.0000	0.2000
PV P	0.0000	0.1000	0.1000	0.1000	0.0000	0.0000	0.0000	0.1000	0.0000	0.2000
Vd1	1.0120	1.0000	1.0310	1.0100	1.0300	0.9914	0.9914	1.0310	1.0050	1.0030
Vd2	1.0300	1.0140	0.9963	1.0100	1.0270	1.0300	1.0300	0.9963	1.0070	1.0010
V 1	1.0080	0.9974	0.9902	0.9971	1.0100	1.0070	1.0070	0.9902	0.9958	0.9927
V 2	1.0020	0.9934	0.9902	0.9937	1.0050	1.0000	1.0000	0.9902	0.9930	0.9919
V 3	0.9980	0.9911	0.9917	0.9918	1.0020	0.9945	0.9945	0.9917	0.9916	0.9914
V 4	0.9971	0.9901	0.9906	0.9909	1.0010	0.9936	0.9936	0.9906	0.9902	0.9907
V 5	1.0020	0.9906	1.0120	0.9974	1.0160	0.9857	0.9857	1.0120	0.9950	0.9937
V 6	0.9994	0.9885	1.0070	0.9945	1.0120	0.9849	0.9849	1.0070	0.9928	0.9919
V 8	0.9840	0.9731	0.9835	0.9777	0.9934	0.9750	0.9750	0.9835	0.9827	0.9824
V 9	0.9848	0.9705	0.9801	0.9765	0.9960	0.9725	0.9725	0.9801	0.9777	0.9780
V 10	0.9837	0.9645	0.9769	0.9721	0.9962	0.9685	0.9685	0.9769	0.9745	0.9732
V 11	0.9825	0.9652	0.9768	0.9721	0.9955	0.9669	0.9669	0.9768	0.9741	0.9736

Training Cases	case 111	case 112
Diesel 1 P	0.7200	1.1500
Diesel 1 Q	0.4200	0.6824
Diesel 2 P	0.6500	0.4000
Diesel 2 Q	0.3800	0.2371
Wind P	0.0000	0.1500
PV P	0.0000	0.2000
Vd1	1.0110	1.0300
Vd2	1.0120	1.0070
V 1	0.9984	0.9986
V 2	0.9948	0.9961
V 3	0.9928	0.9952
V 4	0.9913	0.9945
V 5	0.9996	1.0110
V 6	0.9971	1.0070
V 8	0.9856	0.9847
V 9	0.9811	0.9840
V 10	0.9767	0.9783
V 11	0.9755	0.9779

APPENDIX B: Output Targets

Output Targets	case 1	case 2	case 3	case 4	case 5	case 6	case 7	case 8	case 9	case 10
Diesel 1 P	0.6500	0.8600	0.6500	0.5500	0.7000	0.9000	0.7500	0.7500	0.9200	0.8300
Diesel 1 Q	0.3856	0.5100	0.3856	0.3263	0.4154	0.5450	0.4450	0.4450	0.5500	0.4925
Diesel 2 P	0.6500	0.6500	0.6500	0.3000	0.6500	0.8000	0.5500	0.6500	0.8300	0.7500
Diesel 2 Q	0.3856	0.3856	0.3856	0.1800	0.3856	0.4742	0.3263	0.3856	0.5100	0.4450
S1	0.7558	0.9998	0.7558	0.6395	0.8140	1.0522	0.8721	0.8721	1.0719	0.9651
S2	0.7558	0.7558	0.7558	0.3499	0.7558	0.9300	0.6395	0.7558	0.9742	0.8721
PF1	0.8601	0.8601	0.8601	0.8600	0.8600	0.8554	0.8600	0.8600	0.8583	0.8600
PF2	0.8601	0.8601	0.8601	0.8575	0.8601	0.8602	0.8600	0.8601	0.8520	0.8600
Output Targets	case 11	case 12	case 13	case 14	case 15	case 16	case 17	case 18	case 19	case 20
Diesel 1 P	0.8200	0.8200	0.9000	0.9500	0.6500	0.9200	0.9200	0.9800	0.9500	0.9500
Diesel 1 Q	0.4866	0.4866	0.5340	0.5824	0.3856	0.5460	0.5460	0.5800	0.5600	0.5600
Diesel 2 P	0.7500	0.8200	0.8000	0.8000	0.5500	0.7500	0.7800	0.8000	0.8000	0.8000
Diesel 2 Q	0.4450	0.4866	0.4742	0.4742	0.3263	0.4450	0.4700	0.4742	0.4742	0.4742
S1	0.9535	0.9535	1.0465	1.1143	0.7558	1.0698	1.0698	1.1388	1.1028	1.1028
S2	0.8721	0.9535	0.9300	0.9300	0.6395	0.8721	0.9107	0.9300	0.9300	0.9300
PF1	0.8600	0.8600	0.8600	0.8525	0.8601	0.8600	0.8600	0.8606	0.8615	0.8615
PF2	0.8600	0.8600	0.8602	0.8602	0.8600	0.8600	0.8565	0.8602	0.8602	0.8602
Output Targets	case 21	case 22	case 23	case 24	case 25	case 26	case 27	case 28	case 29	case 30
Diesel 1 P	1.0200	0.6500	1.1000	0.4000	0.6300	0.5500	0.9500	0.9200	0.9500	0.6000
Diesel 1 Q	0.6100	0.3856	0.6800	0.2100	0.3900	0.3000	0.4800	0.4800	0.5500	0.3000
Diesel 2 P	0.9000	0.5500	0.8200	0.4500	0.6000	0.7000	0.7500	0.7500	0.6800	0.4800
Diesel 2 Q	0.5340	0.3263	0.4500	0.2500	0.3200	0.4000	0.4500	0.4500	0.4000	0.2800
S1	1.1885	0.7558	1.2932	0.4518	0.7409	0.6265	1.0644	1.0377	1.0977	0.6708
S2	1.0465	0.6395	0.9354	0.5148	0.6800	0.8062	0.8746	0.8746	0.7889	0.5557
PF1	0.8582	0.8601	0.8506	0.8854	0.8503	0.8779	0.8925	0.8866	0.8654	0.8944
PF2	0.8600	0.8600	0.8767	0.8742	0.8824	0.8682	0.8575	0.8575	0.8619	0.8638
Output Targets	case 31	case 32	case 33	case 34	case 35	case 36	case 37	case 38	case 39	case 40
Diesel 1 P	0.8600	0.9000	0.8400	0.7500	0.6800	0.7300	0.8200	0.6500	0.9000	0.9500
Diesel 1 Q	0.5000	0.5200	0.5000	0.3900	0.4000	0.4100	0.5000	0.3400	0.4600	0.5600
Diesel 2 P	0.8000	0.8500	0.8000	0.6400	0.6400	0.7500	0.6500	0.3900	0.6900	0.6500
Diesel 2 Q	0.4000	0.4500	0.4200	0.3200	0.3500	0.4500	0.3200	0.2200	0.3900	0.3800
S1	0.9948	1.0394	0.9775	0.8453	0.7889	0.8373	0.9604	0.7336	1.0107	1.1028
S2	0.8944	0.9618	0.9035	0.7155	0.7295	0.8746	0.7245	0.4478	0.7926	0.7529
PF1	0.8645	0.8659	0.8593	0.8872	0.8619	0.8719	0.8538	0.8861	0.8904	0.8615
PF2	0.8944	0.8838	0.8854	0.8944	0.8774	0.8575	0.8972	0.8710	0.8706	0.8633

Output Targets	case 41	case 42	case 43	case 44	case 45	case 46	case 47	case 48	case 49	case 50
Diesel 1 P	0.8600	0.8000	0.7100	0.8200	0.9500	1.1000	0.9900	0.5600	0.6800	0.7300
Diesel 1 Q	0.4600	0.4400	0.3600	0.4300	0.5600	0.6200	0.5600	0.3100	0.3600	0.4300
Diesel 2 P	0.6800	0.6900	0.6000	0.8000	0.9500	0.8000	0.7600	0.5600	0.6400	0.7000
Diesel 2 Q	0.3800	0.3500	0.3100	0.4300	0.5000	0.4800	0.4300	0.3200	0.3400	0.4000
S1	0.9753	0.9130	0.7961	0.9259	1.1028	1.2627	1.1374	0.6401	0.7694	0.8472
S2	0.7790	0.7737	0.6754	0.9082	1.0735	0.9330	0.8732	0.6450	0.7247	0.8062
PF1	0.8818	0.8762	0.8919	0.8856	0.8615	0.8712	0.8704	0.8749	0.8838	0.8616
PF2	0.8729	0.8918	0.8884	0.8808	0.8849	0.8575	0.8703	0.8682	0.8831	0.8682
Output Targets	case 51	case 52	case 53	case 54	case 55	case 56	case 57	case 58	case 59	case 60
Diesel 1 P	0.7800	0.7500	0.8000	0.7500	0.8000	0.8300	0.6000	0.7500	0.7000	0.9300
Diesel 1 Q	0.4800	0.4600	0.4200	0.4300	0.4500	0.4500	0.3500	0.3800	0.3500	0.5000
Diesel 2 P	0.8000	0.6200	0.6500	0.6800	0.7000	0.6500	0.7800	0.7300	0.8000	0.9000
Diesel 2 Q	0.4800	0.3800	0.3500	0.3500	0.3500	0.3200	0.3800	0.3800	0.4000	0.4500
S1	0.9159	0.8798	0.9035	0.8645	0.9179	0.9441	0.6946	0.8408	0.7826	1.0559
S2	0.9330	0.7272	0.7382	0.7648	0.7826	0.7245	0.8676	0.8230	0.8944	1.0062
PF1	0.8517	0.8524	0.8854	0.8675	0.8716	0.8791	0.8638	0.8920	0.8944	0.8808
PF2	0.8575	0.8526	0.8805	0.8891	0.8944	0.8972	0.8990	0.8870	0.8944	0.8944
Output Targets	case 61	case 62	case 63	case 64	case 65	case 66	case 67	case 68	case 69	case 70
Diesel 1 P	0.4000	0.8200	0.7000	0.9000	0.9500	0.6500	0.9200	0.9200	0.9800	0.9500
Diesel 1 Q	0.2100	0.4500	0.4154	0.5340	0.5824	0.3856	0.5460	0.5460	0.5800	0.5600
Diesel 2 P	0.5000	0.7000	0.7200	0.8000	0.8000	0.5500	0.7500	0.7800	0.8000	0.8000
Diesel 2 Q	0.2500	0.4154	0.4250	0.4742	0.4742	0.3263	0.4450	0.4700	0.4742	0.4742
S1	0.4518	0.9354	0.8140	1.0465	1.1143	0.7558	1.0698	1.0698	1.1388	1.1028
S2	0.5590	0.8140	0.8361	0.9300	0.9300	0.6395	0.8721	0.9107	0.9300	0.9300
PF1	0.8854	0.8767	0.8600	0.8600	0.8525	0.8601	0.8600	0.8600	0.8606	0.8615
PF2	0.8944	0.8600	0.8612	0.8602	0.8602	0.8600	0.8600	0.8565	0.8602	0.8602
Output Targets	case 71	case 72	case 73	case 74	case 75	case 76	case 77	case 78	case 79	case 80
Diesel 1 P	0.9500	1.0200	0.6500	1.1000	0.6500	0.9200	0.9500	0.8000	0.9000	0.9700
Diesel 1 Q	0.5600	0.6100	0.3856	0.6800	0.3856	0.5500	0.5600	0.4742	0.5000	0.5000
Diesel 2 P	0.8000	0.9000	0.5500	0.8200	0.6500	0.8300	0.6500	0.7000	0.9000	0.8000
Diesel 2 Q	0.4742	0.5340	0.3263	0.4500	0.3856	0.5100	0.3800	0.4000	0.4500	0.4900
S1	1.1028	1.1885	0.7558	1.2932	0.7558	1.0719	1.1028	0.9300	1.0296	1.0913
S2	0.9300	1.0465	0.6395	0.9354	0.7558	0.9742	0.7529	0.8062	1.0062	0.9381
PF1	0.8615	0.8582	0.8601	0.8506	0.8601	0.8583	0.8615	0.8602	0.8742	0.8889
PF2	0.8602	0.8600	0.8600	0.8767	0.8601	0.8520	0.8633	0.8682	0.8944	0.8528

output target	case 81	case 82	case 83	case 84	case 85	case 86	case 87	case 88	case 89	case 90
Diesel 1 P	0.7800	0.6800	0.9600	0.8900	0.8000	0.8000	1.1000	1.0000	0.9500	0.8500
Diesel 1 Q	0.4600	0.3800	0.5000	0.4700	0.4700	0.4742	0.5400	0.6000	0.5500	0.4500
Diesel 2 P	0.7000	0.6000	0.7800	0.7500	0.6500	0.6500	0.7000	0.8000	0.6800	0.5000
Diesel 2 Q	0.4000	0.3400	0.4600	0.4450	0.3600	0.3600	0.4300	0.4600	0.3800	0.2800
S1	0.9055	0.7790	1.0824	1.0065	0.9278	0.9300	1.2254	1.1662	1.0977	0.9618
S2	0.8062	0.6896	0.9055	0.8721	0.7430	0.7430	0.8215	0.9228	0.7790	0.5731
PF1	0.8614	0.8729	0.8869	0.8843	0.8622	0.8602	0.8977	0.8575	0.8654	0.8838
PF2	0.8682	0.8700	0.8614	0.8600	0.8748	0.8748	0.8521	0.8669	0.8729	0.8725
output target	case 91	case 92	case 93	case 94	case 95	case 96	case 97	case 98	case 99	case 100
Diesel 1 P	0.7500	0.8500	0.8500	0.7800	0.4000	0.6500	0.8900	0.8500	0.8800	0.8800
Diesel 1 Q	0.4400	0.4600	0.4700	0.4000	0.2200	0.3800	0.5500	0.5000	0.4800	0.5200
Diesel 2 P	0.5500	0.6500	0.6200	0.7200	0.6500	0.6500	0.8600	0.7800	0.7400	0.7500
Diesel 2 Q	0.3000	0.3800	0.3600	0.3800	0.3800	0.3800	0.5200	0.4400	0.4300	0.4600
S1	0.8695	0.9665	0.9713	0.8766	0.4565	0.7529	1.0462	0.9862	1.0024	1.0222
S2	0.6265	0.7529	0.7169	0.8141	0.7529	0.7529	1.0050	0.8955	0.8559	0.8798
PF1	0.8625	0.8795	0.8751	0.8898	0.8762	0.8633	0.8507	0.8619	0.8779	0.8609
PF2	0.8779	0.8633	0.8648	0.8844	0.8633	0.8633	0.8557	0.8710	0.8646	0.8524
output target	case 101	case 102	case 103	case 104	case 105	case 106	case 107	case 108	case 109	case 110
Diesel 1 P	0.8500	0.9500	0.9500	0.9500	0.7800	0.9500	0.9500	0.9500	0.8800	0.7000
Diesel 1 Q	0.4500	0.5800	0.5700	0.5300	0.4500	0.5300	0.5300	0.5700	0.4800	0.4154
Diesel 2 P	0.8500	0.9000	0.9000	0.8200	0.7500	0.8800	0.8800	0.9000	0.7500	0.6500
Diesel 2 Q	0.4500	0.5500	0.5500	0.5000	0.4500	0.4700	0.4700	0.5500	0.4400	0.3856
S1	0.9618	1.1131	1.1079	1.0878	0.9005	1.0878	1.0878	1.1079	1.0024	0.8140
S2	0.9618	1.0548	1.0548	0.9604	0.8746	0.9976	0.9976	1.0548	0.8695	0.7558
PF1	0.8838	0.8535	0.8575	0.8733	0.8662	0.8733	0.8733	0.8575	0.8779	0.8600
PF2	0.8838	0.8533	0.8533	0.8538	0.8575	0.8821	0.8821	0.8533	0.8625	0.8601

output target	case 111	case 112
Diesel 1 P	0.8600	0.9500
Diesel 1 Q	0.4800	0.5824
Diesel 2 P	0.7500	0.8000
Diesel 2 Q	0.4400	0.4742
S1	0.9849	1.1143
S2	0.8695	0.9300
PF1	0.8732	0.8525
PF2	0.8625	0.8602

APPENDIX C: Test Cases

Test Cases	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	Case 9	Case 10
Diesel 1 P	0.6000	1.2000	0.9800	1.2500	0.5000	1.2000	1.0000	0.4600	0.3200	1.3000
Diesel 1 Q	0.2500	0.7200	0.5824	0.7400	0.2800	0.6200	0.5800	0.2600	0.1900	0.7000
Diesel 2 P	0.4500	0.3000	0.2000	0.2500	0.6000	0.2200	0.8000	0.5500	1.0500	0.3000
Diesel 2 Q	0.1500	0.1800	0.1188	0.1300	0.3500	0.1200	0.5200	0.3000	0.6500	0.1600
Wind P	0.0000	0.0000	0.1000	0.1000	0.2000	0.1500	0.0000	0.0600	0.0500	0.0000
PV P	0.2000	0.0000	0.0600	0.2000	0.2000	0.0300	0.0000	0.1200	0.0100	0.0000
Vd1	0.9997	1.0370	1.0350	1.0280	0.9989	1.0270	1.0300	1.0040	1.0020	1.0310
Vd2	1.0010	1.0020	1.0040	0.9982	1.0080	0.9968	1.0270	1.0090	1.0370	0.9967
V 1	0.9939	0.9958	1.0000	0.9933	0.9953	0.9923	1.0100	0.9983	1.0150	0.9907
V 2	0.9931	0.9953	0.9993	0.9921	0.9934	0.9919	1.0040	0.9956	1.0070	0.9903
V 3	0.9930	0.9962	0.9997	0.9925	0.9921	0.9928	1.0010	0.9942	1.0000	0.9914
V 4	0.9931	0.9960	0.9996	0.9915	0.9923	0.9917	0.9994	0.9934	0.9994	0.9899
V 5	0.9917	1.0180	1.0200	1.0080	0.9909	1.0100	1.0140	0.9961	0.9966	1.0120
V 6	0.9896	1.0130	1.0160	1.0030	0.9895	1.0060	1.0100	0.9943	0.9953	1.0070
V 8	0.9865	0.9870	1.0010	0.9862	0.9787	0.9876	0.9944	0.9842	0.9869	0.9869
V 9	0.9796	0.9915	0.9986	0.9821	0.9747	0.9829	0.9916	0.9808	0.9819	0.9824
V 10	0.9752	0.9873	0.9958	0.9770	0.9695	0.9778	0.9869	0.9761	0.9744	0.9780
V 11	0.9751	0.9872	0.9957	0.9769	0.9694	0.9773	0.9862	0.9766	0.9760	0.9770

Test Cases	case11	case12	case13	case 14	case 15	case 16
Diesel 1 P	0.5000	0.9800	0.6300	0.8500	0.6500	0.4200
Diesel 1 Q	0.2800	0.5600	0.3400	0.5000	0.3500	0.2500
Diesel 2 P	1.1000	1.1000	0.6500	0.3000	0.6500	0.8500
Diesel 2 Q	0.6100	0.6000	0.3500	0.1600	0.3500	0.5000
Wind P	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
PV P	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Vd1	1.0010	1.0320	1.0030	1.0130	1.0130	1.0030
Vd2	1.0280	1.0350	1.0090	1.0040	1.0220	1.0300
V 1	1.0070	1.0140	0.9956	0.9977	1.0090	1.0130
V 2	1.0010	1.0080	0.9936	0.9956	1.0040	1.0070
V 3	0.9965	1.0040	0.9924	0.9937	0.9999	1.0000
V 4	0.9962	1.0040	0.9919	0.9933	0.9997	1.0000
V 5	0.9930	1.0160	0.9933	0.9994	1.0030	0.9965
V 6	0.9916	1.0130	0.9914	0.9963	0.9999	0.9947
V 8	0.9817	0.9968	0.9774	0.9754	0.9803	0.9776
V 9	0.9774	0.9924	0.9774	0.9762	0.9807	0.9780
V 10	0.9719	0.9871	0.9730	0.9705	0.9753	0.9726
V 11	0.9719	0.9871	0.9754	0.9696	0.9745	0.9718

APPENDIX D: First Scenario Results

Results	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	Case 9	Case 10
Diesel 1 P	0.6292	0.8597	0.6845	1.0831	0.8619	0.9350	0.9295	0.6785	0.6922	1.0800
Diesel 1 Q	0.3760	0.4789	0.3366	0.6143	0.4578	0.5270	0.5313	0.3626	0.3807	0.5792
Diesel 2 P	0.6820	0.8103	0.5286	0.7625	0.6797	0.8027	0.7837	0.6574	0.6833	0.8557
Diesel 2 Q	0.3586	0.4619	0.2915	0.4604	0.4019	0.4720	0.4395	0.3607	0.3507	0.5009
Wind P	0.0000	0.0000	0.1000	0.1000	0.2000	0.1500	0.0000	0.0600	0.0500	0.0000
PV P	0.2000	0.0000	0.0600	0.2000	0.2000	0.0300	0.0000	0.1200	0.0100	0.0000
Vd1	1.0150	1.0200	1.0160	1.0240	1.0210	1.0250	1.0230	1.0180	1.0200	1.0260
Vd2	1.0190	1.0220	1.0150	1.0240	1.0170	1.0250	1.0210	1.0180	1.0210	1.0230
V 1	1.0060	1.0060	1.0040	1.0080	1.0030	1.0080	1.0060	1.0050	1.0080	1.0060
V 2	1.0030	1.0010	1.0010	1.0020	1.0010	1.0030	1.0010	1.0010	1.0030	1.0010
V 3	1.0000	0.9982	0.9990	0.9984	0.9987	0.9995	0.9977	0.9990	1.0000	0.9973
V 4	1.0010	0.9979	0.9988	0.9974	0.9988	0.9982	0.9967	0.9982	0.9991	0.9956
V 5	1.0040	1.0070	1.0060	1.0070	1.0080	1.0100	1.0090	1.0070	1.0090	1.0110
V 6	1.0010	1.0040	1.0050	1.0030	1.0060	1.0070	1.0050	1.0050	1.0060	1.0070
V 8	0.9963	0.9832	0.9941	0.9892	0.9906	0.9914	0.9904	0.9920	0.9933	0.9895
V 9	0.9896	0.9876	0.9922	0.9853	0.9866	0.9869	0.9876	0.9886	0.9894	0.9853
V 10	0.9854	0.9833	0.9892	0.9803	0.9816	0.9819	0.9830	0.9840	0.9847	0.9809
V 11	0.9852	0.9833	0.9892	0.9802	0.9815	0.9814	0.9821	0.9845	0.9840	0.9798

Results	case11	case12	case13	case 14	case 15	case 16
Diesel 1 P	0.9130	0.9185	0.8736	0.9749	0.8097	0.7887
Diesel 1 Q	0.5305	0.5019	0.4653	0.5587	0.4731	0.4947
Diesel 2 P	0.8839	0.8110	0.7633	0.6803	0.6592	0.6142
Diesel 2 Q	0.4909	0.4464	0.4371	0.3977	0.3887	0.3664
Wind P	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
PV P	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Vd1	1.0250	1.0220	1.0200	1.0260	1.0260	1.0260
Vd2	1.0250	1.0200	1.0190	1.0260	1.0260	1.0250
V 1	1.0070	1.0040	1.0040	1.0120	1.0130	1.0120
V 2	1.0030	1.0010	1.0000	1.0070	1.0080	1.0080
V 3	1.0000	0.9985	0.9980	1.0020	1.0040	1.0030
V 4	0.9998	0.9982	0.9978	1.0010	1.0030	1.0030
V 5	1.0110	1.0080	1.0060	1.0110	1.0130	1.0130
V 6	1.0080	1.0050	1.0030	1.0070	1.0090	1.0090
V 8	0.9920	0.9900	0.9869	0.9851	0.9870	0.9870
V 9	0.9879	0.9856	0.9868	0.9859	0.9874	0.9875
V 10	0.9823	0.9803	0.9825	0.9803	0.9820	0.9819
V 11	0.9823	0.9802	0.9848	0.9796	0.9813	0.9812

APPENDIX E: Second Scenario Results

Results	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	Case 9	Case 10
Diesel 1 P	0.6727	0.9427	0.7178	1.0371	0.8400	0.9407	0.8593	0.6748	0.8289	1.0378
Diesel 1 Q	0.3575	0.5270	0.3687	0.6134	0.4849	0.5206	0.4937	0.3815	0.4587	0.5780
Diesel 2 P	0.7270	0.7913	0.4751	0.7301	0.7631	0.8300	0.8432	0.6878	0.6146	0.7994
Diesel 2 Q	0.3684	0.4671	0.2756	0.4295	0.4435	0.4780	0.4942	0.3813	0.3482	0.4724
Wind P	0.0000	0.0000	0.1000	0.1000	0.2000	0.1500	0.0000	0.0600	0.0500	0.0000
PV P	0.2000	0.0000	0.0600	0.2000	0.2000	0.0300	0.0000	0.1200	0.0100	0.0000
Vd1	1.0150	1.0260	1.0190	1.0230	1.0240	1.0250	1.0200	1.0190	1.0260	1.0260
Vd2	1.0210	1.0230	1.0140	1.0210	1.0220	1.0250	1.0240	1.0200	1.0210	1.0200
V 1	1.0070	1.0070	1.0040	1.0060	1.0060	1.0080	1.0070	1.0060	1.0090	1.0040
V 2	1.0040	1.0020	1.0010	1.0010	1.0030	1.0030	1.0020	1.0020	1.0050	0.9995
V 3	1.0010	0.9995	0.9991	0.9972	1.0000	0.9996	0.9980	0.9998	1.0020	0.9963
V 4	1.0010	0.9992	0.9990	0.9963	1.0000	0.9985	0.9969	0.9990	1.0010	0.9948
V 5	1.0040	1.0110	1.0080	1.0060	1.0110	1.0100	1.0060	1.0090	1.0150	1.0100
V 6	1.0020	1.0080	1.0060	1.0020	1.0080	1.0070	1.0040	1.0060	1.0110	1.0060
V 8	0.9965	0.9857	0.9951	0.9880	0.9925	0.9916	0.9896	0.9932	0.9970	0.9886
V 9	0.9898	0.9901	0.9930	0.9839	0.9885	0.9870	0.9868	0.9898	0.9931	0.9840
V 10	0.9856	0.9860	0.9902	0.9790	0.9836	0.9819	0.9819	0.9851	0.9882	0.9797
V 11	0.9854	0.9858	0.9903	0.9788	0.9834	0.9816	0.9810	0.9857	0.9877	0.9785
Results	case11	case12	case13	case 14	case 15	case 16				
Diesel 1 P	0.9097	0.8768	0.8712	1.0249	0.8241	0.8679				
Diesel 1 Q	0.5148	0.5054	0.4706	0.5866	0.4802	0.4959				
Diesel 2 P	0.8330	0.9032	0.7628	0.6001	0.5766	0.5623				
Diesel 2 Q	0.4597	0.4727	0.4334	0.3315	0.3214	0.3299				
Wind P	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000				
PV P	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000				
Vd1	1.0230	1.0220	1.0200	1.0260	1.0250	1.0260				
Vd2	1.0220	1.0230	1.0190	1.0210	1.0220	1.0230				
V 1	1.0050	1.0060	1.0030	1.0090	1.0110	1.0110				
V 2	1.0020	1.0020	1.0000	1.0050	1.0070	1.0070				
V 3	0.9991	0.9992	0.9980	1.0010	1.0020	1.0030				
V 4	0.9989	0.9990	0.9979	1.0000	1.0020	1.0030				
V 5	1.0090	1.0090	1.0070	1.0110	1.0120	1.0130				
V 6	1.0060	1.0050	1.0040	1.0080	1.0080	1.0090				
V 8	0.9906	0.9905	0.9870	0.9850	0.9860	0.9870				
V 9	0.9866	0.9863	0.9869	0.9857	0.9864	0.9873				
V 10	0.9809	0.9808	0.9826	0.9802	0.9810	0.9818				
V 11	0.9810	0.9808	0.9849	0.9793	0.9802	0.9810				

APPENDIX F: Third Scenario Results

Results	case 1	case 2	case 3	case 4	case 5	case 6	case 7	case 8	case 9	case 10
Diesel 1 P	0.6763	0.9424	0.6470	1.0042	0.7708	0.9094	0.8972	0.6464	0.7295	0.9627
Diesel 1 Q	0.3641	0.5333	0.3577	0.5875	0.4474	0.5264	0.5209	0.3576	0.4206	0.5551
Diesel 2 P	0.6102	0.7256	0.5880	0.7224	0.7853	0.8274	0.8319	0.6979	0.7469	0.8396
Diesel 2 Q	0.3267	0.4405	0.3192	0.4429	0.4465	0.4687	0.4791	0.3800	0.3969	0.5047
Wind P	0.0000	0.0000	0.1000	0.1000	0.2000	0.1500	0.0000	0.0600	0.0500	0.0000
PV P	0.2000	0.0000	0.0600	0.2000	0.2000	0.0300	0.0000	0.1200	0.0100	0.0000
Vd1	1.0140	1.0250	1.0180	1.0200	1.0200	1.0240	1.0230	1.0170	1.0240	1.0230
Vd2	1.0160	1.0200	1.0180	1.0210	1.0210	1.0250	1.0240	1.0190	1.0250	1.0220
V 1	1.0040	1.0050	1.0060	1.0060	1.0050	1.0080	1.0070	1.0050	1.0110	1.0050
V 2	1.0020	1.0010	1.0020	1.0000	1.0020	1.0030	1.0020	1.0020	1.0060	0.9999
V 3	0.9996	0.9988	1.0000	0.9969	0.9994	0.9994	0.9984	0.9993	1.0020	0.9962
V 4	0.9996	0.9985	0.9998	0.9960	0.9994	0.9981	0.9971	0.9984	1.0010	0.9948
V 5	1.0030	1.0100	1.0080	1.0040	1.0080	1.0100	1.0090	1.0070	1.0130	1.0080
V 6	1.0010	1.0070	1.0060	1.0000	1.0050	1.0070	1.0050	1.0040	1.0100	1.0050
V 8	0.9955	0.9852	0.9953	0.9869	0.9905	0.9913	0.9906	0.9920	0.9961	0.9877
V 9	0.9888	0.9896	0.9933	0.9831	0.9868	0.9868	0.9876	0.9887	0.9922	0.9833
V 10	0.9845	0.9852	0.9904	0.9780	0.9817	0.9816	0.9829	0.9840	0.9874	0.9790
V 11	0.9843	0.9851	0.9905	0.9778	0.9816	0.9814	0.9824	0.9845	0.9868	0.9780

Results	case 11	case 12	case 13	case 14	case 15	case 16
Diesel 1 P	0.8872	0.9061	0.8841	0.9731	0.7847	0.7813
Diesel 1 Q	0.5188	0.5391	0.4948	0.5474	0.4533	0.4538
Diesel 2 P	0.8841	0.7925	0.7359	0.6452	0.6852	0.6977
Diesel 2 Q	0.4937	0.4732	0.4243	0.3663	0.3537	0.3620
Wind P	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
PV P	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Vd1	1.0240	1.0250	1.0220	1.0240	1.0230	1.0230
Vd2	1.0250	1.0220	1.0180	1.0230	1.0250	1.0260
V 1	1.0070	1.0060	1.0030	1.0100	1.0120	1.0120
V 2	1.0030	1.0020	1.0000	1.0050	1.0070	1.0070
V 3	0.9999	0.9995	0.9981	1.0010	1.0030	1.0030
V 4	0.9995	0.9992	0.9979	1.0000	1.0020	1.0030
V 5	1.0100	1.0110	1.0080	1.0090	1.0100	1.0110
V 6	1.0070	1.0070	1.0050	1.0060	1.0070	1.0070
V 8	0.9915	0.9915	0.9877	0.9840	0.9856	0.9857
V 9	0.9872	0.9874	0.9876	0.9848	0.9860	0.9862
V 10	0.9816	0.9819	0.9833	0.9792	0.9804	0.9807
V 11	0.9817	0.9819	0.9856	0.9783	0.9797	0.9799

APPENDIX G: Fourth Scenario Results

Results	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	Case 9	Case 10
Diesel 1 P	0.6727	0.9427	0.7178	1.0371	0.8400	0.9407	0.8593	0.6748	0.8289	1.0378
Diesel 1 Q	0.3575	0.5270	0.3687	0.6134	0.4849	0.5206	0.4937	0.3815	0.4587	0.5780
Diesel 2 P	0.7270	0.7913	0.4751	0.7301	0.7631	0.8300	0.8432	0.6878	0.6146	0.7994
Diesel 2 Q	0.3684	0.4671	0.2756	0.4295	0.4435	0.4780	0.4942	0.3813	0.3482	0.4724
Wind P	0.0000	0.0000	0.1000	0.1000	0.2000	0.1500	0.0000	0.0600	0.0500	0.0000
PV P	0.2000	0.0000	0.0600	0.2000	0.2000	0.0300	0.0000	0.1200	0.0100	0.0000
Vd1	1.0150	1.0260	1.0190	1.0230	1.0240	1.0250	1.0200	1.0190	1.0260	1.0260
Vd2	1.0210	1.0230	1.0140	1.0210	1.0220	1.0250	1.0240	1.0200	1.0210	1.0200
V 1	1.0070	1.0070	1.0040	1.0060	1.0060	1.0080	1.0070	1.0060	1.0090	1.0040
V 2	1.0040	1.0020	1.0010	1.0010	1.0030	1.0030	1.0020	1.0020	1.0050	0.9995
V 3	1.0010	0.9995	0.9991	0.9972	1.0000	0.9996	0.9980	0.9998	1.0020	0.9963
V 4	1.0010	0.9992	0.9990	0.9963	1.0000	0.9985	0.9969	0.9990	1.0010	0.9948
V 5	1.0040	1.0110	1.0080	1.0060	1.0110	1.0100	1.0060	1.0090	1.0150	1.0100
V 6	1.0020	1.0080	1.0060	1.0020	1.0080	1.0070	1.0040	1.0060	1.0110	1.0060
V 8	0.9965	0.9857	0.9951	0.9880	0.9925	0.9916	0.9896	0.9932	0.9970	0.9886
V 9	0.9898	0.9901	0.9930	0.9839	0.9885	0.9870	0.9868	0.9898	0.9931	0.9840
V 10	0.9856	0.9860	0.9902	0.9790	0.9836	0.9819	0.9819	0.9851	0.9882	0.9797
V 11	0.9854	0.9858	0.9903	0.9788	0.9834	0.9816	0.9810	0.9857	0.9877	0.9785
Results	case11	case12	case13	case 14	case 15	case 16				
Diesel 1 P	0.9097	0.8768	0.8712	1.0249	0.8241	0.8679				
Diesel 1 Q	0.5148	0.5054	0.4706	0.5866	0.4802	0.4959				
Diesel 2 P	0.8330	0.9032	0.7628	0.6001	0.5766	0.5623				
Diesel 2 Q	0.4597	0.4727	0.4334	0.3315	0.3214	0.3299				
Wind P	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000				
PV P	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000				
Vd1	1.0230	1.0220	1.0200	1.0260	1.0250	1.0260				
Vd2	1.0220	1.0230	1.0190	1.0210	1.0220	1.0230				
V 1	1.0050	1.0060	1.0030	1.0090	1.0110	1.0110				
V 2	1.0020	1.0020	1.0000	1.0050	1.0070	1.0070				
V 3	0.9991	0.9992	0.9980	1.0010	1.0020	1.0030				
V 4	0.9989	0.9990	0.9979	1.0000	1.0020	1.0030				
V 5	1.0090	1.0090	1.0070	1.0110	1.0120	1.0130				
V 6	1.0060	1.0050	1.0040	1.0080	1.0080	1.0090				
V 8	0.9906	0.9905	0.9870	0.9850	0.9860	0.9870				
V 9	0.9866	0.9863	0.9869	0.9857	0.9864	0.9873				
V 10	0.9809	0.9808	0.9826	0.9802	0.9810	0.9818				
V 11	0.9810	0.9808	0.9849	0.9793	0.9802	0.9810				

APPENDIX H: Fifth Scenario Results

Results	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	Case 9	Case 10
Diesel 1 P	0.7290	0.8354	0.6210	1.0332	0.7856	0.9142	0.9285	0.6725	0.6679	1.0646
Diesel 1 Q	0.4070	0.4833	0.3513	0.6138	0.4524	0.5323	0.5332	0.3764	0.4032	0.6174
Diesel 2 P	0.6444	0.7936	0.5525	0.7855	0.7267	0.8179	0.8378	0.6536	0.6628	0.8175
Diesel 2 Q	0.3627	0.4566	0.3048	0.4648	0.4156	0.4683	0.4828	0.3666	0.3823	0.4785
Wind P	0.0000	0.0000	0.1000	0.1000	0.2000	0.1500	0.0000	0.0600	0.0500	0.0000
PV P	0.2000	0.0000	0.0600	0.2000	0.2000	0.0300	0.0000	0.1200	0.0100	0.0000
Vd1	1.0190	1.0200	1.0160	1.0230	1.0200	1.0240	1.0240	1.0180	1.0210	1.0290
Vd2	1.0200	1.0210	1.0160	1.0240	1.0180	1.0240	1.0250	1.0180	1.0220	1.0220
V 1	1.0070	1.0050	1.0050	1.0080	1.0040	1.0080	1.0080	1.0050	1.0090	1.0050
V 2	1.0040	1.0010	1.0010	1.0020	1.0010	1.0030	1.0030	1.0010	1.0040	1.0010
V 3	1.0010	0.9980	0.9993	0.9981	0.9988	0.9993	0.9989	0.9992	1.0010	0.9974
V 4	1.0010	0.9977	0.9991	0.9971	0.9989	0.9982	0.9977	0.9985	0.9999	0.9957
V 5	1.0070	1.0070	1.0070	1.0060	1.0070	1.0100	1.0100	1.0080	1.0100	1.0130
V 6	1.0040	1.0040	1.0050	1.0020	1.0050	1.0070	1.0070	1.0050	1.0070	1.0080
V 8	0.9983	0.9829	0.9944	0.9886	0.9901	0.9914	0.9914	0.9925	0.9943	0.9903
V 9	0.9916	0.9874	0.9923	0.9847	0.9862	0.9867	0.9887	0.9893	0.9904	0.9859
V 10	0.9874	0.9831	0.9895	0.9796	0.9812	0.9817	0.9840	0.9846	0.9857	0.9815
V 11	0.9872	0.9829	0.9896	0.9795	0.9811	0.9814	0.9833	0.9850	0.9850	0.9805

Results	case11	case12	case13	case 14	case 15	case 16
Diesel 1 P	0.8931	0.8945	0.8053	0.9545	0.7188	0.7193
Diesel 1 Q	0.5065	0.5058	0.4529	0.5560	0.4230	0.4309
Diesel 2 P	0.7950	0.8119	0.7274	0.6398	0.5657	0.5842
Diesel 2 Q	0.4551	0.4639	0.4126	0.3731	0.3244	0.3379
Wind P	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
PV P	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Vd1	1.0220	1.0220	1.0170	1.0250	1.0180	1.0190
Vd2	1.0210	1.0210	1.0160	1.0230	1.0200	1.0220
V 1	1.0040	1.0050	1.0020	1.0100	1.0090	1.0100
V 2	1.0010	1.0010	0.9989	1.0050	1.0050	1.0050
V 3	0.9984	0.9988	0.9970	1.0010	1.0010	1.0010
V 4	0.9983	0.9985	0.9966	1.0000	1.0000	1.0010
V 5	1.0080	1.0080	1.0040	1.0100	1.0070	1.0080
V 6	1.0050	1.0050	1.0010	1.0060	1.0040	1.0040
V 8	0.9899	0.9903	0.9851	0.9841	0.9828	0.9833
V 9	0.9859	0.9860	0.9851	0.9850	0.9832	0.9837
V 10	0.9803	0.9805	0.9807	0.9793	0.9777	0.9785
V 11	0.9803	0.9804	0.9831	0.9786	0.9768	0.9776

APPENDIX I: Sixth Scenario Results

Results	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	Case 9	Case 10
Diesel 1 P	0.7155	0.9171	0.6556	1.0170	0.7722	0.9285	0.9062	0.6636	0.6594	0.9623
Diesel 1 Q	0.3820	0.5140	0.3542	0.5975	0.4421	0.5219	0.5269	0.3577	0.3969	0.5648
Diesel 2 P	0.6657	0.8038	0.5578	0.7699	0.7244	0.8142	0.8344	0.6522	0.6041	0.8315
Diesel 2 Q	0.3264	0.4559	0.3120	0.4660	0.4102	0.4542	0.4834	0.3461	0.3653	0.4994
Wind P	0.0000	0.0000	0.1000	0.1000	0.2000	0.1500	0.0000	0.0600	0.0500	0.0000
PV P	0.2000	0.0000	0.0600	0.2000	0.2000	0.0300	0.0000	0.1200	0.0100	0.0000
Vd1	1.0160	1.0240	1.0180	1.0220	1.0190	1.0240	1.0230	1.0170	1.0200	1.0240
Vd2	1.0180	1.0220	1.0170	1.0230	1.0180	1.0240	1.0240	1.0170	1.0200	1.0220
V 1	1.0050	1.0060	1.0050	1.0070	1.0030	1.0070	1.0070	1.0040	1.0070	1.0040
V 2	1.0030	1.0020	1.0020	1.0020	1.0000	1.0030	1.0020	1.0000	1.0030	0.9999
V 3	1.0000	0.9990	0.9997	0.9978	0.9984	0.9990	0.9986	0.9985	1.0000	0.9964
V 4	1.0000	0.9987	0.9994	0.9968	0.9985	0.9979	0.9975	0.9978	0.9991	0.9947
V 5	1.0050	1.0100	1.0080	1.0050	1.0060	1.0100	1.0090	1.0060	1.0090	1.0090
V 6	1.0020	1.0070	1.0060	1.0020	1.0040	1.0060	1.0060	1.0040	1.0060	1.0050
V 8	0.9967	0.9848	0.9949	0.9880	0.9895	0.9910	0.9911	0.9914	0.9933	0.9878
V 9	0.9901	0.9892	0.9930	0.9840	0.9855	0.9864	0.9883	0.9880	0.9894	0.9836
V 10	0.9858	0.9851	0.9901	0.9790	0.9805	0.9814	0.9835	0.9834	0.9848	0.9791
V 11	0.9856	0.9850	0.9901	0.9789	0.9804	0.9809	0.9828	0.9838	0.9841	0.9781

Results	case11	case12	case13	case 14	case 15	case 16
Diesel 1 P	0.8539	0.7890	0.8534	0.9484	0.6774	0.6665
Diesel 1 Q	0.5004	0.4850	0.4805	0.5272	0.3956	0.4071
Diesel 2 P	0.8254	0.8714	0.7848	0.5994	0.4832	0.4580
Diesel 2 Q	0.4858	0.5067	0.4475	0.3353	0.2752	0.2777
Wind P	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
PV P	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Vd1	1.0220	1.0200	1.0210	1.0220	1.0140	1.0150
Vd2	1.0230	1.0240	1.0200	1.0200	1.0160	1.0150
V 1	1.0060	1.0060	1.0040	1.0080	1.0060	1.0060
V 2	1.0020	1.0020	1.0010	1.0040	1.0020	1.0020
V 3	0.9989	0.9989	0.9985	0.9993	0.9986	0.9988
V 4	0.9986	0.9988	0.9982	0.9991	0.9986	0.9985
V 5	1.0080	1.0060	1.0070	1.0070	1.0030	1.0040
V 6	1.0050	1.0040	1.0040	1.0040	1.0000	1.0010
V 8	0.9901	0.9895	0.9875	0.9822	0.9801	0.9803
V 9	0.9857	0.9852	0.9874	0.9830	0.9805	0.9806
V 10	0.9802	0.9796	0.9831	0.9774	0.9750	0.9752
V 11	0.9804	0.9798	0.9855	0.9766	0.9742	0.9744

APPENDIX J: Seventh Scenario Results

Results	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	Case 9	Case 10
Diesel 1 P	0.7282	0.8907	0.5832	1.0173	0.7818	0.9139	0.9112	0.6349	0.7665	1.0680
Diesel 1 Q	0.3930	0.5155	0.3481	0.6020	0.4415	0.5375	0.5260	0.3540	0.4173	0.6107
Diesel 2 P	0.6473	0.7556	0.6204	0.8735	0.7083	0.7786	0.8990	0.6833	0.6462	0.6930
Diesel 2 Q	0.3462	0.4399	0.3583	0.5139	0.3985	0.4599	0.5071	0.3735	0.3494	0.4120
Wind P	0.0000	0.0000	0.1000	0.1000	0.2000	0.1500	0.0000	0.0600	0.0500	0.0000
PV P	0.2000	0.0000	0.0600	0.2000	0.2000	0.0300	0.0000	0.1200	0.0100	0.0000
Vd1	1.0180	1.0230	1.0170	1.0230	1.0190	1.0250	1.0240	1.0160	1.0290	1.0270
Vd2	1.0190	1.0210	1.0200	1.0280	1.0170	1.0240	1.0270	1.0180	1.0240	1.0160
V 1	1.0060	1.0050	1.0070	1.0100	1.0030	1.0080	1.0090	1.0050	1.0110	1.0010
V 2	1.0030	1.0010	1.0030	1.0040	1.0000	1.0030	1.0040	1.0010	1.0070	0.9978
V 3	1.0010	0.9983	1.0000	0.9992	0.9981	0.9991	0.9995	0.9989	1.0040	0.9954
V 4	1.0010	0.9980	1.0000	0.9983	0.9983	0.9981	0.9984	0.9981	1.0030	0.9938
V 5	1.0060	1.0090	1.0070	1.0070	1.0060	1.0100	1.0100	1.0060	1.0180	1.0110
V 6	1.0030	1.0060	1.0050	1.0030	1.0040	1.0070	1.0070	1.0040	1.0140	1.0060
V 8	0.9975	0.9842	0.9950	0.9897	0.9893	0.9914	0.9920	0.9917	1.0010	0.9882
V 9	0.9908	0.9885	0.9931	0.9855	0.9855	0.9866	0.9891	0.9884	0.9998	0.9840
V 10	0.9867	0.9844	0.9901	0.9807	0.9802	0.9816	0.9847	0.9838	0.9987	0.9797
V 11	0.9864	0.9841	0.9903	0.9805	0.9802	0.9813	0.9838	0.9844	0.9979	0.9787

Results	case11	case12	case13	case 14	case 15	case 16
Diesel 1 P	0.9772	1.0413	0.8563	0.9804	0.8306	0.8473
Diesel 1 Q	0.5563	0.5811	0.4921	0.5729	0.4471	0.4577
Diesel 2 P	0.8331	0.7257	0.7760	0.7230	0.5861	0.5650
Diesel 2 Q	0.4710	0.4098	0.4447	0.4290	0.3170	0.3084
Wind P	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
PV P	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Vd1	1.0280	1.0290	1.0220	1.0280	1.0220	1.0230
Vd2	1.0240	1.0190	1.0200	1.0280	1.0210	1.0210
V 1	1.0070	1.0040	1.0040	1.0130	1.0100	1.0100
V 2	1.0030	1.0020	1.0010	1.0080	1.0060	1.0060
V 3	1.0000	0.9993	0.9988	1.0030	1.0020	1.0020
V 4	1.0000	0.9990	0.9984	1.0020	1.0010	1.0010
V 5	1.0130	1.0130	1.0080	1.0120	1.0100	1.0100
V 6	1.0090	1.0100	1.0050	1.0090	1.0060	1.0070
V 8	0.9931	0.9931	0.9880	0.9865	0.9848	0.9849
V 9	0.9891	0.9889	0.9880	0.9872	0.9850	0.9853
V 10	0.9835	0.9835	0.9837	0.9816	0.9797	0.9798
V 11	0.9837	0.9835	0.9861	0.9809	0.9788	0.9791