MARMARA UNIVERSITY
FACULTY OF ENGINEERING

Overvoltage and Undervoltage Problems and Their Solutions in 3 Phase Unbalanced Distribution Networks Using OpenDSS

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GRADUATION PROJECT REPORT

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Overvoltage and Undervoltage Problems and Their Solutions in 3 Phase Unbalanced Distribution Networks Using OpenDSS

by

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ABSTRACT

Power distribution systems will go through changes in the near future. Cars with internal combustion engines will be replaced by EVs. People will charge their EVs at homes or at workplaces, new renewable energy sources will arise and people will tend to use PV on their roofs, and unpredictable load demands may appear. Briefly, the need for electricity will increase. An increase in demand will come with problems. In this paper, a futuristic situation full of EVs, PVs, and other power system components has been set up by taking the IEEE 123-Bus system as a base. Their interactions have been observed and issues that can happen with these interactions have been analyzed. Voltage level optimization has been performed by adjusting power control elements and voltage regulation optimization algorithm by considering ANSI standards. Results have shown us that our optimization is beneficial for a situation like this.

LIST OF SYMBOLS

- **Electric Vehicles Parameters**

$$tEV_{idling} = \ idling\ time\ of\ electric\ vehicles$$

$$tEV_{inUse} = \ in\,use\ time\ of\ electric\ vehicles$$

$$tEV_{charging} = \ charging\ time\ of\ electric\ vehicles$$

$$EV_{max} = \ maximum\ battery\ capacity\ of\ electric\ vehicles$$

$$EV_{in} = instantenous\ energy\ amount\ of\ electric\ vehicles$$

$$EV_{abs} = \ absorbed\ energy\ of\ electric\ vehicles$$

$$EV_{diss}\ = dissatisfaction\ level\ of\ the\ user\ when\ choosing\ the\ charging\ time$$

$$VEV_{pu} = \ instantenous\ voltage\ magnitude\ of\ nodes\ with\ EV\ charging\ stations$$

- **Photovoltaic Panels Parameters**

$$PV_{supp} = \ supplied\ energy\ from\,photovoltaic\ panels$$

$$tPV_{idling} = \ idling\ time\ of\ photovoltaic\ panels$$

$$tPV_{supp} = \ supplying\ time\ of\ photovoltaic\ panels, when\ sun\ is\ up$$

$$VPV_{pu} = \ instantenous\ voltage\ magnitude\ of\ nodes\ with\ Photovoltaic\ panels$$

- **Storage Devices Parameters**

$$S_{max} = \ maximum\ battery\ capacity\ of\ storage\ devices$$

$$S_{min} = \ minumum\ energy\ of\ storage\ devices$$

$$tS_{charhing} = \ charging\ time\ of\ storage\ devices$$

$$tS_{discharhing} = \ discharhing\ time\ of\ storage\ devices$$

$$S_{in} = instantenous\ energy\ amount\ of\ storage\ devices$$

$$VS_{pu} = \ instantenous\ voltage\ magnitude\ of\ nodes\ with\ storage\ devices$$

ABBREVIATIONS

ANSI: The American National Standards Institute

EPRI: Electric Power Research Institute

IEEE: The Institute of Electrical and Electronics Engineers

OpenDSS: The Open Distribution System Simulator

EV: Electric Vehicles

PV: Photovoltaic Panels

Pu: Per unit

RegTap: Regulator Tap Position

PC: Power Conversion

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1. INTRODUCTION

The regulation of voltage is one of the key responsibilities of distribution utilities [1]. Many power system components impact this voltage level. With improvements in technology, the need for high-quality electricity increases. Furthermore, the demand for electricity increases day by day. Future electric distribution systems must be prepared for any unpredictable demand. However, even now electric distribution systems face a lot of problems. Future expansions of the existing distribution systems, quality improvement of the electricity are the main problems. Apart from these problems, it is inevitable that EVs are going to be a crucial part of our life. The number of EVs is already around 35 million all over the world [2]. Additionally, charging these vehicles will have a detrimental impact on the existing distribution systems. The effect of this additional electricity demand caused by EVs needs to be analyzed before implementing them in the real-life. Since existing generation plants run by fossil fuels which have damaged our nature for a long time have come to an end, renewable energy sources help us at this point. Integration of energy sources into the existing distribution systems should be considered as well. To increase the living standard of people and take precautions for the problems that may appear in near future, simulations need to be done, results need to be analyzed and improvements need to be made.

In this paper, we worked on an unbalanced three-phase power distribution system. We took as a base the IEEE 123-Bus system which provides us with voltage problems. We tried to create a futuristic environment full of EVs at different buses, numerous PVs, and storage devices randomly distributed. The addition of these components brings about the service voltage to go under 0.95 pu or exceed 1.05 pu which is considered as the undervoltage and overvoltage violation of the ANSI standard [3]. We approached to solve these problems by implementing different control devices and an optimization algorithm used to control the voltage regulators.

All simulations were done on OpenDSS provided by EPRI. Thanks to its COM interface which enables researchers to interact with OpenDSS by using high-level programming languages like MATLAB and Python, MATLAB was our primary editor interfering with the existing IEEE 123-Bus system. Optimization was based on adjusting power control elements and a small optimization algorithm for voltage regulators was performed to beautify the result.

1.1. Thesis Content

In introduction part, we state what our problem is, what makes this problem important to work on, if there is any standard by which we should abide and finally how we carry out our solution.

In research objective part, we explain what our aims are with this project. We touch on why these simulations are important to carry out.

Related literature is the part where we look through all the articles that have been published and approached the same problem. We look at what they did to tackle the problem and their results. We try to get some information that will help us handle the problem. We compare our work with these articles and list similarities and differences.

Design part is the heart of our work. We explain our constraints that should be considered along the way. We talk about the cost of design and engineering standards that will validate our result at the end. Since we use a lot of different components on a new platform, it is better to give some insight of what we use to readers. Readers get prepared as they read the definitions. After warm-ups, numerous graphs meet readers as to make them more comfortable with how our components work.

In method part we explain how we solve the voltage problem by giving the logic behind.

Result and discussion part is where we prove ourselves right. We show readers all the plots and explain every tiny part of it. We make sure that there is nothing missing in our solution. Everything complies with each other.

As for the conclusion part, we sum up what we did along the project. Our work is validated by the engineering standards.

2. RESEARCH OBJECTIVE

As new businesses are launched and new neighborhoods arise, demand for electricity will increase. Even if we never consider EVs or renewable energy sources, future expansions of the existing distribution systems have to be considered. However, It is most likely that we are going to see a lot of people charging their vehicles in their garages, setting up a PV system on their roofs, and getting some energy from it. There is going to be a great change in the distribution systems. It is better to do some simulations and some optimizations of the existing systems before the new era comes.

In our project, we create a futuristic environment by taking the IEEE 123-Bus system as a base where there are a number of PVs, numerous EVs of different brands, and storage devices located at different buses. This environment greets us with challanges. First of all, since this is an unbalanced system, it has voltage drop problems [4]. Our major goal is to examine what kind of problems may arise in the distribution system after the addition of these new components, how to use some control devices to mitigate the bad impacts of these components, and finally how to optimize the voltage level so that it complies with ANSI standard for voltage levels.

3. RELATED LITERATURE

Article [5] states that the amount of electrical energy produced by PV is affected by temperature and radiation. A standard PV receives solar light and turns it into electrical energy with wavelengths of 06-07um, according to another reference listed in this article [6].

In addition, it has been observed that when more than one PV is added to certain distribution systems, overvoltage values occur in the system. It has been observed that the electrical energy produced by PV in high irradiation time intervals (at noon) is more than the need of the grid. Accordingly, as seen in the graphs below, when PV is added to our system, it has been observed that the voltage values go out of the desired ranges. And it has been emphasized that when we add more than one PV to our system, we need to make our own voltage regulation mechanism. Therefore, after adding our control elements to our system, we set up our own voltage regulator algorithm via RegTap as stated in the article [7].

The effects of EVs on the electrical distribution system depend on when the vehicle is added to the system, when it leaves the system, its charging characteristics and how far it will travel. Some restrictions are also mentioned in the article [8], which states that we can understand when it is included in the system by the time when our electric vehicle starts to charge. For example, people will want to charge their electric vehicles as soon as possible and continue their way, but it is stated that this will cause economic and some technical problems. In addition, PV has been added to the distribution system with EV added in the article [8], and it has been mentioned that PVs will prevent system losses and improve the voltage profile [8].

In addition, as discussed in the article [9] when to include EVs in our system, we have included the time when people come home from work, but in the article [9], it was written 4-8 pm. For Turkey, this time is between 7-9 pm. We also considered the case where they go to work from home, not just when they come home from work. And in line with this thought, we also included our EVs in our system between 8-11 am [9].

4. DESIGN

4.1. Realistic constraints and conditions

All parameters that have been used explaining the constraints were given definitions in the list of symbols part.

- **EV Constraints**

$$EV_{in} \leq EV_{max} \tag{1}$$

$$EV_{abs} = 0 \; at \; tEV_{inUse} \;\; and \; tEV_{idling} \tag{2}$$

$$EV_{abs} > 0 \; at \; tEV_{charging} \tag{3}$$

$$EV_{diss} = \; 0 \; at \; tEV_{charging} \tag{4}$$

$$VEV_{pu} = a \; at \; t_1 \;\; VEV_{pu} = b \; at \; t_2 \quad t_2 > t_1 \quad and \; b < a \qquad during \; tEV_{charging} \tag{5}$$

- **PV Constraints**

$$V_{supp} \geq 0 \; at \; tPV_{supp} \tag{6}$$

$$PV_{supp} = \; 0 \; at \; tPV_{idling} \tag{7}$$

$$VPV_{pu} = a \; at \; t_1 \;\; VPV_{pu} = b \; at \; t_2 \quad t_2 > t_1 \quad and \; b > a \qquad during \; tPV_{supp} \tag{8}$$

- **Storage Devices Constraints**

$$S_{min} \leq S_{in} \leq S_{max} \tag{9}$$

$$S_{min} = 20\% \; of \; S_{max} \tag{10}$$

$$VS_{pu} = a \; at \; t_1 \;\; VS_{pu} = b \; at \; t_2 \quad t_2 > t_1 \quad and \; b > a \quad during \; tS_{discharhing} \tag{11}$$

$$VS_{pu} = a \; at \; t_1 \;\; VS_{pu} = b \; at \; t_2 \quad t_2 > t_1 \quad and \; b < a \quad during \; tS_{charhing} \tag{12}$$

4.2. Cost of the design

Since our project is based on simulation, there is no cost. One of the simulation programs we use, OPENDDS, is open source and the other program we use is MATLAB which is campus licensed. However, we will need a certain amount of money to implement what we do in real life (Storage devices cost, PV cost etc.).

4.3. Engineering Standards

IEEE 1547 standard is designed by the Electrical and Electronics Engineers Institute. It contains some criteria about the connection of the distributed energy sources to the grid [10].

According to ANSI standard, the service voltages should be within ±5% of their nominal voltage level which translates to 0.95 to 1.05 pu voltage. When a service voltage goes below 0.95 pu, it is considered as undervoltage violation and if the service voltage exceeds 1.05 pu, then it is an overvoltage violation [3].

4.4. Details of the design

IEEE Distribution Test Systems

IEEE Distribution Test Systems are widely used by researchers to implement new concepts and test distribution systems [11]. These systems consist of loads, generators, transformers, lines, and many more. Since they are pre-defined systems, it is handy for engineers to work on them. There are different IEEE Distribution Test Systems provided by OpenDSS. 13-Bus system, 34-Bus system, 123-Bus system, and 8500-Node are some of those. If these systems were not defined in OpenDSS, researchers would have to insert all the data in the system which would be tedious and easy to make mistakes. Every system has its own characteristics. There are different reasons to choose which system to work on. 13-Bus system is very small and is used to test common features of distribution system analysis. 34-Bus system is an actual feeder located in Arizona. As for the 123-Bus system, it operates at 4.16 kV and it has voltage problems. 8500-Node is used to test whether algorithms work properly for a really big system. All this information about distribution test systems is taken from the article [3]. In this report, 123-Bus system is analyzed and worked on.

123-Bus System

123-Node feeder operates at 4.16 kV. It has voltage drop problems waiting to be solved by researchers. It is characterized by overhead and underground lines, unbalanced loading [4]. The topology is shown in Fig. 4.4.1 for the 123-Node feeder provided by OpenDSS, there are 132 buses with 7 voltage regulators. There are 99 nodes in phase a, 84 nodes in phase b and finally 95 nodes in phase c.

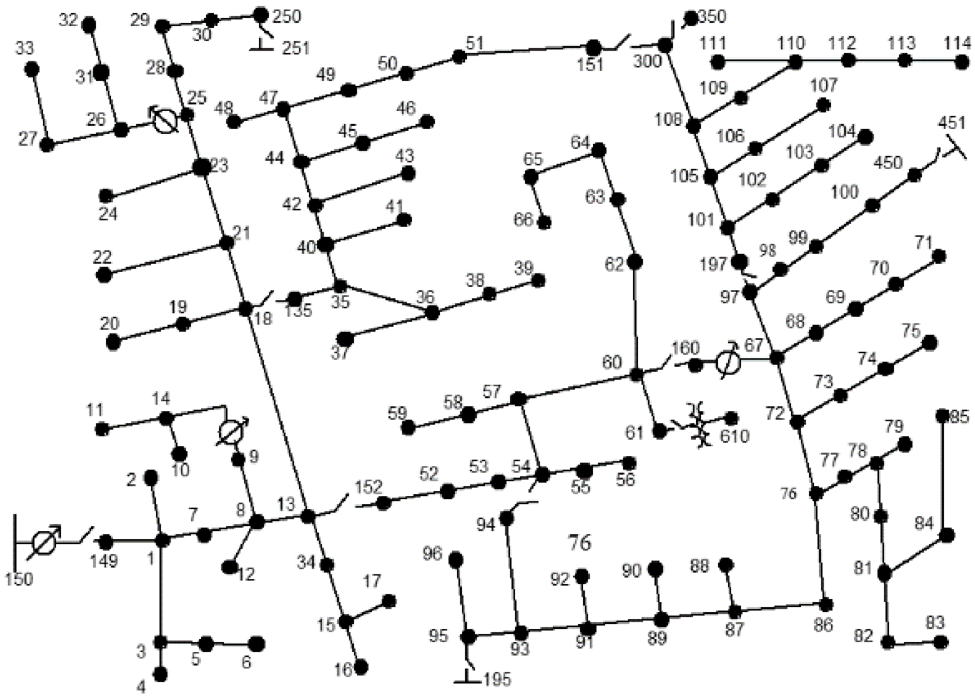

Fig. 4.4.1 Feeder topology of the IEEE 123-bus system [12].

OpenDSS

Many pieces of equipment are involved in an electrical distribution system. Examples include transformers, transmission lines, distribution lines, substations. All used equipment has numerous parameters, and a small change is of great importance in maintaining the power balance of the system. To perform power analysis, a large system of equations must be solved. Doing this solution manually is very likely to cause errors. For this reason, computer programs should be used for power analysis. With the developing software, power systems can now be simulated very easily, and the effect of a change can be found very easily. As a result, it allows us to start the physical work more confidently for the establishment of the electricity distribution system with more precise results.

One of these programs is OpenDSS. OpenDSS is a power distribution system simulator that makes it easy to perform complex analyses. It was developed in 1997 by EPRI (Electric Power Research Institute). Even though its graphical user interface has not been developed much, it provides researchers with flexibility for power distribution system analysis. Unbalanced, multi-phase power flow, fault analysis, linear and nonlinear analysis, and so many different analyses can be done using OpenDSS. It consists of a full library of traditional assets such as lines, transformers, etc. Different DER models like PV systems and energy storage devices can be implemented. That it has a scripting language that is close to object-oriented languages attracts researchers since It is easy to get used to its syntax. One of the best features of OpenDSS is that it has a COM interface that enables OpenDSS to work with modern programming languages like Matlab and Python. How this is done is shown in Fig. 4.4.2 Any change can be done on Matlab GUI and data can be imported to Matlab to visualize it better. OpenDSS comes with explanatory documents about how we can do what. Traditional assets used in OpenDSS have documents to explain how an asset should be used, what its parameters are and how calculations are made. Another flexibility that OpenDSS provides is that it has pre-defined IEEE Test Cases. 13 Bus system, 123 Bus system, and 8500-Node system and many more can be directly used which enables engineers to work on these well-known bus systems effortlessly [13].

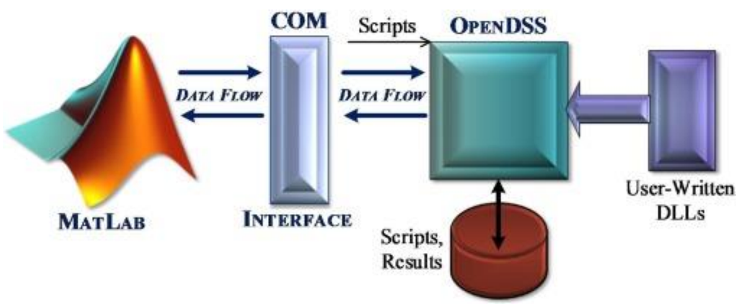

Fig. 4.4.2 OpenDSS COM Interface [14].

PV

The Photo-Voltaic cell converts the energy emitted by the sun into electricity [15]. That means PV provides us the increasing the voltage when they are added to distribution systems. However, PV can not effect all time intervals directly because as you see on the definition, we need sun to benefit from the PV's.

You can see the shematic diagram of the PV System which is used on OPENDSS (See Fig. A1)**.** The properties of PV is also available (see Table A2).

STORAGE DEVICES:

The storage devices element is a power conversion element that can act like a load that absorbs the voltage from the grid while it is charging and that can act like a generator that provides the voltage to the grid while it is discharging. If in load shape values have negative value, storage devices elements will be charging; if those values are positive that means our storage devices will be discharging [19]. Its model is given (see Fig. B1)**.** The properties of storage devices are also available (see Table B2).

INVCONTROL:

For Inverter control, Voltages are taken to check any control should be done or not. These voltages should belong to the PC element. There are two main functions that we have. These are volt-var and volt-watt. The volt-var control provides the managing the var output [19]. The volt-watt controls the maximum kW output [16]. Inverter control properties is available (see Table C1).

Electric Vehicles

Electric vehicles are run by electric motors for propulsion. Since there are many ways to generate electricity, they can be powered in many ways. They have been replacing the internal combustion engine vehicles recently. There are a lot of incentives made by governments. There are already many electric vehicles out there but in near future with the improvements in charging, they will put an end to old combustion engine vehicles. Car brands have already produced electric vehicles and some of their cars are accessible with their parameters (see Table D1). However, charging these number of cars mean additional loads in the distribution systems. Therefore, before we move to an era that EVs have surpassed combustion engine cars, simulations should be done, and future expansions should be made in the existing distribution systems [17].

Addition of Electric Vehicles

In this Project, IEEE 123-Bus system has been worked on. Numerous EVs have been inserted randomly at different buses as if they were loads. All EVs have been assigned a load shape. The load shape is considered that residents charge their cars at work. Then they come home and charge it again for tomorrow. The topology of 123-Bus system with electric vehicles at some buses is given in Fig. 4.4.3

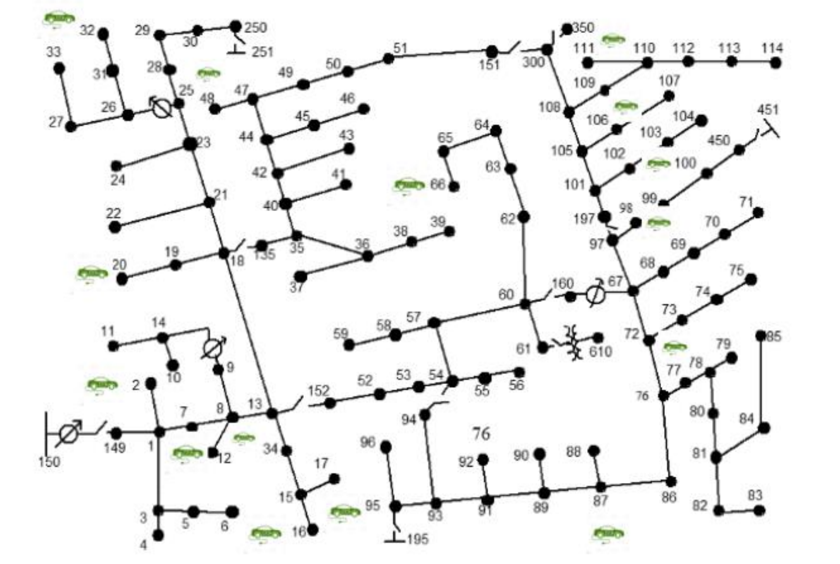

Fig. 4.4.3 123-Bus topology with charge stations of electric vehicles.

A futuristic situation for when the cars are charged is considered wisely that this is what an actual loadshape will look like in the future. Load shape is shown in Fig. 4.4.4

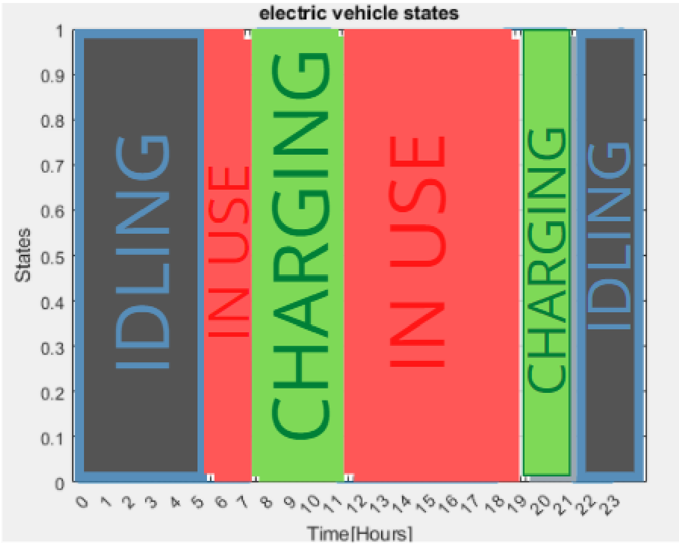

Fig. 4.4.4 An average load shape of electrical vehicles.

Addition of Photovoltaic Panels

As for the renewable energy sources, a lot of PVs have been inserted randomly at buses. The topology of 123-Bus system and PVs characteristics are shown respectively in Fig. 4.4.5 and Fig. 4.4.6

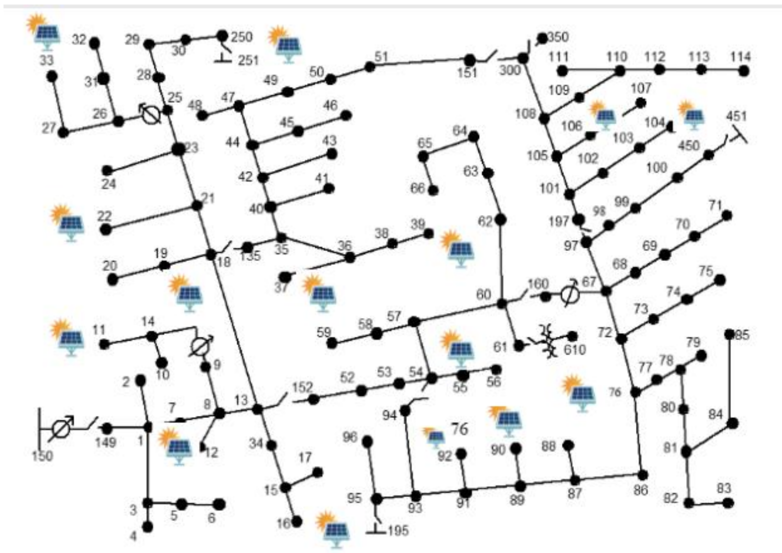

Fig. 4.4.5 123-Bus topology with photovoltaic panels at buses.

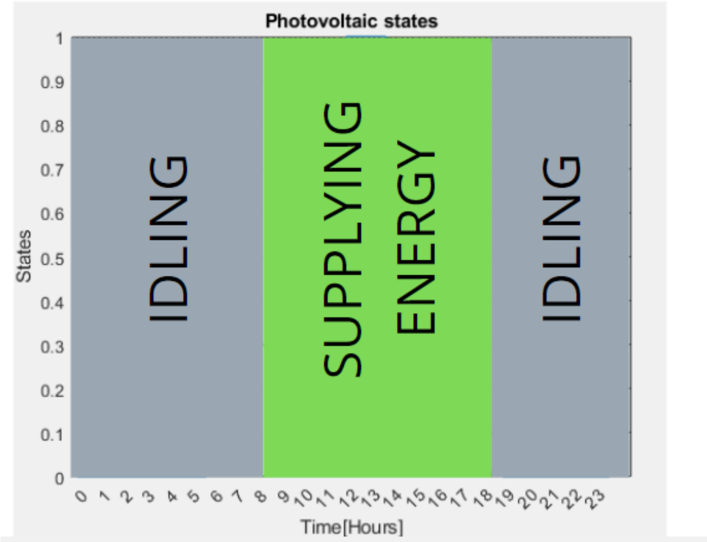

Fig. 4.4.6 PV characteristics.

Addition of Storage devices

It is time to insert storage devices into our system. Renewable energy sources without storage devices can not be thought. We considered three different storage devices curves for this system. Storage devices are distributed randomly at buses. Charging and discharging times of storage devices curve 3 complies with our PV system as PVs work extensively around noon. All storage devices curve have one feature in common. Since 5 P.M. to 10 P.M. are the rush hours, all storage devices discharge at these times to regulate the system. The feeder topolgy with storage devices and storage devices curves can be seen respectively in Fig. 4.4.7, Fig. 4.4.8, Fig. 4.4.9, Fig. 4.4.10

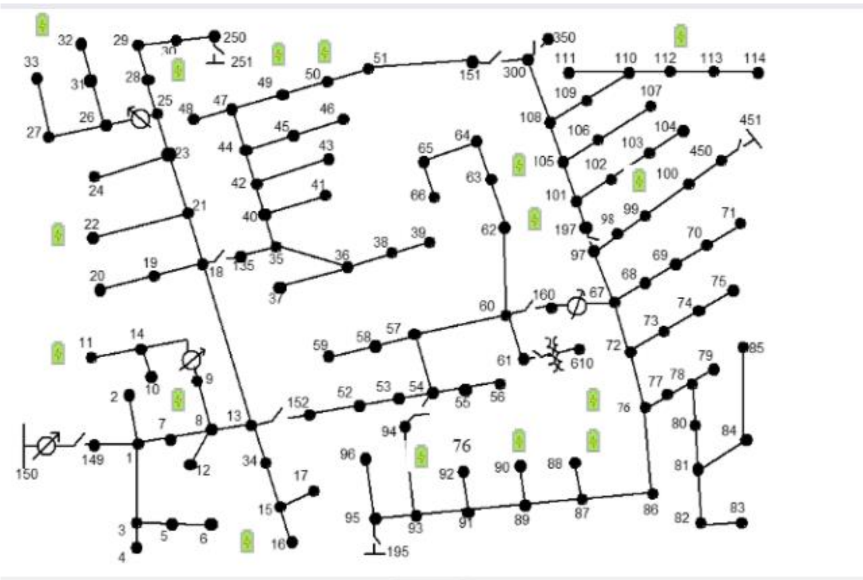

Fig. 4.4.7 123-Bus topology with storage devices at buses.

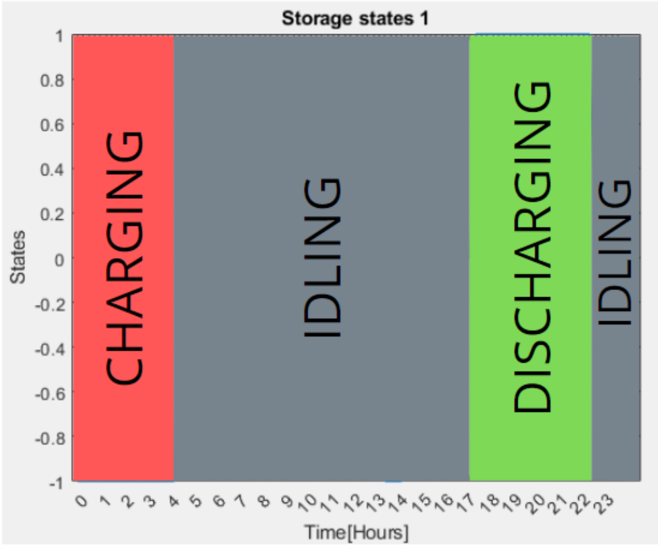

Fig. 4.4.8 Storage devices curve characteristics 1

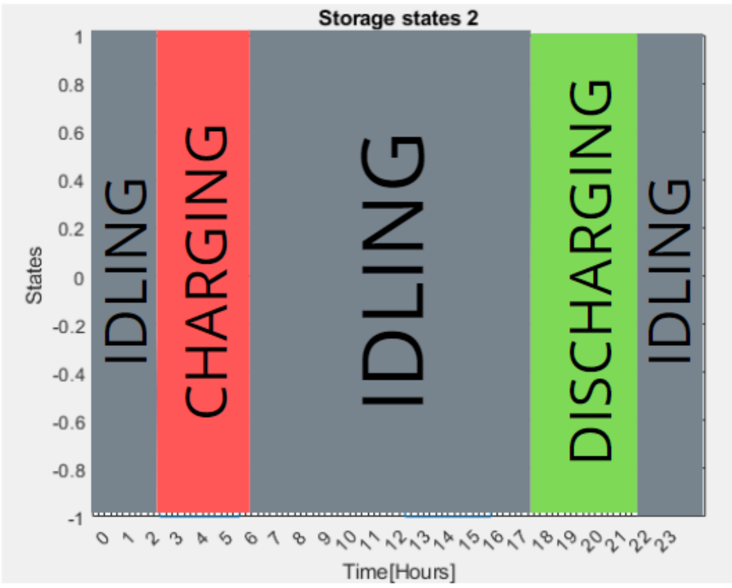

Fig. 4.4.9 Storage devices curve characteristics 2

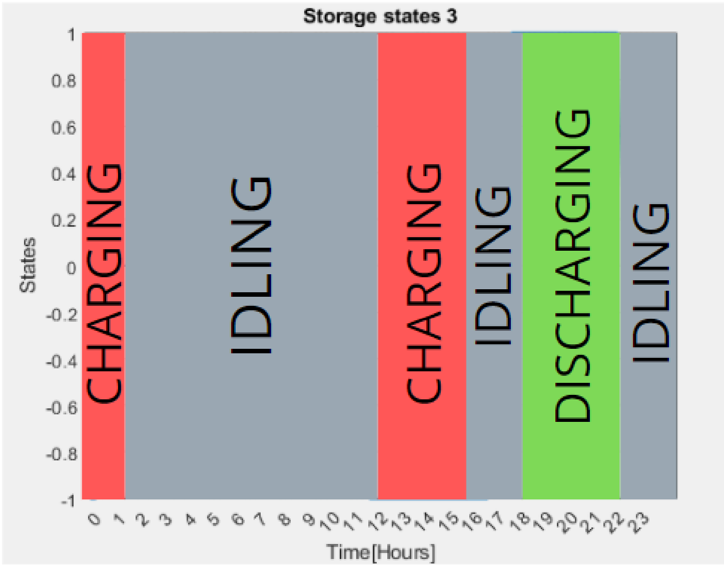

Fig. 4.4.10 Storage devices curve characteristics 3

Final Topology

Finally, Fig. 4.4.11 shows the final IEE 123-Bus system topology with all the components inserted into the system.

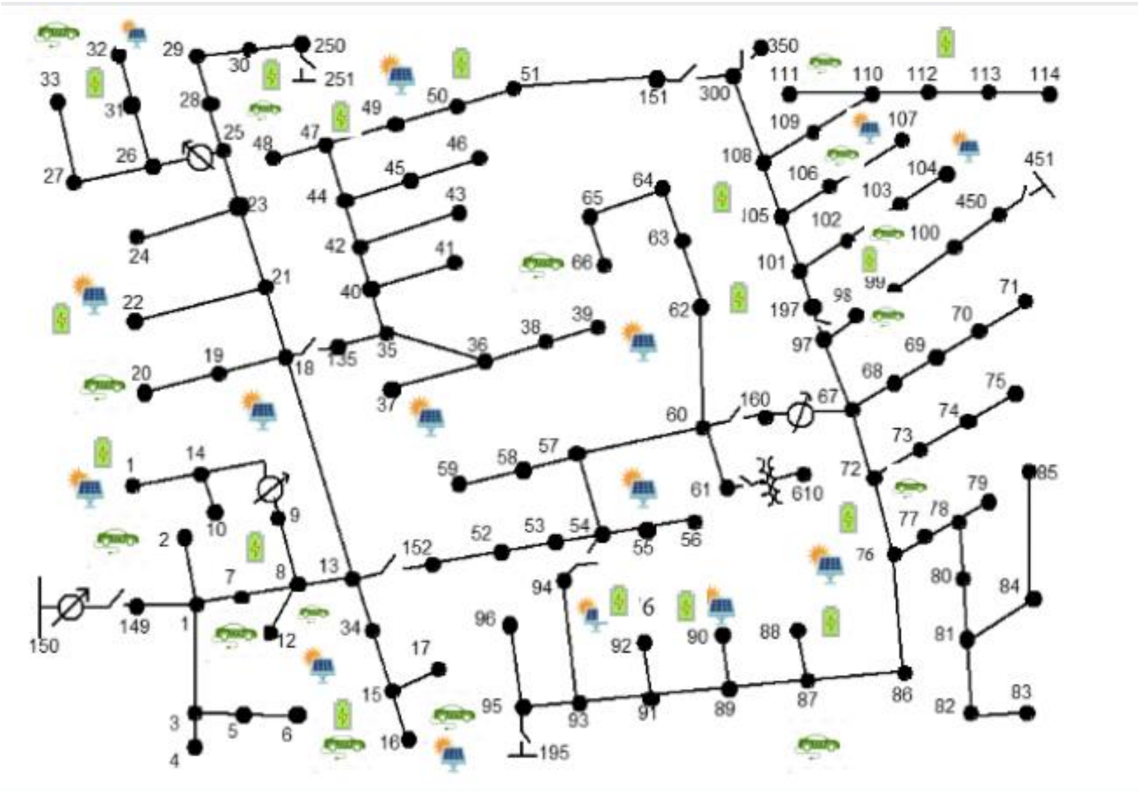

Fig. 4.4.11 Final IEEE 123-Bus topology with all components inserted

5. METHODS

It is known that each element we add to our existing electricity distribution system will have an impact. These effects change with the addition of each of our elements to the system. For example, when we initially add EVs to existing system at a certain time intervals, it is expected that our voltages will decrease. Because EVs will act as a new load in our system and need to draw power to be charged.

After adding our EVs to the existing system, PVs were added. The effect of our PVs occurs at noon and cannot be effective for the evening hours. Since our PVs will generate power to our system, our voltage value will increase and will exceed the desired value. We tried to regulate our voltage value, which increases and reaches the points we do not want, by adding a new element, the 'Inverter Control' device to our system. During this arrangement, our system will help to bring it to the level we want when the desired voltage values are exceeded, and it will help to increase it to the level we want in the time intervals when our voltage value is already low. Despite all this, our tension level remains below the desired level due to the high demand when people come home from work. We have added storage devices to our system to interfere with these time intervals. This device takes power as well as giving power to the system. For this reason, it is expected that our storage devices will be charged to the system when the demand is low, thus reducing the high voltage value by taking power from our system and giving power to the system by discharging at intervals when the demand is high and therefore the voltage value is lower than desired. In this way, it is expected that our voltage levels will remain in the desired range.

After adding all the above-mentioned elements to our system, we observed that the voltage values were slightly different from the desired level. That's why we optimized over RegTap values. After solving our system by randomly changing the RegTap values between -16 and 16, we tried to find the most appropriate RegTap value so that our voltage value remains within the desired value range. After giving the appropriate RegTap value, we saw that our voltage values were at the desired level in 3 phases.

6. RESULTS AND DISCUSSION

We added LOADSHAPE to our distribution system named 123Bus on OPENDSS and then got its graphics for each of the 3 phases. As seen in Figure 6.1.1, 6.1.2 and 6.1.3, our voltage is at its lowest during the evening (returning home from work) when electricity demand is highest. It is observed that our voltages are high during the night hours when the electricity demand is the lowest. The black lines seen in the figures are drawn according to the ANSI standard mentioned above.

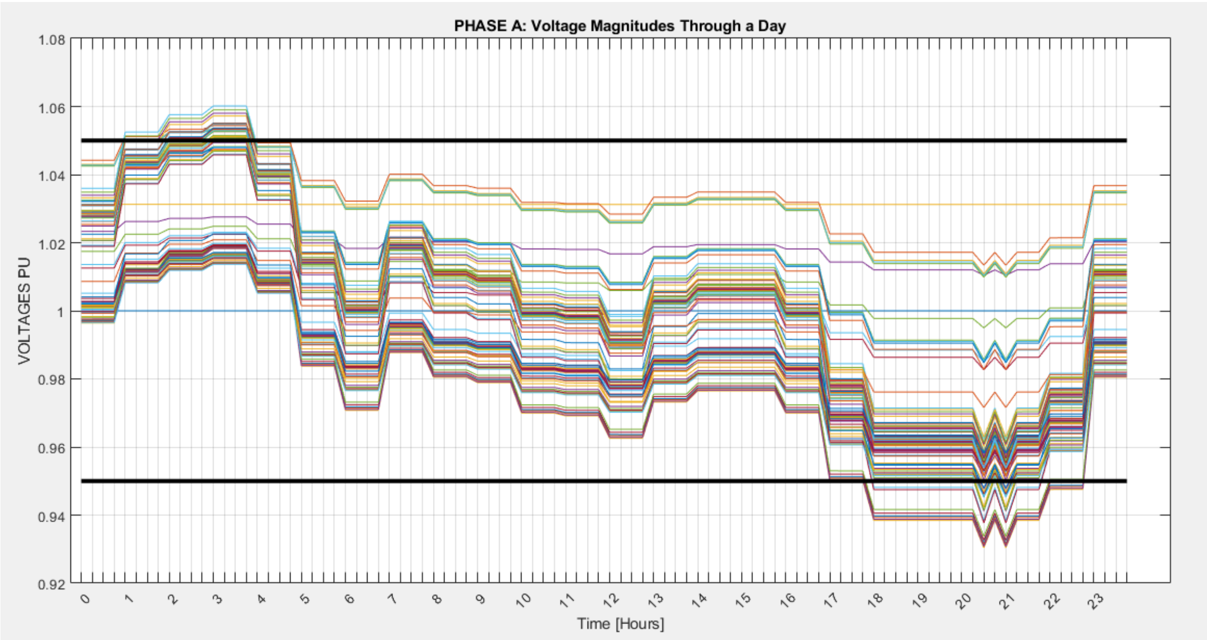

Figure 6.1.1 Phase A: Voltage Magnitudes Through a Day

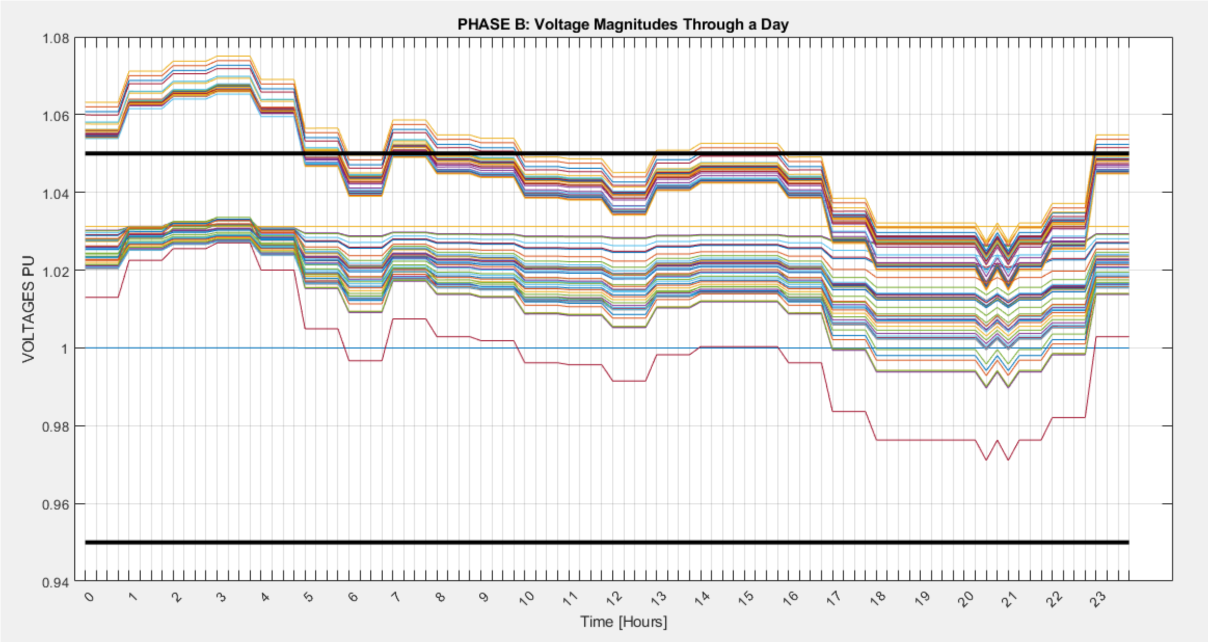

Figure 6.1.2 Phase B: Voltage Magnitudes Through a Day

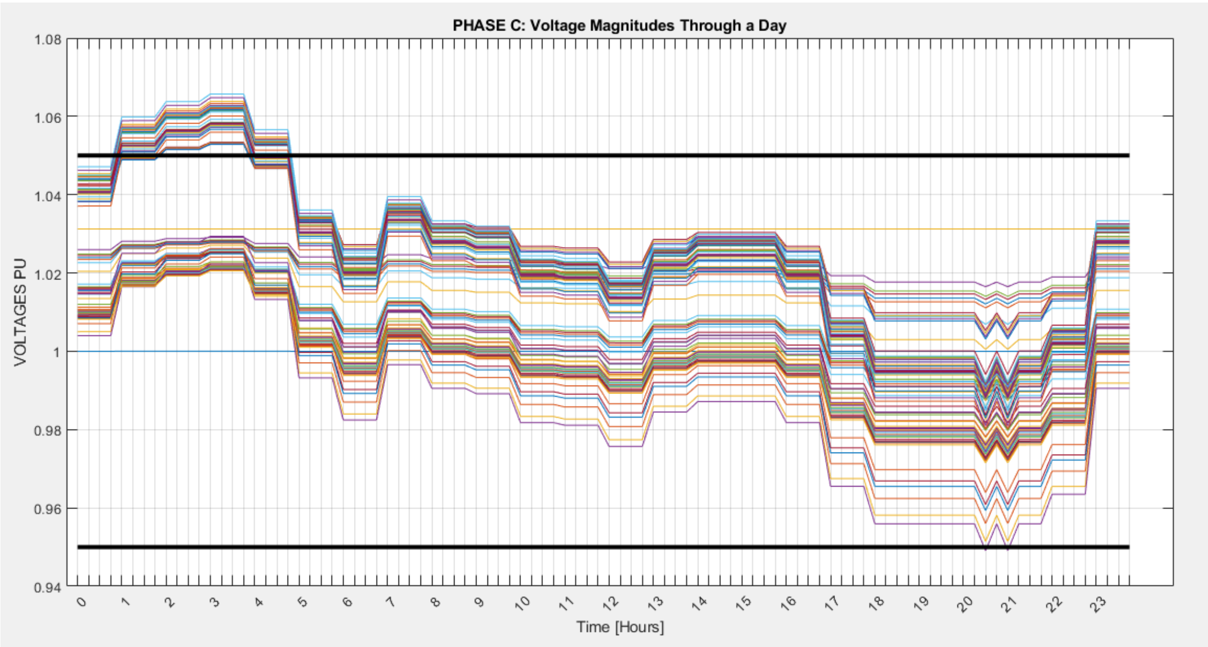

Figure 6.1.3 Phase C: Voltage Magnitudes Through a Day

By adding LOADSHAPE, graphics that resemble a typical real-life electricity distribution system are obtained. Thereupon, the addition of electric vehicles, which are expected to take more place in our lives soon, has started. Electric vehicles have been added to our system approximately between 09:00a.m and 13: 00p.m and between 5: 30p.m and 9:30p.m in the evening. As seen in Figure 6.2.1, 6.2.2 and 6.2.3, it was observed that the voltage level of each phase of our system decreased during these time intervals.

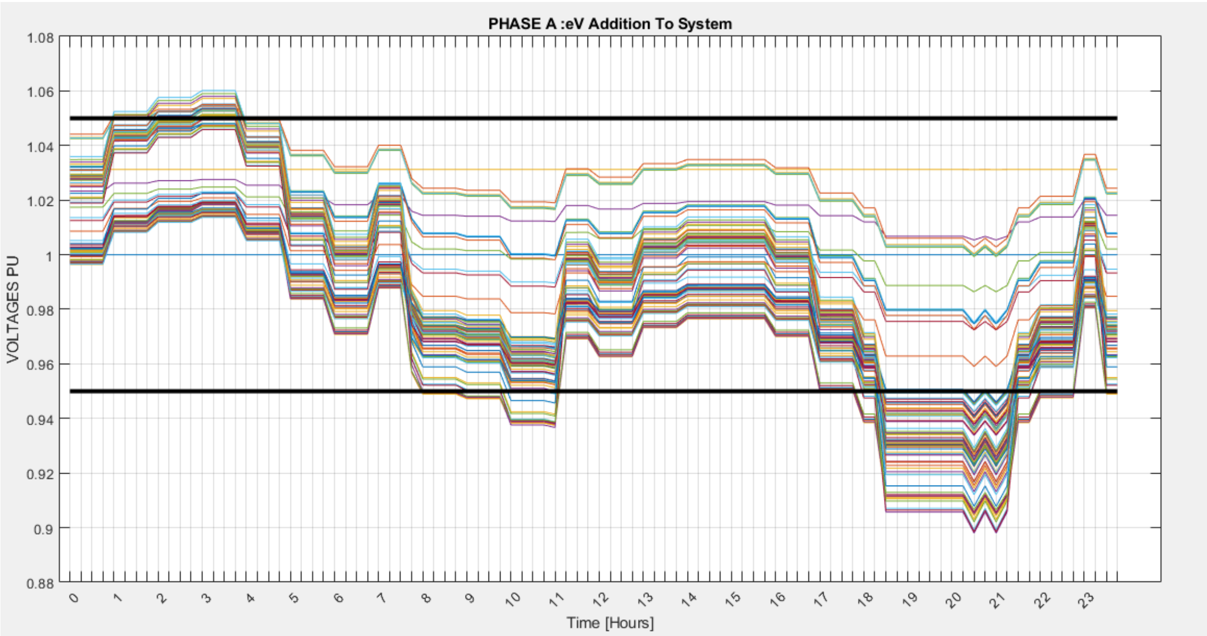

Figure 6.2.1 Phase A: eV Addition to System

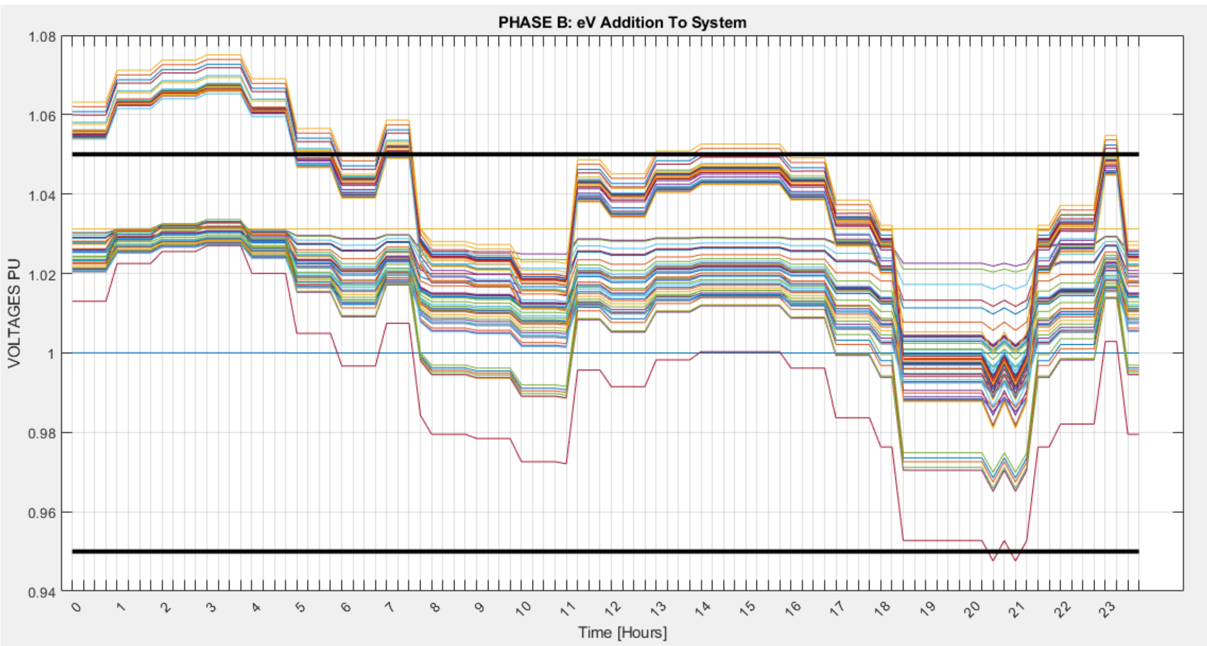

Figure 6.2.2 Phase B: eV Addition to System

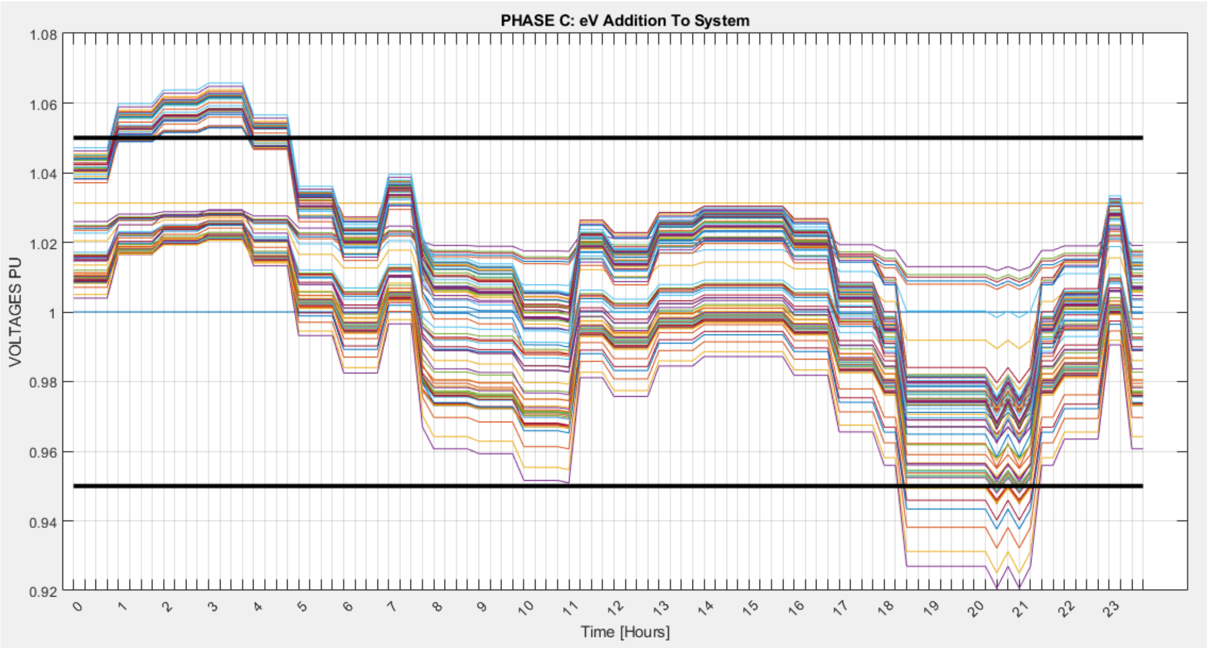

Figure 6.2.3 Phase C: eV Addition to System

After observing the effects of these vehicles, which will enter our lives soon with the inclusion of EVs in our system, on our distribution system, studies have been started to bring the voltage levels between 0.95 pu and 1.05 pu according to the ANSI standard. First, we have included PV in our system to increase the electrical voltage that drops at noon. In Figure 6.3.1, 6.3.2 and 6.3.3, the graphs of our system with PV are given.

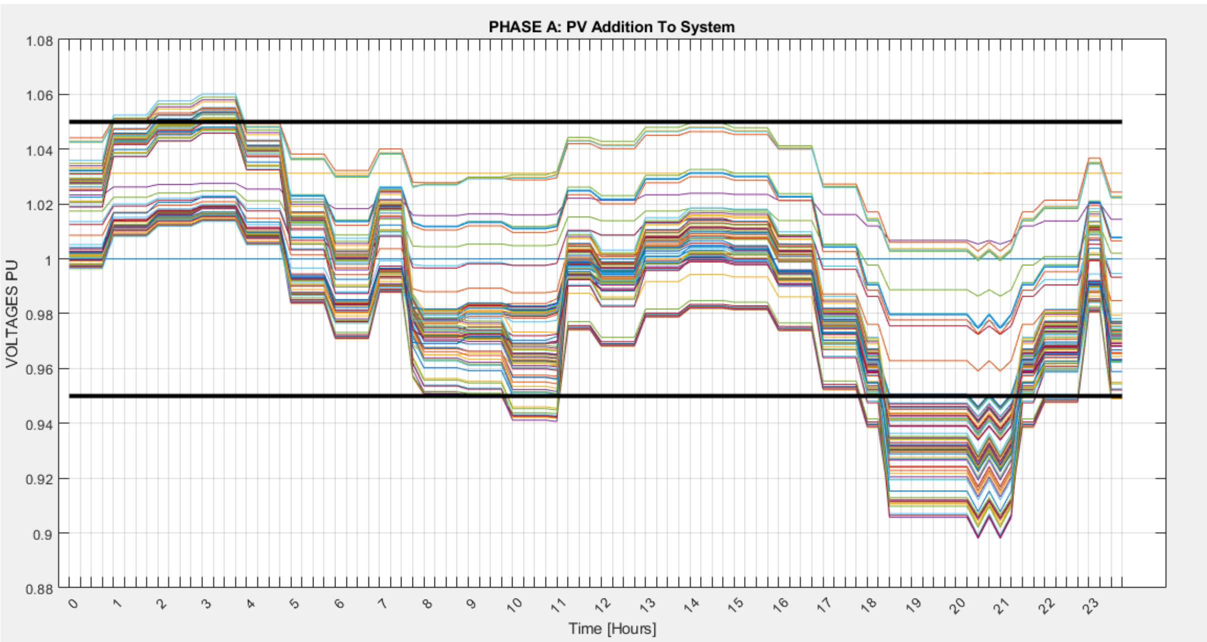

Figure 6.3.1 Phase A: PV Addition to System

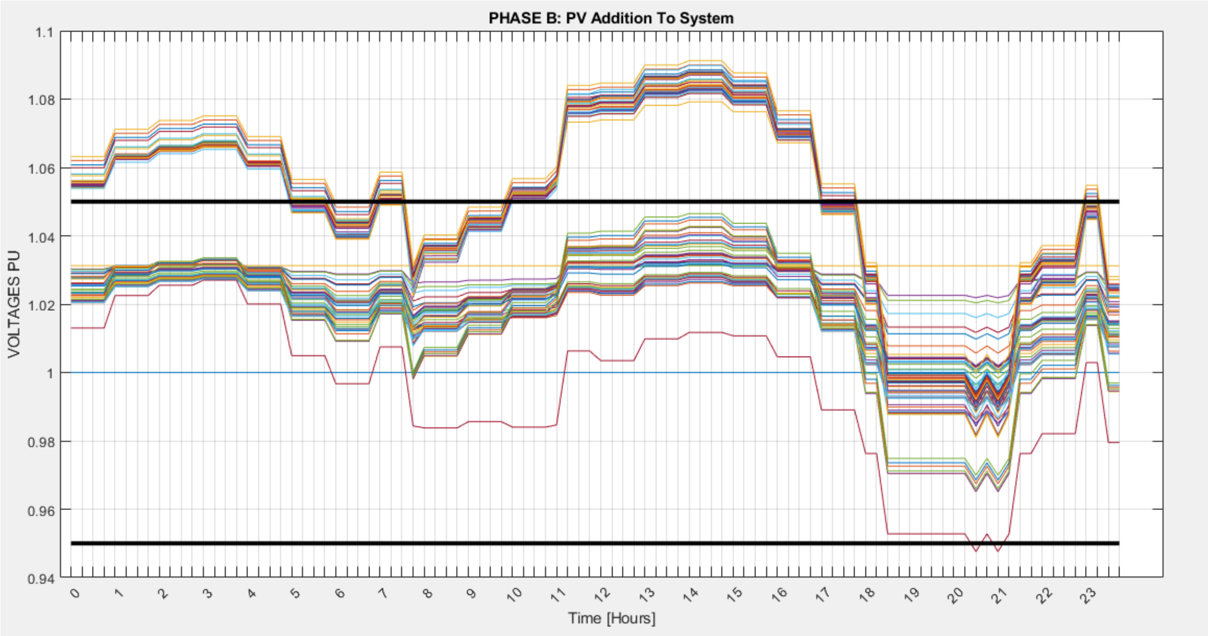

Figure 6.3.2 Phase B: PV Addition to System

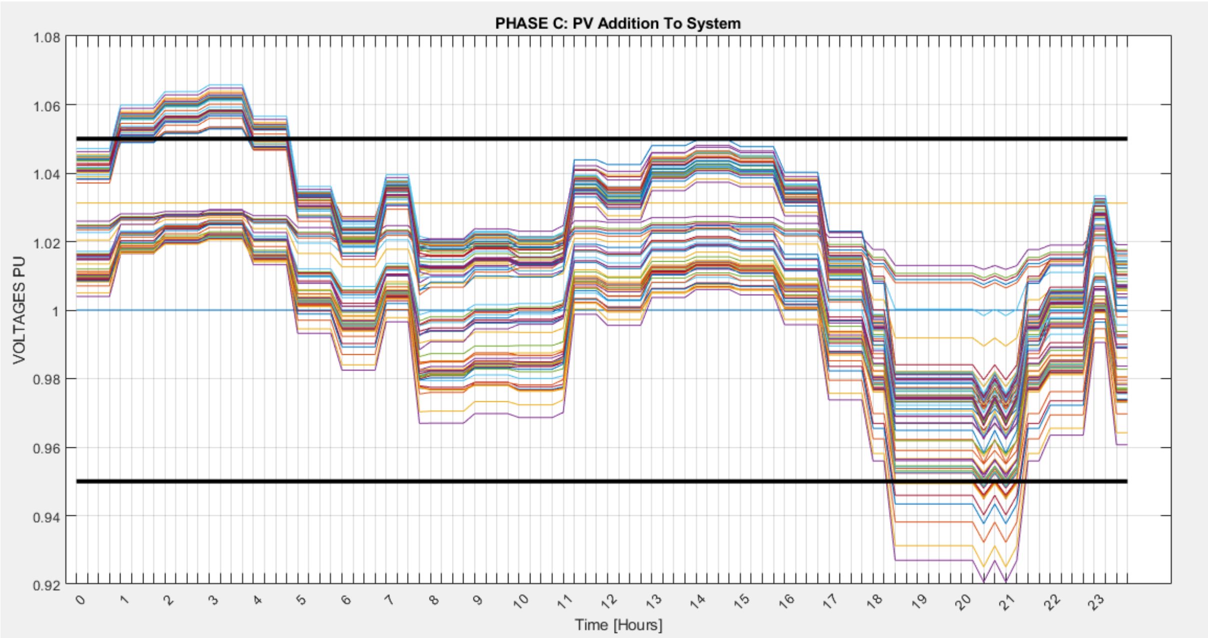

Figure 6.3.3 Phase C: PV Addition to System

As seen in Figure 6.2.1, 2, 3 and Figure 6.3.1, 2, 3 graphs, our PVs showed their effect during daylight hours, increasing our voltage levels for each phase. As expected, this effect is most effective at noon. A problem encountered when PV is added is that our voltage value increases and goes out of the desired range at noon. As seen in Figure 6.3.a, b, c, our voltage levels remain low in the evening hours. 'Inverter Control' has been added to our system to bring our voltage values, which increase with the effect of PV at noon and lower at night, to the desired range. You can see the Inverter Control effect in Figure 6.4.1, 6.4.2 and 6.4.3.

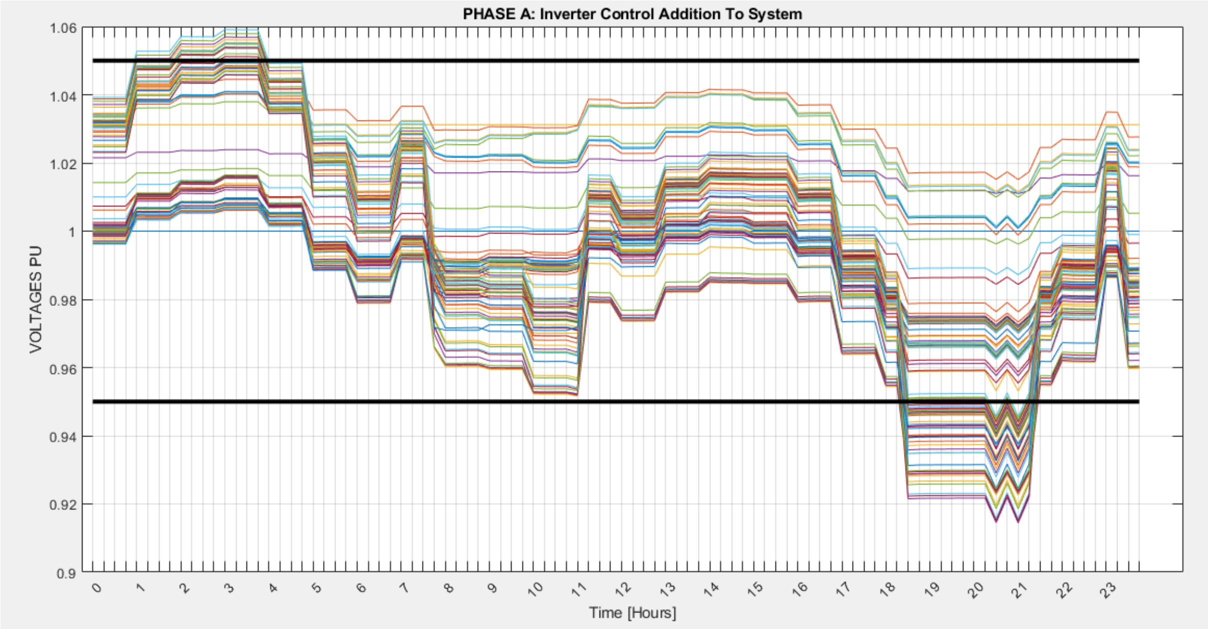

Figure 6.4.1 Phase A: Inverter Control Addition to System

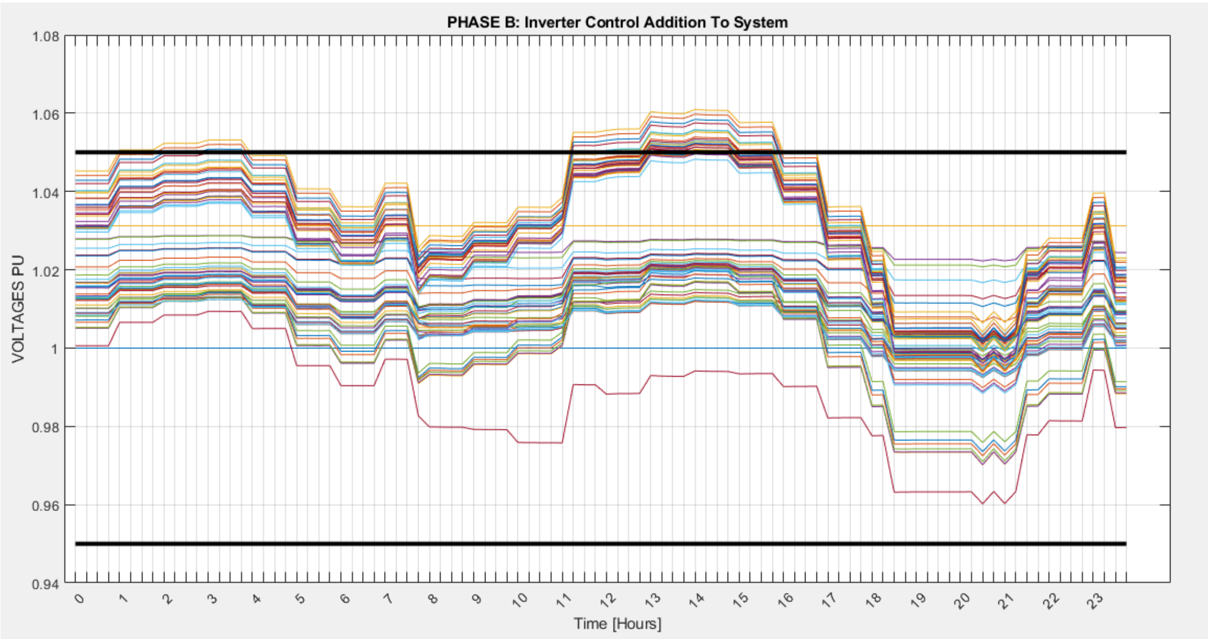

Figure 6.4.2 Phase B: Inverter Control Addition to System

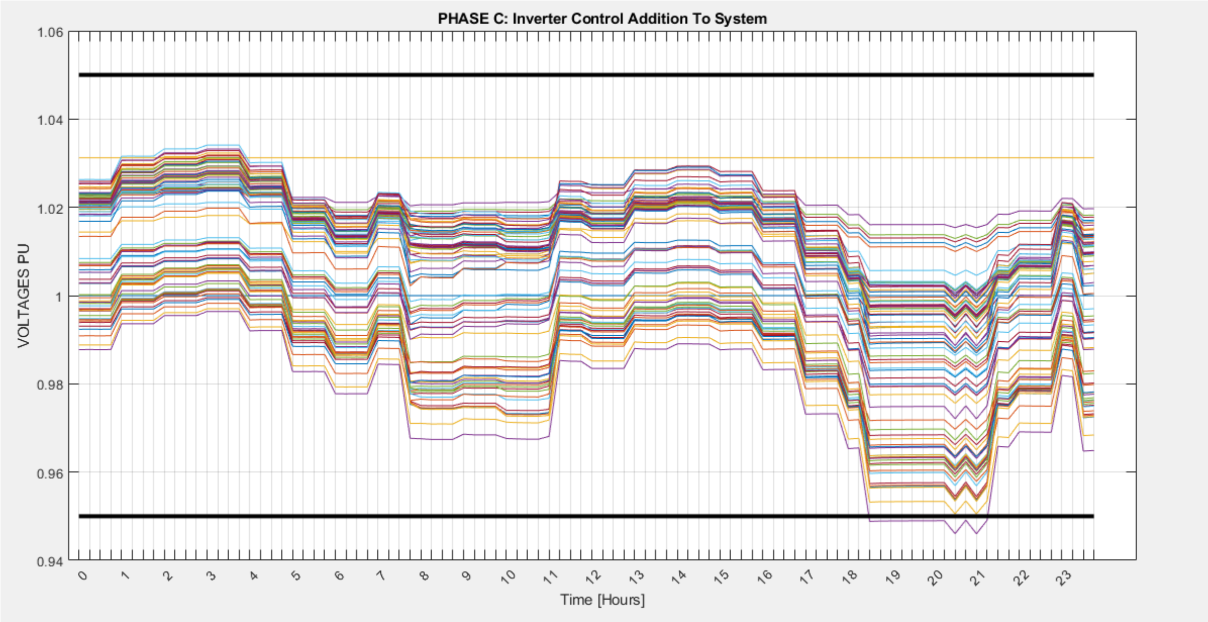

Figure 6.4.3 Phase C: Inverter Control Addition to System

As seen in Figure 6.3.1, 2, 3 and Figure 6.4.1, 2, 3 our voltage values decrease at noon and rise in the evening, approaching the desired range. However, since it does not yet provide the desired range, storage devices have been added to our system. You can see the storage devices effect in 6.5.1, 2, 3 And Figure 6.5.4, 5, 6 shows the maximum amount of power that our storage devices can store and the minimum amount of power that our storage devices need to have. In addition, the charging and discharging time intervals of our storage devices are also seen.

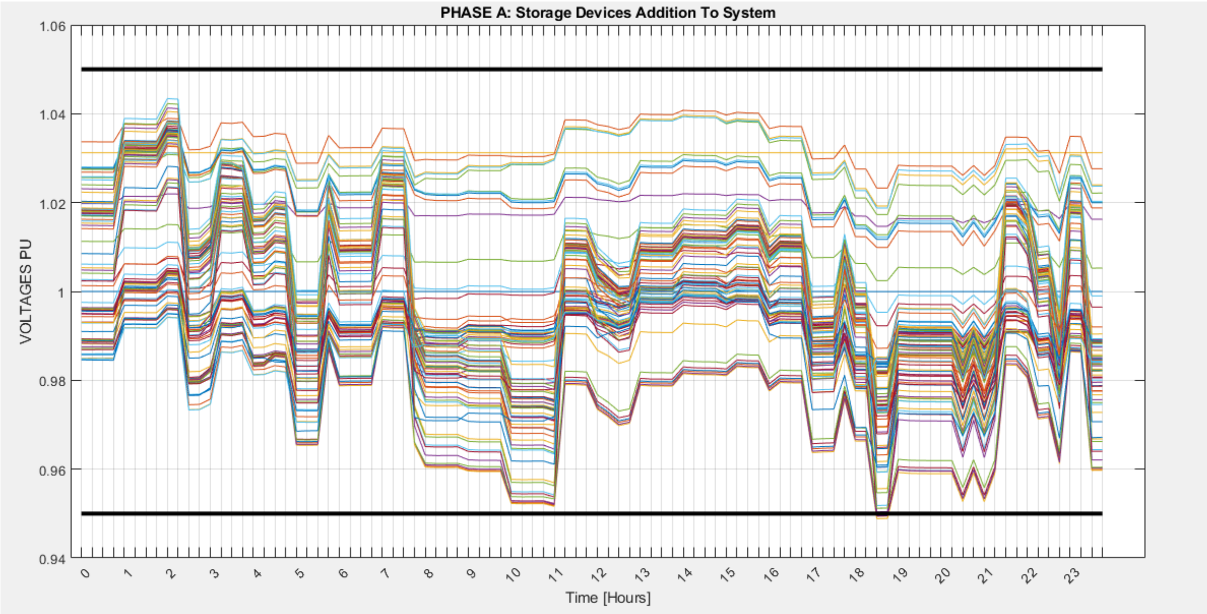

Figure 6.5.1 Phase A: Storage Devices Addition to System

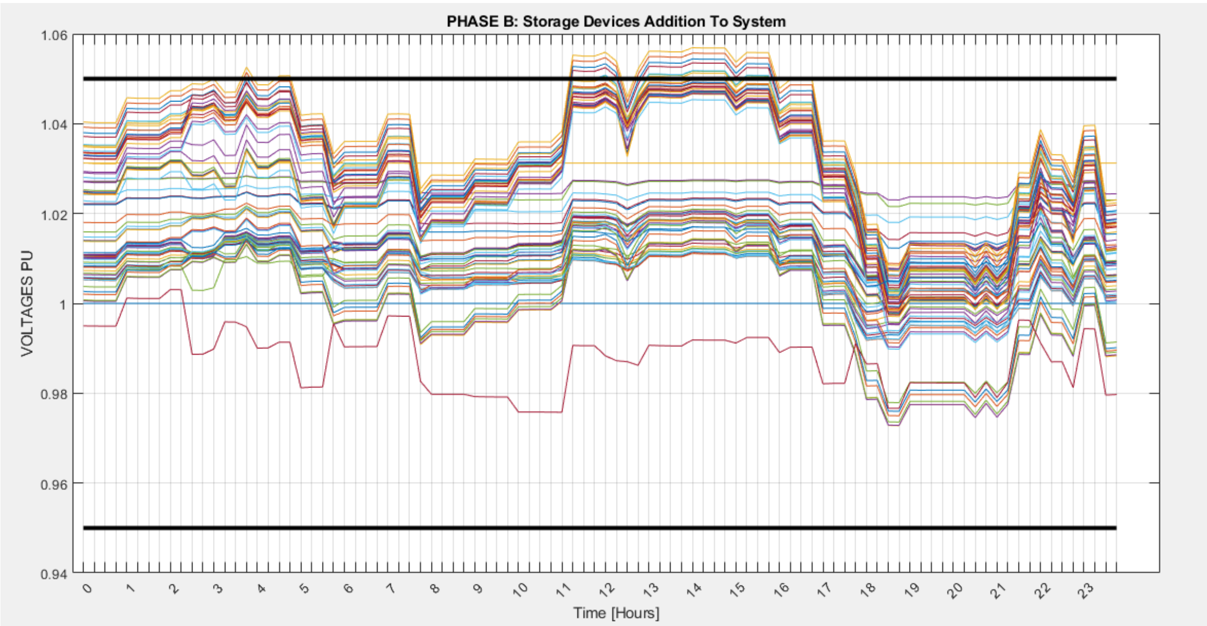

Figure 6.5.2 Phase B: Storage Devices Addition to System

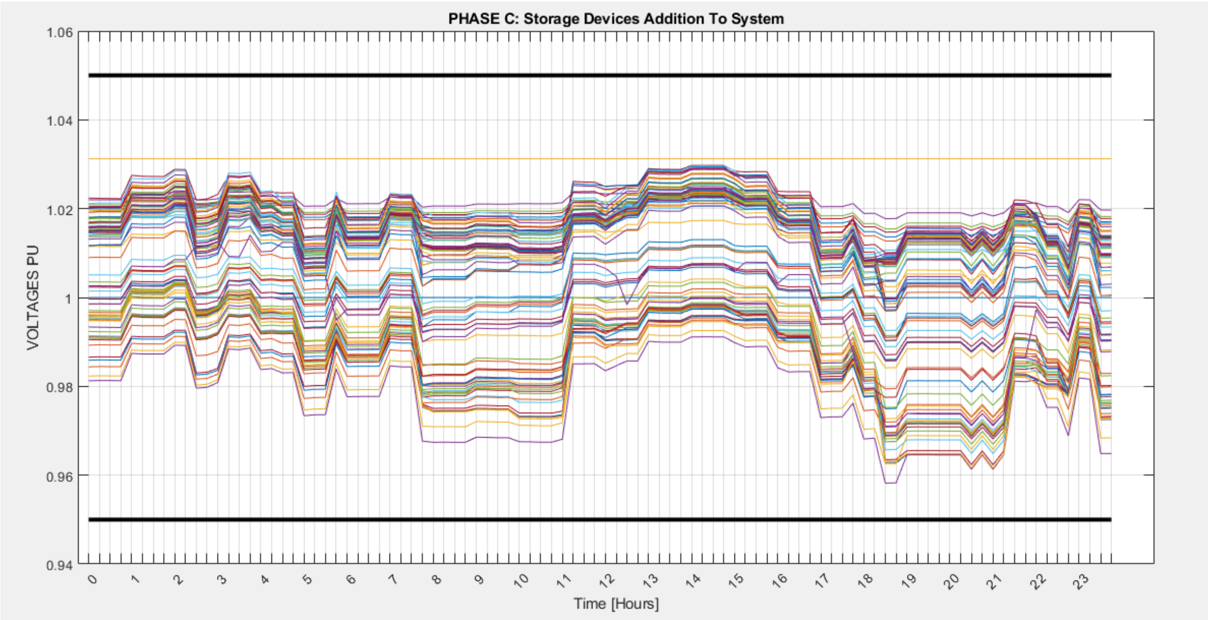

Figure 6.5.3 Phase C: Storage Devices Addition to System

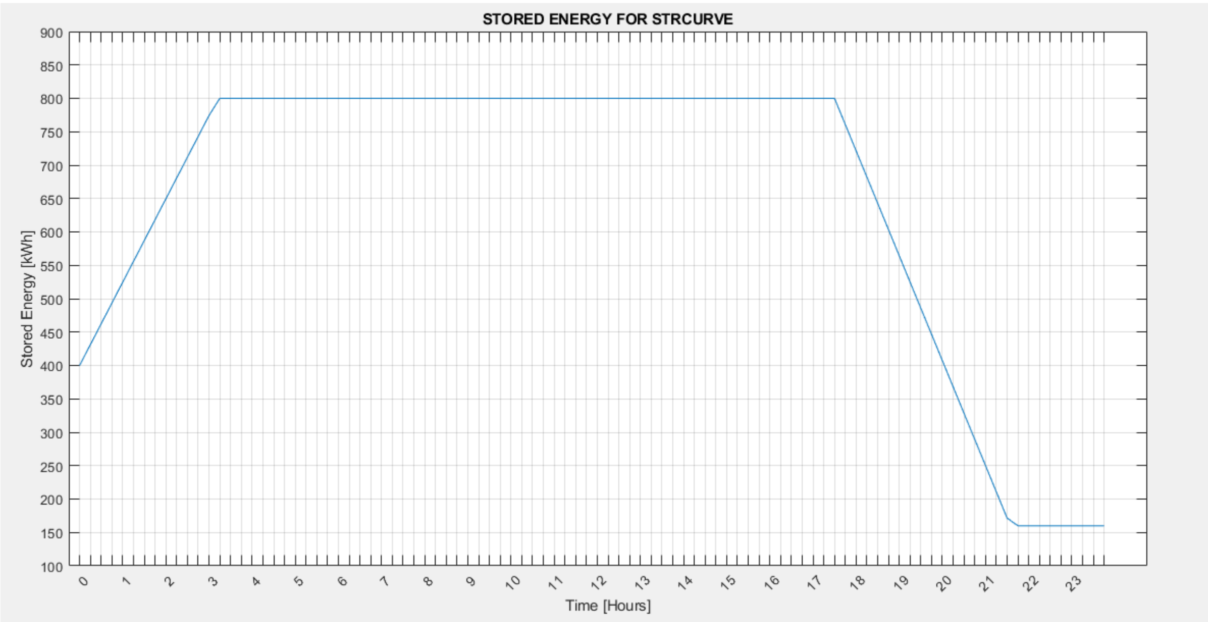

Figure 6.5.4 Stored Energy For STRCURVE

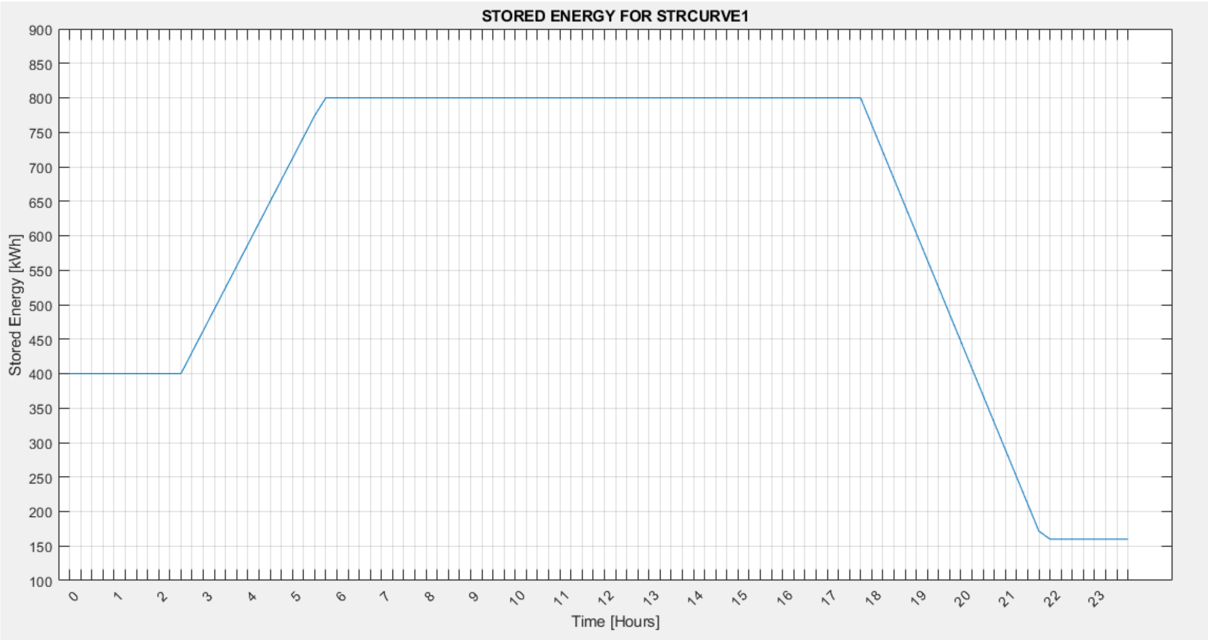

Figure 6.5.5 Stored Energy for STRCURVE1

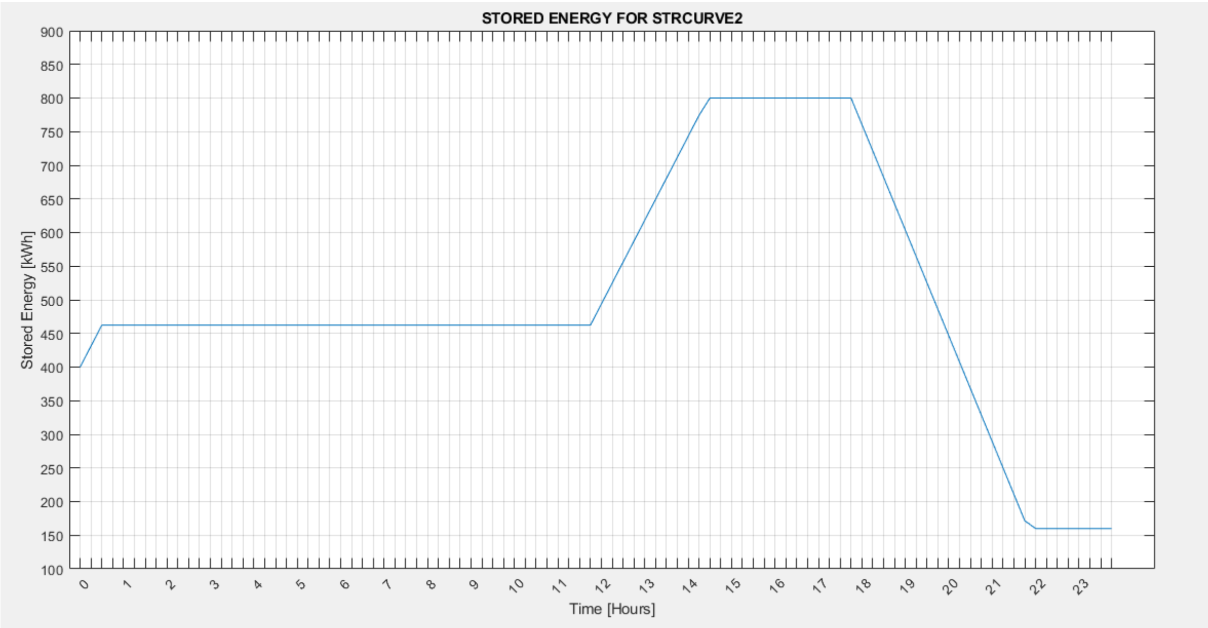

Figure 6.5.6 Stored Energy for STRCURVE2

If you look at the graphs of Figure 6.4.1, 2, 3 and Figure 6.5.1, 2, 3, it seems that the excess voltage values found in Figure 6.4.1, 2, 3 decrease because we charge our storage devices device at these time intervals. At the same time, especially if we look at the evening hours, our voltage values have increased to the desired level. And our standard is provided especially for PHASE A and PHASE C. However, there is a problem in PHASE B at noon.

To solve this problem, the most suitable Tap position was found in PHASE B by randomly changing the Tap numbers of the Regulators in our system. You can see the effect of the changed Regulator Tap numbers in Figure 6.6.1, 2, 3.

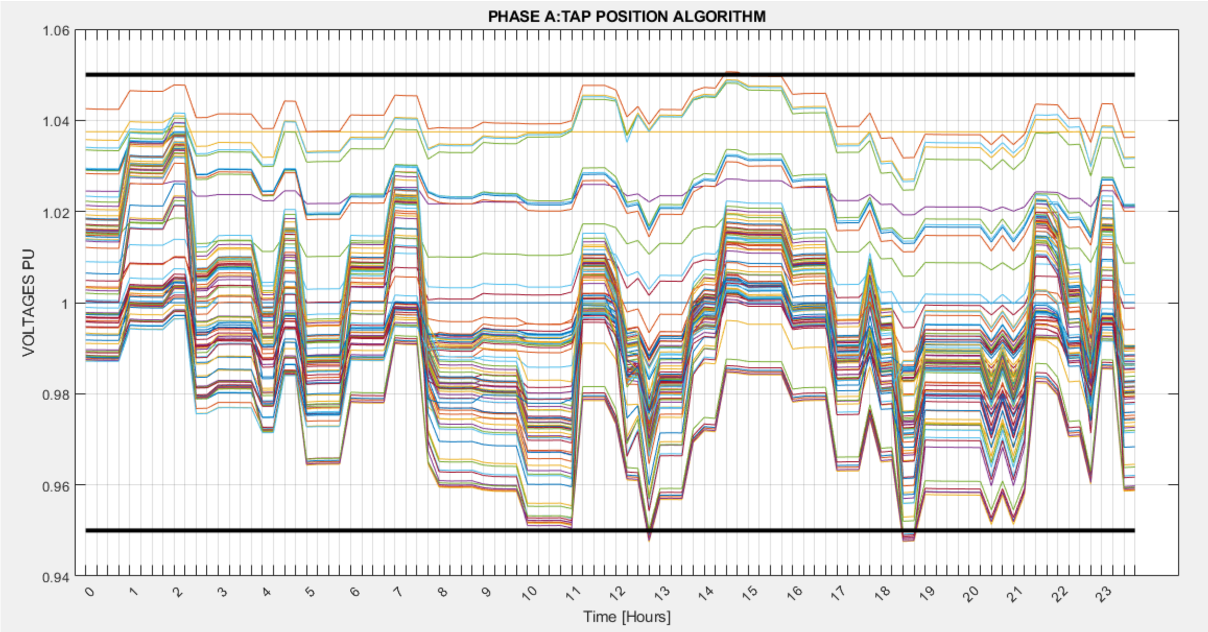

Fig. 6.6.1 Phase A: Tap Position Algorithm

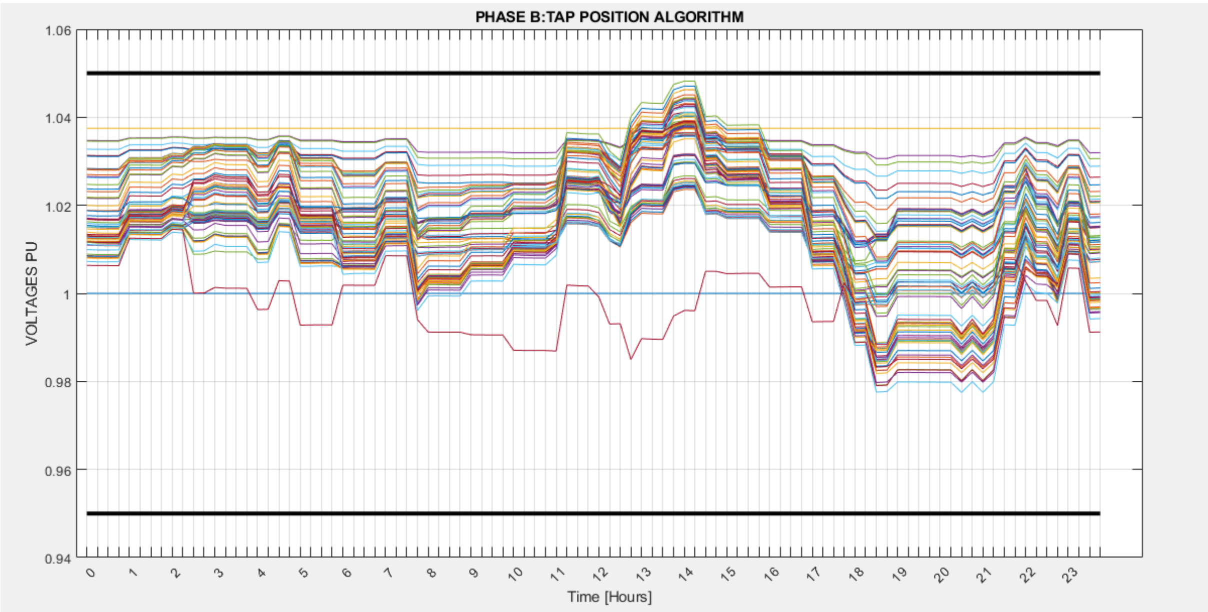

Figure 6.6.2 Phase B: Tap Position Algorithm

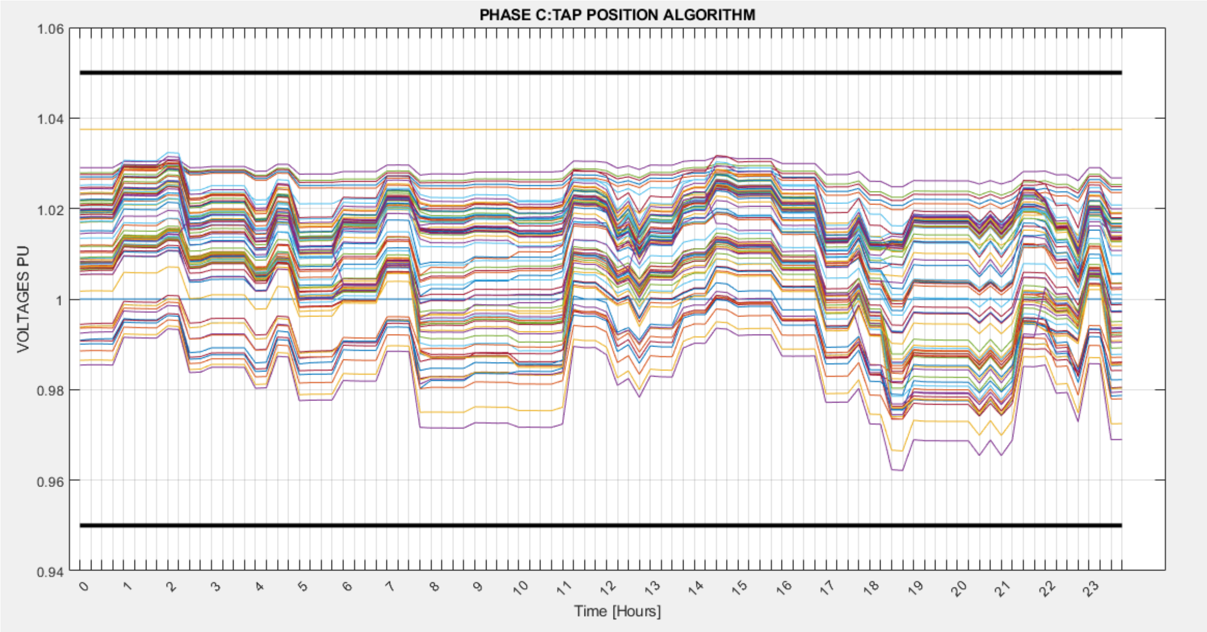

Figure 6.6.3 Phase C: Tap Position Algorithm

As shown in figure 6.6.1, 2, 3, our distribution networks voltages have met the ANSI standard and the voltage values have entered the desired level ranges.

7. CONCLUSION

This paper carries out a simulation on IEEE 123-Bus system provided by OpenDSS. MATLAB is used primarily for interfering with the power distribution system. All engagements are done in three phases. Load shape is added to the system to make the simulations more realistic. Then electric vehicles and photovoltaic panels are included randomly at buses. Their impacts on the system are observed. To control the voltage level, Inverter control with mode VOLT-VAR is inserted into all photovoltaic panels. Its effect is seen and validated. Storage devices are included at different buses to beautify the node voltage magnitudes. Storage devices charge-discharge or idling states are observed and plotted. Finally, an optimization algorithm for voltage regulators is built and results become more promising. All engineering standards have been proven right.

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APPENDICES

Appendice A: Photovoltaic Panels

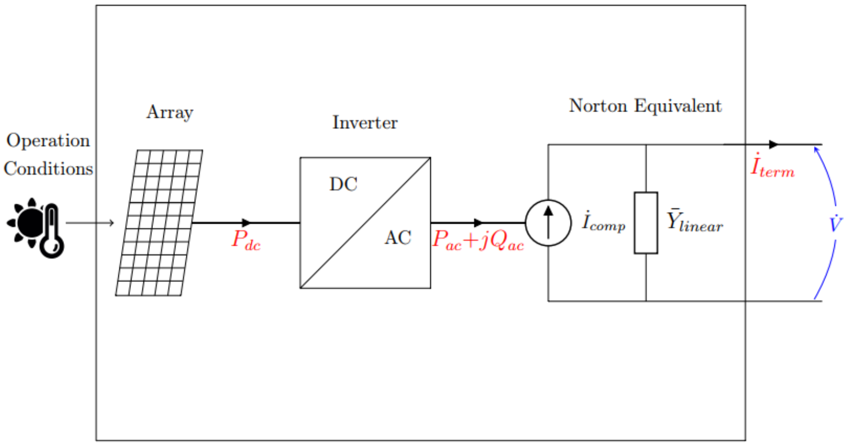

Fig. A1 Usage of PV on OpenDSS[19]

PROPERTIES:	DEFINITIONS:
Bus1	It defines as from where PV is connected to our electrical distribution system
Phases	It defines as how many phases PV has
Pmpp	It defines as provided maximum active power in kW from PV
kV	Nominal rated voltage for PV
kVA	Apparent Power
effcurve	Efficiency curve of inverter
P-TCurve	Correction factor of the PV
daily	Daily irradiance curve. (this is related with the behaviour of PV)

Table A2 Properties of PV on OpenDSS[19]

Appendice B: Storage devices

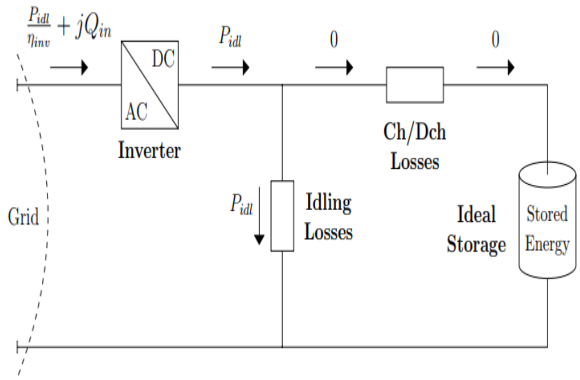

Fig. B1 Storage devices characterisctics[19]

FEATURES:	DEFINITOIN:
Bus1	It defines as from where PV is connected to our electrical distribution system
Kv	Nominal rated voltage for PV
kWrated	active power output of inverter in kW
%reserve	percentage of the kwhrated that can serve
Kwhrated	Rated storage devices capacity
%stored	Present amount of energy stored
Dispmode	dispmode in follow mode means that the kW output of storage devices follows the loadshape until its charge is being full or exhausted
Daily	It means that we have a active loadshape which is followed by the Dispmode
State	The storage devices element continue to charge until its max point whisch is described by kwhrated, after that point it change its position to idling.
Model	In model 1, The storage devices element provides or absorbs the Constant Power

Table B2 Properties of Storage devices on OpenDSS[19]

Appendice C: Inverter Control

FEATURES:	DEFINITIONS
Mode:	This mode provides to control the vars (reactive power),
voltage_curvex_ref	It uses as base voltage the rated voltage of the controlled element;
vvc_curve1	This represents the XYcurve containing the volt-var curve. Positive values are providing the base reactive power (increase the voltage value of the system), negative values are absorbing the base reactive power. (decrease the voltage value of the system)

Table C1 Properties of Inverter Control on OpenDSS[19]

Appendice D: Electric Vehicles

CAR BRAND	BATTERY USABLE	ENERGY CONSUMPTION
Mercedes EQS 450+	107.8 KWh	168 Wh/km
Tesla Model 3	57 KWh	150 Wh/km
Opel Corsa-e	45 KWh	158 Wh/km
BMW i3 120 Ah	37.9 KWh	161 Wh/km
Honda e	28.5 KWh	168 Wh/km
Kia e-Soul 39 kWh	77.4 KWh	170 Wh/km
Porsche Taycan	83.7 KWh	180 Wh/km

Table D1 Car brands and their properties [18].