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Characterization & Modeling of Representative Distribution Circuits in GridLAB-D

California Solar Initiative Project, Advanced Distribution Analytic Services Enabling High Penetration Solar PV

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1 INTRODUCTION

California has many ambitious goals to increase the amount of solar power generated and used inside its borders, such as a goal to increase distributed generation, a program of incentives to support distributed solar photovoltaics, and California Senate Bill (SB) 350 that requires 50% renewable energy portfolio standard by 2030. However, there are limits on the amount of distributed generation that current systems can hold. This is because there are current operational limits on the system and its equipment. For example, high PV penetration can lead to thermal overloads at secondary transformers, voltage flicker, or high voltages on the secondary line, among other things. The limit to the amount of distributed solar that any one distribution circuit can hold is referred in this paper as the "Native Limit" of the system. It is the point at which any additional PV system will violate the operation constraints of the circuit. These limits are outlined and discussed further in section 5 – Clearing Violations of Base Cases.

The goal of this project, the California Solar Initiative Research, Development, Demonstration, and Deployment Solicitation #4 – High Penetration Study (CSI4), is to determine these native limits of distributed solar PV penetration on the Southern California Edison (SCE) system. Once native limits are known, then strategies for upgrading the system to allow for higher penetrations of PV can be determined, thus allowing for California to meet its target renewable energy portfolio standard. To do this, computer models of SCE's distribution system are used to test levels of increasing PV on each distribution circuit using a PV-adoption model and Monte-Carlo simulation.

However, since there are over 4,500 circuits in the SCE territory, creating circuit models for all of SCE's circuits at the level of detail required for this study would require an exorbitant amount of time and labor. For this reason, a set of representative circuits were chosen to represent all of SCE's circuits. This was done by first clustering all of SCE's circuits based on their characteristics and then determining the circuits that would serve as representative of the rest of SCE's territory. With these defined representative circuits (RCs), models were created of each RC in GridLAB-D™, an open source software with the ability to model behind-the-meter resources and demands, created by the U.S. Department of Energy's Pacific Northwest National Lab. Using the GridLAB-D models, native PV limits can be determined for each RC, after which point the mitigation technologies and upgrade paths can be defined.

In summary, the project can be broken down into the following pieces (see **Figure 1.1**): clustering of circuits, creating the RC models in GridLAB-D, determining the native limits of each RC, and outlining the mitigation strategies and technologies for system upgrades. This report will cover clustering methodology and model creation to a high level, as shown by the dashed line in Figure 1.1. More detailed reports on the residential and commercial modeling process will be published separately from this report.

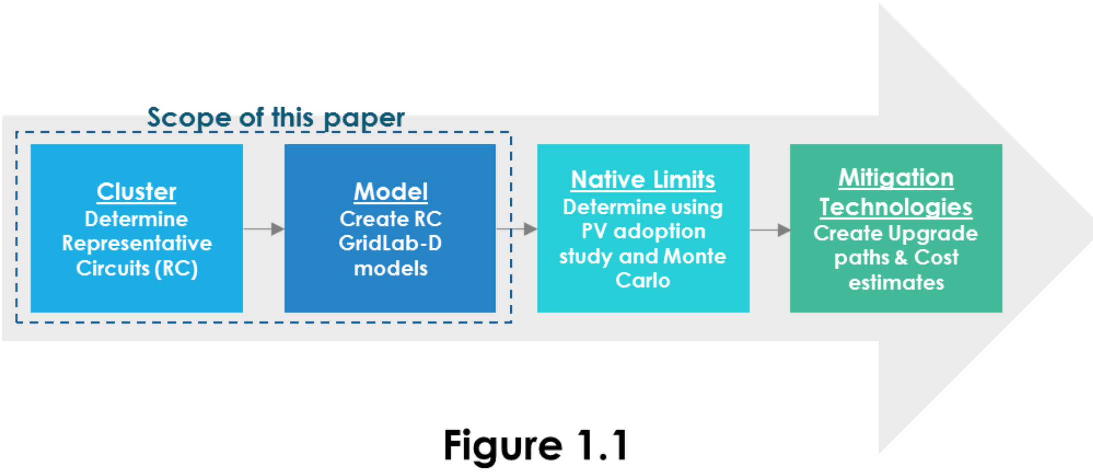


Figure 1.1

The project partners are SCE, Pacific Northwest National Lab (PNNL), and Qado Energy. Battelle was also contracted to complete the representative models of commercial customer types. Qado Energy's GridUnity™ platform will host these RC models. The platform can be used to run the Monte-Carlo deployments of PV on each RC model. The goal is to allow utility distribution planners as well as third parties such as solar developers to analyze native limits and upgrade strategies for increasing solar penetration on any of SCE's distribution circuits.

2 Clustering Methodology for SCE Circuits

2.1 Overview

The first part of the project was to determine the representative circuits by clustering all of SCE's circuits based on their characteristics. As shown in Figure 2.1, this was done by first identifying these defining characteristics, conducting K-means clustering, and finally determine the RCs based on the clustered data.

Southern California Edison owns and operates approximately 4,500 distribution circuits spanning 50,000 square miles with wide varieties of climate zones and load types. In order to accurately determine the varied impacts of high penetration solar PV across the SCE service territory, it is necessary to develop and test models of circuits that effectively capture that same variety. For this study, representative circuits were selected from each of three defining classes for distribution circuits: rural circuits, urban 2-4kV class circuits, and urban 12-16kV circuits. Ultimately, 8 rural circuits, 5 circuits from the urban 2-4kV class, and 17 circuits from the urban 12-16kV were selected – a total of 30 representative circuits.

This selection process was run on the circuit data compiled for SCE's CSI RD&D Solicitation #3 project with EPRI to evaluate alternatives to the 15% rule.

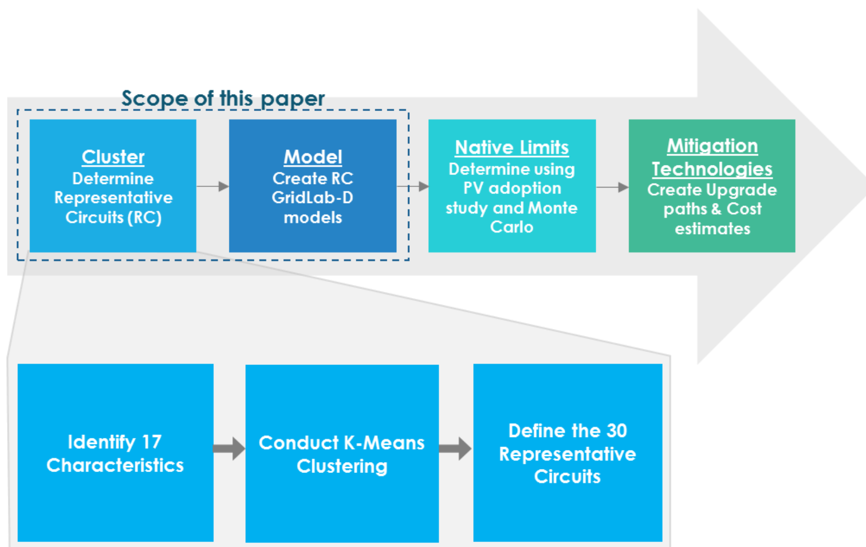


Figure 2.1

2.2 Data Dimensions Considered

Seventeen data dimensions were taken into consideration during the selection process for the representative circuits (RC). The clustering algorithm and mechanics will be described in greater detail in the next section. At a high level, the data dimensions represent areas in which a set of circuits should exhibit good similarity if they are all to be represented by a single circuit from within the group.

<u>**Voltage Class**</u> (2-4kV & 12-16kV)

Taken into consideration because of the dramatic differences in circuit design, construction and operation between the two classes.

Climate Zone

The primary California Building Climate Zone Area occupied by the loads on circuit. Taken into consideration because of the dramatic differences in load shape and magnitude across various climate zones, include coastal, mountainous and high desert.[1]

Connected Service Transformer Capacity

The sum of the nameplate KVA ratings for all transformers connected to a circuit. Taken into consideration to group circuits by (roughly) the total magnitude of load they serve, separating highly built out and heavily loaded circuits from less developed and more lightly loaded circuits.

Circuit Peak Load

Taken into consideration as an additional indication of total load served by a circuit, separating heavily loaded circuits from lightly loaded circuits.

Miles of 3-Phase Circuit

Taken into consideration because of the operational differences and differences in limiting factors between long and short circuits, especially with respect to voltage.

Miles of 1 or 2-Phase Overhead Circuit

Taken into consideration to capture the operational differences and differences in limiting factors between primarily overhead circuits and primarily underground circuits, as well as the same differences between primarily 3-phase circuits and circuits with a mix of 3-phase and single or bi-phase loading.

Percentage of Energy (kilowatt-hours) Sold to Residential/Commercial/Industrial/Agricultural End-Use Customers

Incorporated as four distinct data dimensions (the percentage for each customer type). Taken into consideration in order to group like circuits based on the types of load they serve.

Total Number of Customers

Taken into consideration in order to separate circuits dominated by a few large loads from those that serve a large number of smaller loads.

Percentage of Residential Customers in the High/Medium/Low Income PRIZM Categories

Incorporated as three distinct data dimensions (the percentage for each income level). Taken into consideration to separate circuits serving predominantly high-income residential customers from circuits serving predominantly lower-income residential customers, due to their heuristically observed load shape differences (when controlled from climate zone)

> **PRIZM** is a socioeconomic segmentation determined to a resolution of zip+4 code by the Nielsen company.[2]

[1] http://www.energy.ca.gov/maps/renewable/building_climate_zones.html

[2] http://www.claritas.com/MyBestSegments/Default.jsp

Number of Voltage Regulators

Taken into consideration to separate out the (relatively uncommon) SCE circuit operated with a voltage regulator because of their operational differences.

Number of Capacitor Banks

Taken into consideration to group like circuits together based on the relative availability of capacitors to support voltage regulation.

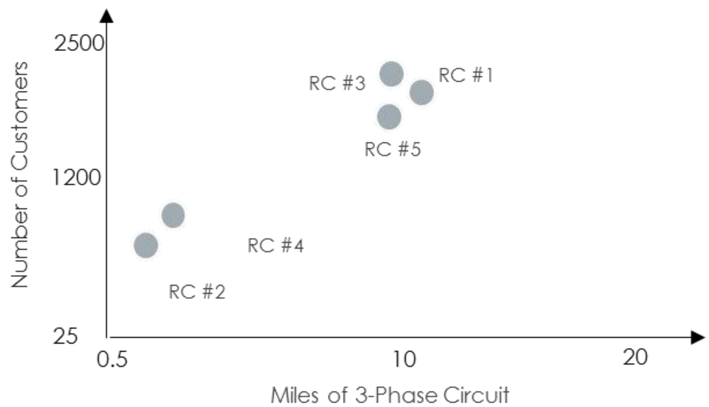
Number of Circuit Tie Points

Taken into consideration to group dense, tightly-meshed urban circuits together.

2.3 K-Means Clustering Implementation

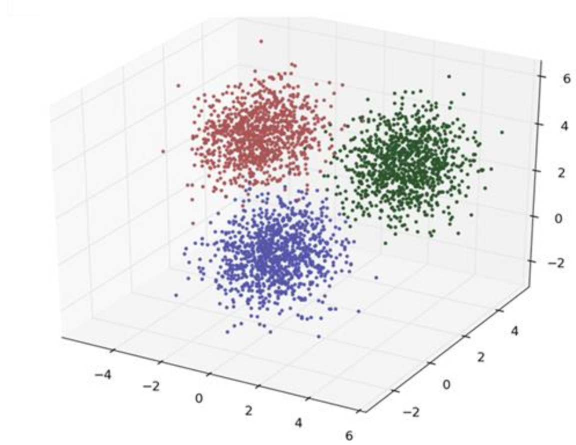
One of the most common, popular and straightforward methods used in cluster analysis is *k-means clustering*. In this method, SCE's 4,500 circuits are represented by their position in a 17-dimensional vector space. The position of a circuit with respect to any two of the above dimensions can be represented on a 2-D plane, as shown conceptually in **Figure 2.3.1**.

Figure 2.3.1
5 clusters with 2 dimensions



The objective of k-means clustering is to take the total number of observations and group them into "k" clusters, where each circuit belongs to the cluster it is closest to. Each cluster has a centroid, and the circuit whose position is nearest the centroid was selected as the representative circuit for all circuits in that cluster. In **Figure 2.3.2,**[3] a large set of observations (analogous to circuits) are clustered into 3 groups (k = 3) based on 3 dimensions.

Figure 2.3.2
3 clusters with 3 dimensions



In order to set up the circuits for the cluster analysis, each of the dimensions needed to be scaled and normalized. This was done in two steps. First, the maximum value across all circuits for any given

3 http://eamusic.dartmouth.edu/~mcasey/m102/03_MachineLearning/3dGaussianClustering.png

Table 2.3.1: Scaling of Importance of Circuit Dimensions			
Dimension	**Scale**	**Dimension**	**Scale**
Voltage Class	8	% of Energy Sold – Agricultural Customers	2
Climate Zone	8	Total Number of Customers	2
Connected Service Transformer Capacity	4	% of Residential Customers PRIZM High Income	2
Circuit Peak Load	4	% of Residential Customers PRIZM Medium Income	2
Miles of 3 Phase Circuit	2	% of Residential Customers PRIZM Low Income	2
Miles of 1 or 2 Phase Circuit	2	Number of Voltage Regulators	1
% of Energy Sold – Residential Customers	2	Number of Capacitor Banks	1
% of Energy Sold – Commercial Customers	2	Number of Circuit Tie Points	1
% of Energy Sold – Industrial Customers	2		

dimension was set equal to one, the minimum value across all circuits for that same dimension was set equal to zero, and all other circuits had their values normalized accordingly. This prevented the vector space from having a large empty zone at the front or back of any one dimension. Second, many dimensions were scaled up based on their relative importance. Dimensions that, for example, were scaled up by a factor of 8, were essentially "stretched out" 8x as far, creating 8x the separation between any two observations along that particular dimension. By selectively choosing which dimensions would be scaled and by how much, we were able to bias the clustering algorithm to group circuits around our highest priority dimensions. Dimension scale factors are shown in **Table 2.3.1**.

Note: In some cases, due to systematic problems (e.g missing or incomplete SCADA or customer data) for a particular circuit, the second or even third-nearest circuit to a cluster centroid was chosen as the representative.

2.4 Determining Appropriate K

There is a tradeoff between accuracy of circuit representation and the number of representative circuits to model. Given this, a sensitivity analysis was performed to determine the optimal number of clusters, k, or number of representative circuits. This was determined to be k = 30 [as actually performed, k = 8 for the rural circuits, k = 5 for the

Figure 2.4.1
Urban Clusters, 16/12kV only

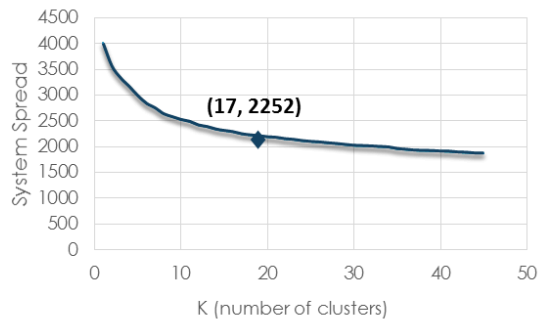


Figure 2.4.2
Urban Clusters, 4/2.4kV only

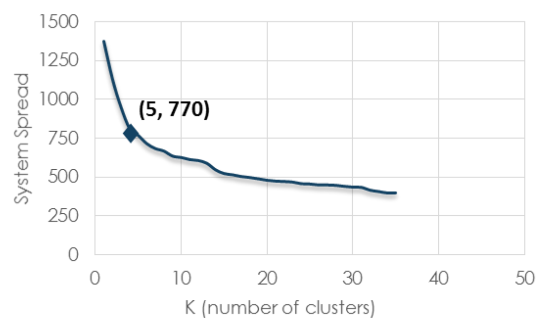
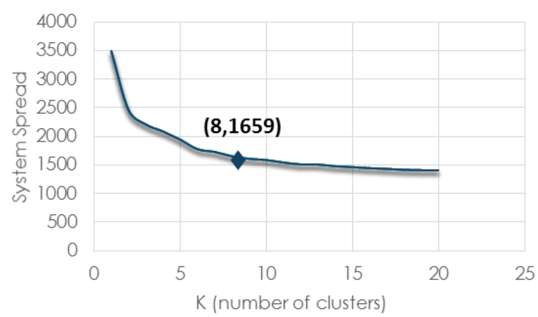


Figure 2.4.3
Rural Clusters



2-4kV urban circuits, and k = 17 for the 12-16kV urban circuits]. However, three of these 30 circuits were removed from the project due to their small representation of the SCE territory and the significant time requirements required to complete each additional model. This is discussed in more detail in section 4-GridLAB-D Model of Representative Circuits. **Thus, a set of 27 circuits are modeled out of 30 (k clusters) representative circuits initially chosen**.

Increasing k, or number of representative circuits, would ultimately increase the accuracy of each RC as a representative of other circuits. This is because a larger k means that a greater number of clusters are available to fill the 17-dimensional vector space, and therefore, each cluster will be smaller on average. With a smaller cluster, the average distance between any given circuit in a cluster and that cluster's centroid will be less; therefore, the set of circuits in that cluster will be more accurately represented by the circuit nearest the centroid. We refer to this "average distance" as the "system spread." Having a minimal system spread would optimize the accuracy of each representative model.

However, minimizing the system spread by increasing k clusters comes at a cost, namely, the additional time and effort required to build out circuit models for a greater number of circuits. This temporal cost of creating models is significant. As was shown by the sensitivity study and reproduced in **Figures 2.4.1 – 2.4.3**, there are diminishing marginal returns in system spread minimization for each additional cluster. The number of representative circuits was heuristically chosen based on these sensitivity curves. The aim was to determine a number of representative circuits, or k clusters, that would balance the accuracy of representation and the time and effort required to represent these circuits through creating models for each k circuit. This point lies between where each additional cluster yields dramatic improvements in system spread (accuracy of the representation) and where additional clusters yield little in the way of system spread improvements.

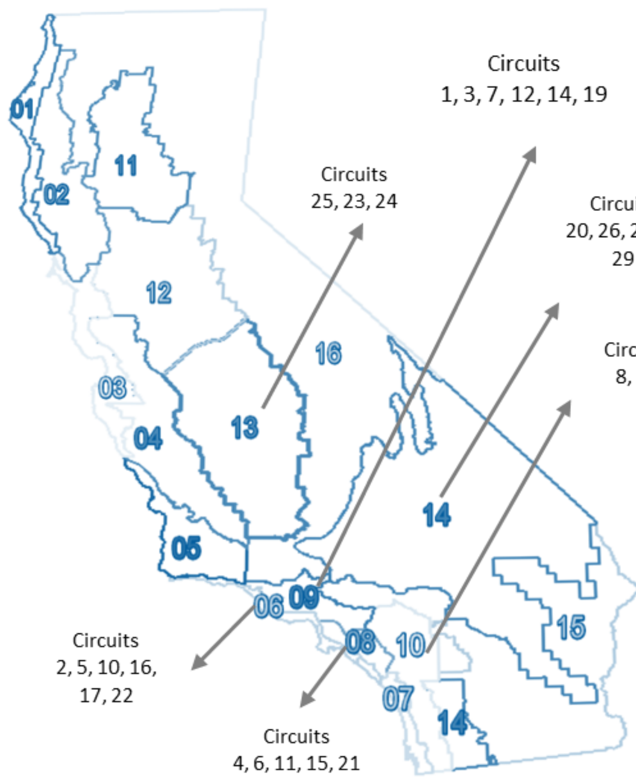
3 CHARACTERISTICS OF REPRESENTATIVE CIRCUITS

3.1 OVERVIEW OF REPRESENTATIVE CIRCUITS

The physical and demographic characteristics of the representative circuits (RCs) are discussed in this section. A summary of the representative circuits is tabulated in **Table 3.1**. The range of circuits represented by any one RC is [27 – 301] or [1% - 7%] of SCE circuits. In total, the RCs represent 3,982 circuits or 95% of SCE territory. These circuits spread through SCE's territory, in the various climate zones of California. **Figure 3.1** shows an illustration of where the representative circuits lie in respect to the California Climate Zones[4]. Climate zone is one of the highest weighted factors in the clustering methodology used to determine the representative circuits, as climate greatly affects the HVAC load.

Figure 3.1

Representation of California Climate Zones



Note that because of the initial k= 30 clusters, the circuits were numbered from 1 to 30. However, as mentioned in section 2, there were 3 of these 30 RCs that were removed from the project. To keep consistent with the models and numbering, the circuits IDs are left as they were. In summary, **there are a total of 27 RCs**, but the data presented here will not include circuits # 9, 18, or 30.

3.2 CUSTOMER DEMOGRAPHICS CONSIDERED IN CREATING MODELS

There are many customer characteristics that are considered in building the models of the representative circuits. These characteristics include customer type (residential, commercial, industrial, agricultural), energy consumption of the customer, geographic type (urban, suburban, second city, country), life-stage (young, family, mature), and socioeconomic class of residential customers. The representative circuits encompass a range of energy consumption by customer type, as well as a range of customer type

[4] more information on the climate zones can be found at: http://www.energy.ca.gov/maps/renewable/building_climate_zones.html

Table 3.1						
Circuit	# of SCE circuits represented	% of SCE circuits represented	Peak Loading	Existing Installed PV Capacity	Climate Zone	Customer Count
#1	132	3%	Medium	Low	9	High
#2	97	2%	Medium	Low	6	Low
#3	216	5%	High	Medium	9	High
#4	211	5%	High	Medium	8	High
#5	118	3%	Medium	Low	6	Medium
#6	211	5%	Medium	Low	8	High
#7	153	4%	Medium	Medium	9	Medium
#8	148	4%	Medium	Low	10	High
#10	122	3%	Medium	Low	6	Medium
#11	91	2%	Medium	Low	8	Medium
#12	157	4%	High	Medium	9	High
#13	143	3%	High	Low	10	High
#14	104	2%	High	Low	9	High
#15	139	3%	Medium	Low	8	Medium
#16	133	3%	High	Medium	6	High
#17	111	3%	Medium	Low	6	Medium
#19	301	7%	Low	Low	9	Medium
#20	36	1%	Low	Low	14	Medium
#21	252	6%	Low	Low	8	High
#22	178	4%	Medium	Low	6	High
#23	224	5%	Medium	Low	13	High
#24	171	4%	Medium	Low	13	Medium
#25	93	2%	Low	Low	13	Low
#26	64	2%	Low	Low	14	Medium
#27	106	3%	Low	Low	14	Medium
#28	107	3%	Medium	High	14	High
#29	164	4%	Medium	Low	14	High
Total	**3982**	**95%**				

Values used:	Peak Loading (MVA)	PV Capacity (kW)	Customer Count
low	≤ 2	≤ 100	≤ 100
medium	8-Feb	100 - 1000	100 - 900
high	≥ 8	≥ 1000	≥ 900

distribution. The customer count breakdown and energy breakdown based on customer type are given in **Appendix Table 3.2.**

Additionally, understanding the customer demographics is necessary in order to build the behind-the-meter load models in GridLAB-D. When creating these models, the results are calibrated to SCE's customer energy consumption data. As part of the calibration process, the life-stage, socioeconomic class, and geography type are used by the engineers to guide their assumptions on the energy consumption behaviors of the customers. This data is given in **Appendix Table 3.3** for each of the representative circuits. Note that Circuits 2 & 11 are mostly commercial and therefore do not have applicable values for Appendix Table 3.3.

3.3 Physical Characteristics

As discussed in the clustering methodology, the RCs represent various physical characteristics of SCE circuits. Presented here are summaries of the more important physical characteristics. A detailed list of characteristics for each representative circuit is given in **Appendix Table 3.3.1.**

Figure 3.3.1

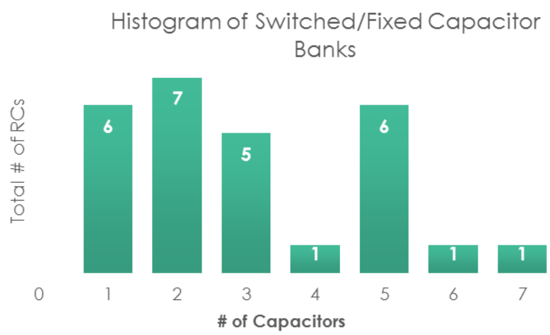


Figure 3.3.2

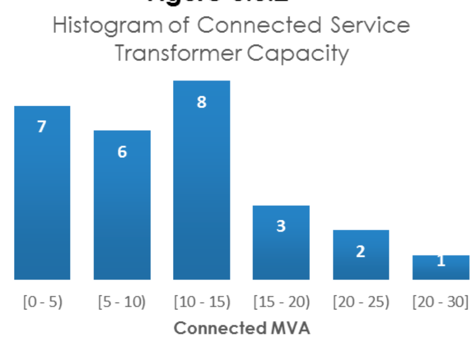


Figure 3.3.3

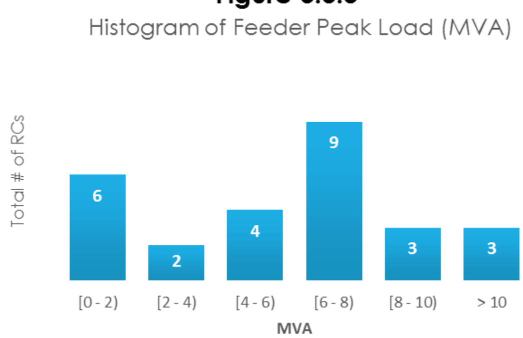


Figure 3.3.4

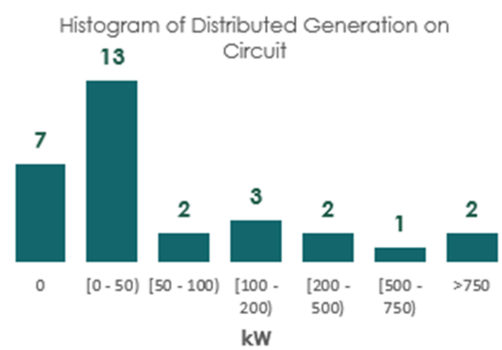


Table 3.3 Nominal Voltages of Representative Circuits		
Nominal Voltage	# of Circuits	Circuits
4 kV	6	19, 20, 21, 22, 25, 26
12 kV	16	2, 4, 6, 7, 8, 10, 11, 12, 13, 15, 17, 23, 24, 27, 28, 29
16 kV	5	1, 3, 5, 14, 16

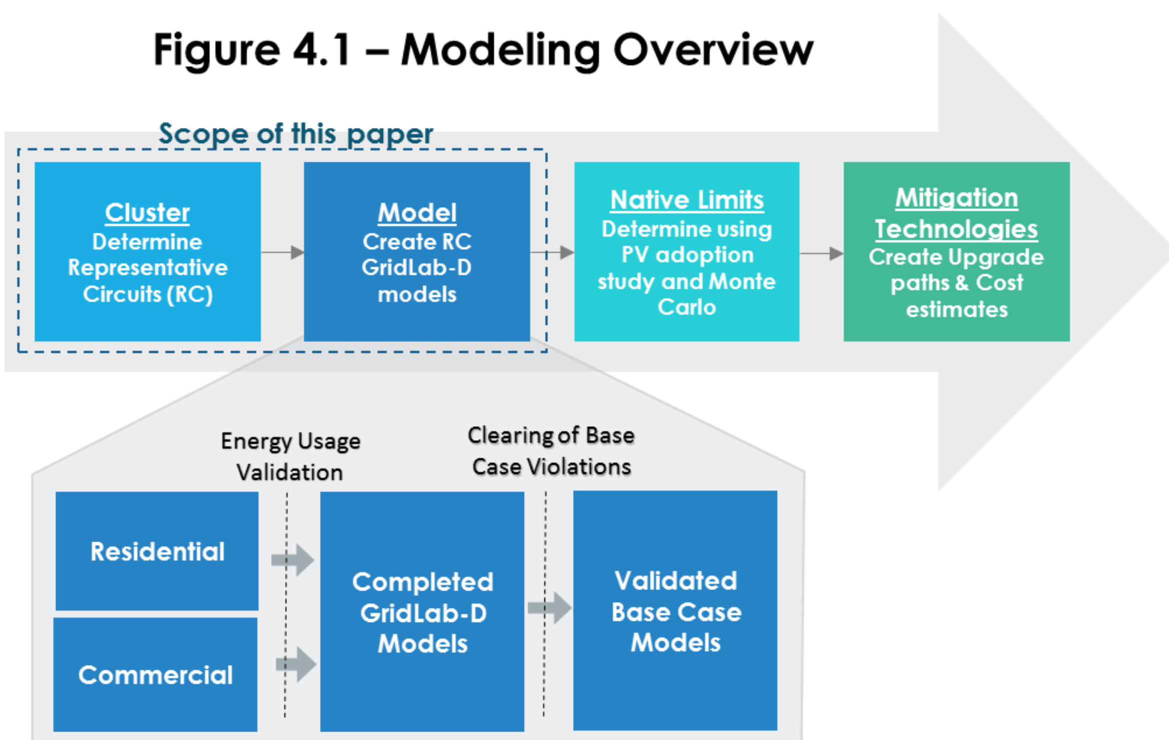
4 MODEL CREATION

The circuit models were created in GridLAB-D, an open-source software created by Pacific Northwest National Lab. It is a scripted software with no user interface. One of the goals of this CSI RD&D Solicitation #4 project is to provide a graphical user interface (GUI) and an online platform for creating these models in Qado Energy's GridUnity Platform. The details of the GridUnity Platform will not be discussed in this paper.

Figure 4.1– Modeling Overview illustrates the model building sequence. Residential and Commercial models were created for these two distinct set of customers. These models were then incorporated into a connectivity model that encompasses the entire representative feeder. These models were then validated against the aggregate usage across the feeder for 4 weeks of the year (one week per season). Then, these models were cleared of violations to create a final base case model.

As with any tool, GridLAB-D has its advantages and disadvantages. The most significant advantage of GridLAB-D over other modeling software is that it allows for behind-the-meter load modeling. This granularity allows for the modeling of distinct loads in GridLAB-D, such as HVAC, lights, plug loads, pool pumps, cooking ovens, PV, and electric vehicle charging. This is particularly useful when simulating demand response events in the model. Since demand response is one of the mitigation technologies investigated in this project, building the models in GridLAB-D was a necessity at the time of project

Figure 4.1 – Modeling Overview



formation. The largest disadvantage of the software is its lack of user interface, which makes the modeling process more time intensive and more prone to errors.

The GridLAB-D models for this project were derived from existing models created by SCE within the CYME software. These CYME connectivity models were converted into GridLAB-D models. However, there were many issues that occurred when mapping the customers to their appropriate transformers in the model. The existing transformer to load model in CYME is not accurate and is a known roadblock to the progress of creating accurate connectivity models to use in power flow and distributed energy resource (DER) analysis. A separate effort at SCE is looking to resolve this issue by creating a transformer to load model mapping algorithm using metering data. This algorithm is still in production at the time of writing and was not used in the GridLAB-D model building process.

Overall, the modeling process was a lengthy and time-consuming one. Manual changes to the customer data for mapping to the connectivity model needed to be made. Outdated data for both customers and distribution system structures and devices led to inconsistent data that also needed to be manually changed. Some of these issues include but are not limited to: missing secondary transformers from the CYME model, transformers with incorrect sizing and properties, and transformers with inconsistent naming that do not match what is provided in the customer data. Additionally, the nature of the model building process was an iterative one. Each residential model was calibrated to its customer usage and each full model was validated against the circuit consumption from SCADA data. A more detailed discussion of this iterative process for the residential model can be found in a separate publication for this project on Residential Models[5].

4.1 Summary of Residential & Commercial Models

Residential

GridLAB-D models were created for each residential customer on each representative circuit. These granular models included load models for HVAC, lights, plug loads, pool pumps, cooking ovens, and PV systems, if any on the house. The customer data was matched to tax assessor data for that customer. This information gave a holistic view of the customer characteristics, as discussed in section 3.2 Customer Demographics Considered in Creating Models. Load schedules for the GridLAB-D models were created based on the demographics of the customers. A more detailed discussion of this iterative process for the residential model can be found in a separate publication for this project on Residential Model.[5]

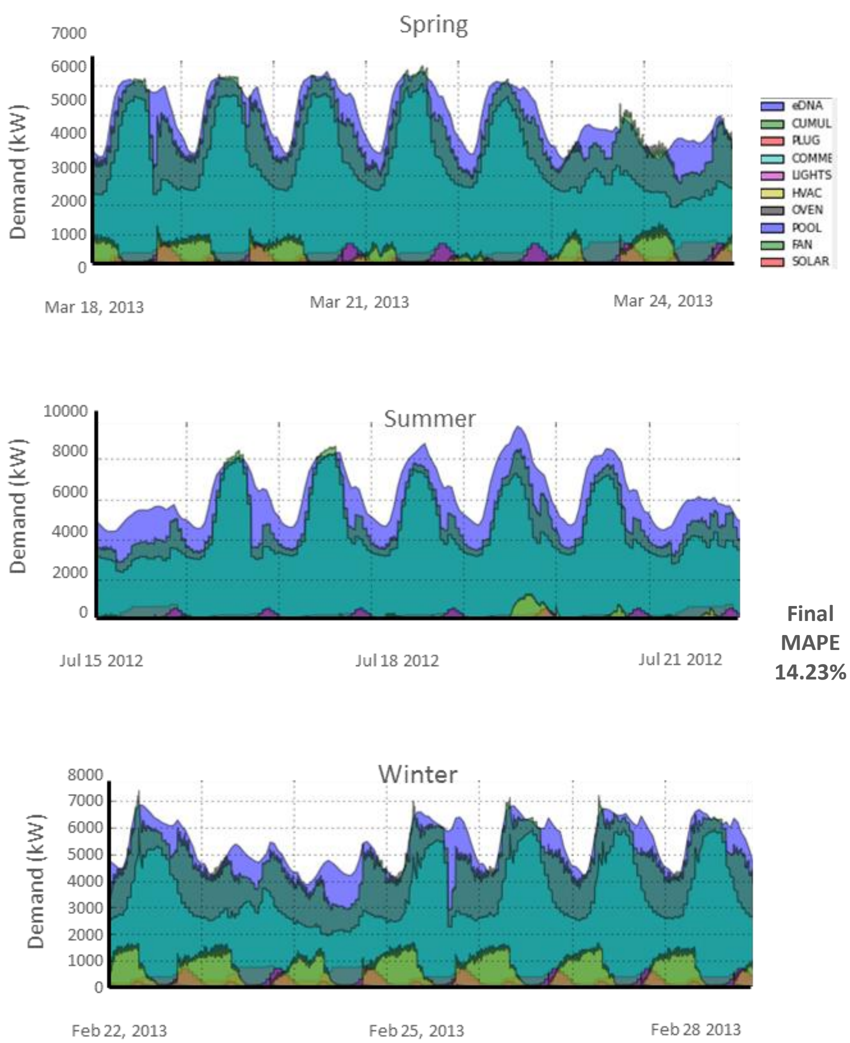
Commercial

Unlike the heuristic nature of the models of residential customers, the nature of the commercial customers was statistical. The statistical model of the energy usage of commercial customers accounted for temperature, hour of the day, season, and day of the week. This allows for a separation between the usages due to heating and cooling from the intrinsic usage of the customers. For more information on the details of the statistical commercial models, please see the separate publication for this project on Commercial Models.[5]

[5] These future publications will can be found at http://www.calsolarresearch.ca.gov/funded-projects/111-advanced-distribution-analytic-services-enabling-high-penetration-solar-pv

4.2 Validation Base Case Usage Models

Figure 4.2.1 Final Validation Load Shapes and MAPE



Once the model was fully expanded to include connectivity of all costumers (residential and commercial), then the model was validated against SCADA data for four weeks of the year, one week per season. The team aimed to reach a mean absolute percent error (MAPE) of less than 10% throughout all four weeks. However, achieving a MAPE of less than 10% was difficult to achieve and required an extensive amount of time, due to the heuristic nature of the residential load models, the statistical approximation of the commercial loads, and the slow iterative process of changing the model files in batch. For these reasons, it was decided to accept a MAPE of 17% or less. Even with this more relaxed validation criteria, the full model was able to achieve reasonably similar shapes to the SCADA data, including capturing the seasonal peak and load fluctuations. For example, see **Figure 4.2.1 Final Validation Load Shapes and MAPE,** which shows final validation of spring, summer and winter peak weeks of circuit #16. The final MAPE for all four seasons was 14.23%.

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4.3 CLEARING VIOLATIONS ON BASE CASES

When SCE developed the circuit models for the 30 prototypical circuits it was with the understanding that these models represented feeders that were operating within acceptable limits. As a result, it is necessary for all of the base case circuit models to run without violating any limits. This chapter discusses the changes/corrections that PNNL made to the original SCE circuit models so that their base case simulations would run with no violations.

Operating Limits to Determine the Circuit Native PV Limits

As part of the project a set of operating limits was determined that are applied to all feeders. These limits determine the level at which no additional solar PV can be added to a circuit without upgrading one or more components. The operational limits, as defined by SCE, are:

1) Limit: Exceeding any device thermal limit, 100% rating (200% for secondary service transformers)
2) Limit: Any instantaneous voltage over 1.10 p.u. at any point in the system.
3) Limit: ANSI C84.1: 0.95>V>1.05 p.u. for 5 minutes at >10% of meters in the system.
4) Warning: Any reverse power that exceeds 50% of the minimum trip setting of the substation breaker or a recloser. (Requires analysis of protection coordination)
5) Limit: Any reverse power that exceeds 75% of the minimum trip setting of the substation breaker or a recloser.
6) Limit: any voltage change at a PV point of common coupling that is greater than 5% between two one-minute simulation time-steps. (Adapted from the Voltage fluctuation design limits, May 1994)
7) Limit: 3V drop or 5V rise across the secondary distribution system (Defined as the high side of the service transformer to the customer meter)
8) Limit: Average circuit power factor <0.85.
9) Limit: Nameplate solar minus native load exceeds 10 MVA for a 12 kV feeder, 13 MVA for a 16 kV feeder, or 32 MVA for a 33 kV feeder. E.g. a 12kV feeder with 8 MVA of load can support 18 MVA.
10) Limit: Total short circuit contribution from downstream generation not to exceed 87.5% of substation circuit breaker rating

To more easily evaluate these ten limits a new "violation object" was coded into GridLAB-D. The purpose of the violation object is to reduce the need to post process simulation results. This is especially important for the outputs of time-series simulations where there can be a substantial amount of output data. The violation object evaluates the first eight of the ten violations. Violation 9 can be determined from the base model and violation 10 will be handled separately with GridUnity.

The violation recorder produces two files for each simulation that is run. The first is a log of all violations that occur during the simulation. This file lists all violations at all time-steps so it is possible for a single object to generate thousands of violations. For example, the load on a conductor may exceed the thermal rating for 135 minutes, generating a violation at each one-minute time-step. The second file is a summary of the total number of violations that occur for each of the eight violations.

Initial Base Case Violations

Of the 30 feeders that SCE is working with, 15 were sent to PNNL for validation. The 15 feeders were: 2, 3, 4, 5, 6, 7, 8, 11, 17, 19, 21, 22, 23, 24, and 29. When these 15 circuits were initially run it was apparent that there were a number of problems that were common across all circuits. In order to run the 15 circuit models, and to properly apply the limits of 4.3, it was necessary to make a number of changes/corrections. A Python script was developed that made the following changes to all circuit models that SCE sent to PNNL:

1) The values of Geometric Mean Radium (GMR) for all commercial building secondary service drops were changed from inches to feet. This corrected a unit's error in the original models that was causing voltage problems.
2) The simulation time step was changed from 300 seconds to 60 seconds. This change ensured the proper time step of simulation.
3) Ampacity ratings were added to all overhead and underground conductors. These were added to determine if conductors and/or transformers were overloaded at any point during the simulation.
4) Inclusion of additional solar. This value was zero for the examination of the base cases, but will be used for later work examining higher penetration levels of PV.
5) The violation object was added so that when the simulation was run the occurrence of violations from section 4.3 would be aggregated.
6) The secondary service transformers "to" nodes were changed from "node" objects to "triplex node" objects. This corrected topological errors in the construction of the original models.
7) The nominal voltage of nodes was corrected to actual nominal, and not average values;
    a. 2,309.47 V to 2,400 V
    b. 6,928.41 V to 7,200 V
    c. 9,237.88 V to 9,600 V
8) The nominal voltage of capacitors were correct to actual nominal, and not average values:
    a. 2,309.47 V to 2,400 V
    b. 6,928.41 V to 7,200 V
    c. 9,237.88 V to 9,600 V
9) Transformer primary voltages were correct to actual nominal, and not average values:
    a. 2,309.47 V to 2,400 V
    b. 6,928.41 V to 7,200 V
    c. 9,237.88 V to 9,600 V
10) The swing node voltage was changed from a constant value to a time-series value. This provides a more accurate time-series representation of the circuits voltage profile.

Comparison of Violation Summaries

Once the changes were made by using the Python script the simulations for each circuit were run. These simulations covered one week in each of the four seasons. With the exception of three circuits the simulations returned results that indicated that the circuits were currently exceeding their Native PV limit; the three circuits were 4, 19, and 22. Manual changes were then made to the feeders to clear the violations; these specific changes will be discussed in the next section. The summaries of the violations are provided in the appendix for each of the 15 circuit models, with values for pre and post manual changes. The outputs of the simulations run after the Python script are listed in the "Original" column and outputs of the simulations run after manual changes were made are listed in the "Corrected" column. The circuits are presented in the following order: 23, 19, 6, 11, 5, 24, 22, 4, 21, 29, 17, 7, 8, 2, and 3.

The purpose of Appendix B Tables 4.1 through 4.15 is to show that after the necessary manual changes were made, the individual circuit models indicated no violations. At this point the circuit models are considered to be accurate representations of those in actual operation.

Specific Changes to Clear Base Case Violations

In order to generate the simulation results in the "corrected" column of the tables in the Appendix, it was necessary to make a number of manual changes to the individual feeders. These changes represent adjustments that were required so that the models more accurately represent the actual operational circuits, which should not currently have any violations. For three circuits there were no manual changes that were required; the three circuits were 4, 19, and 22. The other 12 circuits required a varying degree of adjustments based on the number of violations. See Appendix B Table 4.16 for a summary of the changes made to each circuit model.

5 CONCLUSION

By using the various characteristics of SCE's distribution circuits to cluster the circuits, representative circuits were determined. A total of 27 representative circuits were chosen, however discussed in this paper are the highest ranked circuits, e.i. the circuits with the highest representation of SCE's territory. These representative models were then modeled in GridLAB-D. Discussed in this paper was the clustering methodology and the method of base case model creation. Base case models incorporate both residential and commercial customers. A set of violations and limits were defined and set to serve as criteria that must be met for a model to be considered a "base case".

The next step of the project is to run PV-adoption simulations on these base case models in order to determine the native limits of PV penetration of the feeders.

APPENDIX A

Table 3.3												
	Lifestage Breakdown (%)			Geographic Location Breakdown (%)				Socioeconomic Class Breakdown(%)				
RC #	Mature	Young	Family	Urban	Second City	Sub Urban	Country	Lower Class	Lower Middle Class	Uppper Middle Class	Upper Class
1	26	31	43	0	60	40	0	0	1	3	96
2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
3	2	30	68	0	0	29	71	0	0	22	78
4	27	29	44	36	0	64	0	0	13	35	52
5	0	16	84	0	91	9	0	0	1	86	13
6	44	29	27	91	0	9	0	0	0	19	81
7	36	41	23	97	0	3	0	0	0	3	97
8	0	100	0	0	0	100	0	0	0	100	0
10	38	48	14	27	0	73	0	0	32	41	27
11	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
12	0	100	0	0	0	100	0	0	0	0	100
13	25	6	69	0	100	0	0	0	32	64	4
14	24	2	74	100	0	0	0	0	76	21	3
15	0	100	0	0	0	100	0	0	0	100	0
16	32	57	11	0	0	100	0	50	24	19	7
17	0	78	22	0	0	100	0	0	78	0	22
19	35	46	19	32	0	68	0	1	21	35	43
20	25	51	24	0	100	0	0	0	97	3	0
21	26	7	67	99	0	1	0	0	72	7	21
22	59	31	10	0	0	100	0	0	0	19	81
23	36	20	44	0	94	6	0	0	14	65	21
24	44	18	38	0	0	0	100	9	58	21	12
25	79	14	7	0	0	21	79	43	43	14	0
26	0	100	0	0	0	100	0	0	0	100	0
27	0	100	0	0	0	100	0	0	0	100	0
28	35	25	40	0	0	100	0	0	55	42	3
29	3	18	79	0	91	9	0	0	0	20	80

Table 3.2								
	Customer Count Break-down (%)				Energy Make-Up (%)			
RC #	Commercial	Domestic	Industrial	Other	Commercial	Residential	Industrial	Agricultural
1	6	93	0	1	21	78	0	1
2	93	0	2	5	23	0	77	0
3	7	92	0	1	16	77	0	7
4	4	96	0	0	21	78	0	1
5	40	54	0	5	64	6	30	0
6	20	78	1	2	60	27	6	8
7	30	70	0	1	58	11	31	0
8	7	93	0	1	28	73	0	0
10	16	81	0	3	27	9	62	2
11	94	0	4	2	84	0	16	0
12	15	83	0	2	49	31	21	0
13	6	94	0	1	21	77	2	0
14	16	82	1	1	48	11	42	0
15	7	93	0	0	55	23	22	0
16	32	65	1	2	60	15	25	0
17	67	29	3	1	70	4	24	2
19	8	90	0	2	18	82	0	0
20	8	90	0	1	32	68	0	0
21	9	89	0	2	36	64	0	0
22	1	99	0	0	2	99	0	0
23	9	89	0	2	37	63	0	1
24	22	33	2	43	15	23	22	40
25	9	88	0	3	21	78	0	0
26	14	85	0	0	20	80	0	0
27	14	82	0	3	52	43	0	5
28	20	78	0	2	55	45	0	0
29	8	91	0	0	33	66	0	1

Table 3.3.1									
RC #	High/Low Voltage	Nominal voltage, kV	Total 3-ph ckt miles, mi	Total 2-ph and 1-ph miles, mi	# of line voltage regulators	# of switched/fixed capacitor banks	Conservation voltage reduction?	Connected service transformer capacity, kVA	Feeder peak load, kVA (calculated)
1	66/16	16.34	6.6	7.8	0	3	No	9,625	7,097
2	66/12	12	9.2	0.5	0	4	No	14,360	5,783
3	66/16	16.34	6.5	12.3	0	2	No	13,940	11,106
4	66/12	12	9.5	19.0	0	5	No	12,775	8,846
5	66/16	16.34	4.0	0.2	0	2	No	9,850	5,690
6	66/12	12	8.3	4.9	0	3	No	12,984	7,016
7	66/12	12	8.6	2.4	0	2	No	9,775	6,231
8	66/12	12	6.8	6.8	0	5	No	8,769	6,077
10	66/12	12	9.5	1.2	0	5	No	17,477	7,952
11	66/12	12	7.6	0.0	0	2	No	15,808	5,971
12	66/12	12	12.7	6.4	0	5	No	21,170	9,857
13	66/12	12	8.3	12.9	0	5	No	12,663	8,164
14	66/16	16.34	6.9	0.6	0	3	No	15,020	10,204
15	66/12	12	2.6	1.0	0	2	No	8,208	4,082
16	66/16	16.34	14.2	5.3	0	5	No	29,155	11,055
17	66/12	12	7.7	0.0	0	3	No	24,340	7,918
19	66/4.16	4.16	3.5	1.0	0	3	No	2,523	1,751
20	33/4.8	4.8	2.6	0.5	0	1	No	1,123	590
21	16/4.16	4.16	3.2	1.7	0	1	No	2,220	1,579
22	16/4.16	4.16	2.6	5.1	0	1	No	2,760	2,097
23	66/12	12	5.5	9.4	0	6	No	13,913	7,923
24	66/12	12	11.9	1.4	0	1	No	7,631	2,951
25	12/4.16	4.16	3.4	0.3	0	1	No	695	707
26	33/4.16	4.16	1.9	4.8	0	2	No	2,408	1,017
27	33/12	12	6.7	7.1	0	2	No	4,545	1,820
28	66/12	12	7.3	6.9	0	7	No	14,859	7,189
29	115/12	12	10.3	7.9	0	1	No	12,910	7,081

Table 3.3.2							
Rep Circuit Num	Nominal voltage, kV	Feeder peak load, kVA	Existing PV capacity installed, kW	Rep Circuit Num	Nominal voltage, kV	Feeder peak load, kVA	Existing PV capacity installed, kW
1	16	7097	35	16	16	11055	134
2	12	5783	0	17	12	7918	0
3	16	11106	219	19	4	1751	48
4	12	8846	110	20	5	590	0
5	16	5690	4	21	4	1579	0
6	12	7016	9	22	4	2097	44
7	12	6231	602	23	12	7923	22
8	12	0	0	24	12	2951	28
10	12	7952	19	25	4	707	0
11	12	5971	24	26	4	1017	0
12	12	9857	226	27	12	1820	48
13	12	8164	38	28	12	7189	2158
14	16	10204	65	29	12	7081	30
15	12	4082	0				

APPENDIX B

Table 4.1: Circuit 23 violations before and after manual changes

23					
Summer			Fall		
	Original	Corrected		Original	Corrected
VIOLATION1 TOTAL	71,546	0	VIOLATION1 TOTAL	39,764	0
TRANSFORMER (1 of 269 transformers in violation)	120	0	TRANSFORMER (0 of 269 transformers in violation)	0	0
OVERHEAD LINE (8 of 290 lines in violation)	71,426	0	OVERHEAD LINE (6 of 290 lines in violation)	39,764	0
UNDERGROUND LINE (0 of 174 lines in violation)	0	0	UNDERGROUND LINE (0 of 174 lines in violation)	0	0
TRIPLEX LINE (0 of 1254 lines in violation)	0	0	TRIPLEX LINE (0 of 1254 lines in violation)	0	0
VIOLATION2 TOTAL	0	0	VIOLATION2 TOTAL	0	0
NODE (0 of 640 nodes in violation)	0	0	NODE (0 of 640 nodes in violation)	0	0
TRIPLEX NODE (0 of 222 nodes in violation)	0	0	TRIPLEX NODE (0 of 222 nodes in violation)	0	0
TRIPLEX METER (0 of 1268 meters in violation)	0	0	TRIPLEX METER (0 of 1268 meters in violation)	0	0
COMMERCIAL METER (0 of 104 meters in violation)	0	0	COMMERCIAL METER (0 of 104 meters in violation)	0	0
VIOLATION3 TOTAL	1,753	0	VIOLATION3 TOTAL	23	0
TRIPLEX NODE (0 of 222 nodes in violation)	0	0	TRIPLEX NODE (0 of 222 nodes in violation)	0	0
TRIPLEX METER (0 of 1268 meters in violation)	0	0	TRIPLEX METER (0 of 1268 meters in violation)	0	0
COMMERCIAL METER (3 of 104 meters in violation)	1,753	0	COMMERCIAL METER (1 of 104 meters in violation)	23	0
VIOLATION4 TOTAL	0	0	VIOLATION4 TOTAL	0	0
VIOLATION5 TOTAL	0	0	VIOLATION5 TOTAL	0	0
VIOLATION6 TOTAL (0 of 14 inverters in violation)	0	0	VIOLATION6 TOTAL (0 of 14 inverters in violation)	0	0
VIOLATION7 TOTAL	23,135	0	VIOLATION7 TOTAL	6,983	0
TRIPLEX METER (0 of 1268 meters in violation)	0	0	TRIPLEX METER (0 of 1268 meters in violation)	0	0
COMMERCIAL METER (3 of 104 meters in violation)	23,135	0	COMMERCIAL METER (2 of 104 meters in violation)	6,983	0
VIOLATION8 TOTAL	0	0	VIOLATION8 TOTAL	0	0
Spring			Winter		
	Original	Corrected		Original	Corrected
VIOLATION1 TOTAL	33,430	0	VIOLATION1 TOTAL	31,777	0
TRANSFORMER (0 of 269 transformers in violation)	0	0	TRANSFORMER (0 of 269 transformers in violation)	0	0
OVERHEAD LINE (6 of 290 lines in violation)	33,430	0	OVERHEAD LINE (4 of 290 lines in violation)	31,777	0
UNDERGROUND LINE (0 of 174 lines in violation)	0	0	UNDERGROUND LINE (0 of 174 lines in violation)	0	0
TRIPLEX LINE (0 of 1254 lines in violation)	0	0	TRIPLEX LINE (0 of 1254 lines in violation)	0	0
VIOLATION2 TOTAL	0	0	VIOLATION2 TOTAL	0	0
NODE (0 of 640 nodes in violation)	0	0	NODE (0 of 640 nodes in violation)	0	0
TRIPLEX NODE (0 of 222 nodes in violation)	0	0	TRIPLEX NODE (0 of 222 nodes in violation)	0	0
TRIPLEX METER (0 of 1268 meters in violation)	0	0	TRIPLEX METER (0 of 1268 meters in violation)	0	0
COMMERCIAL METER (0 of 104 meters in violation)	0	0	COMMERCIAL METER (0 of 104 meters in violation)	0	0
VIOLATION3 TOTAL	1,134	0	VIOLATION3 TOTAL	0	0
TRIPLEX NODE (0 of 222 nodes in violation)	0	0	TRIPLEX NODE (0 of 222 nodes in violation)	0	0
TRIPLEX METER (0 of 1268 meters in violation)	0	0	TRIPLEX METER (0 of 1268 meters in violation)	0	0
COMMERCIAL METER (2 of 104 meters in violation)	1,134	0	COMMERCIAL METER (0 of 104 meters in violation)	0	0
VIOLATION4 TOTAL	0	0	VIOLATION4 TOTAL	0	0
VIOLATION5 TOTAL	0	0	VIOLATION5 TOTAL	0	0
VIOLATION6 TOTAL (0 of 14 inverters in violation)	0	0	VIOLATION6 TOTAL (0 of 14 inverters in violation)	0	0
VIOLATION7 TOTAL	12,575	0	VIOLATION7 TOTAL	4,660	0
TRIPLEX METER (0 of 1268 meters in violation)	0	0	TRIPLEX METER (0 of 1268 meters in violation)	0	0
COMMERCIAL METER (2 of 104 meters in violation)	12,575	0	COMMERCIAL METER (2 of 104 meters in violation)	4,660	0
VIOLATION8 TOTAL	0	0	VIOLATION8 TOTAL	0	0

Table 4.2: Circuit 19 violations before and after manual changes

19					
Summer			Fall		
	Original	Corrected		Original	Corrected
VIOLATION1 TOTAL	0	0	VIOLATION1 TOTAL	0	0
TRANSFORMER (0 of 71 transformers in violation)	0	0	TRANSFORMER (0 of 71 transformers in violation)	0	0
OVERHEAD LINE (0 of 141 lines in violation)	0	0	OVERHEAD LINE (0 of 141 lines in violation)	0	0
UNDERGROUND LINE (0 of 8 lines in violation)	0	0	UNDERGROUND LINE (0 of 8 lines in violation)	0	0
TRIPLEX LINE (0 of 498 lines in violation)	0	0	TRIPLEX LINE (0 of 498 lines in violation)	0	0
VIOLATION2 TOTAL	0	0	VIOLATION2 TOTAL	0	0
NODE (0 of 147 nodes in violation)	0	0	NODE (0 of 147 nodes in violation)	0	0
TRIPLEX NODE (0 of 53 nodes in violation)	0	0	TRIPLEX NODE (0 of 53 nodes in violation)	0	0
TRIPLEX METER (0 of 504 meters in violation)	0	0	TRIPLEX METER (0 of 504 meters in violation)	0	0
COMMERCIAL METER (0 of 36 meters in violation)	0	0	COMMERCIAL METER (0 of 36 meters in violation)	0	0
VIOLATION3 TOTAL	14	14	VIOLATION3 TOTAL	0	0
TRIPLEX NODE (0 of 53 nodes in violation)	0	0	TRIPLEX NODE (0 of 53 nodes in violation)	0	0
TRIPLEX METER (10 of 504 meters in violation)	14	14	TRIPLEX METER (0 of 504 meters in violation)	0	0
COMMERCIAL METER (0 of 36 meters in violation)	0	0	COMMERCIAL METER (0 of 36 meters in violation)	0	0
VIOLATION4 TOTAL	0	0	VIOLATION4 TOTAL	0	0
VIOLATION5 TOTAL	0	0	VIOLATION5 TOTAL	0	0
VIOLATION6 TOTAL (0 of 6 inverters in violation)	0	0	VIOLATION6 TOTAL (0 of 6 inverters in violation)	0	0
VIOLATION7 TOTAL	0	0	VIOLATION7 TOTAL	0	0
TRIPLEX METER (0 of 504 meters in violation)	0	0	TRIPLEX METER (0 of 504 meters in violation)	0	0
COMMERCIAL METER (0 of 36 meters in violation)	0	0	COMMERCIAL METER (0 of 36 meters in violation)	0	0
VIOLATION8 TOTAL	0	0	VIOLATION8 TOTAL	0	0
Spring			Winter		
	Original	Corrected		Original	Corrected
VIOLATION1 TOTAL	0	0	VIOLATION1 TOTAL	0	0
TRANSFORMER (0 of 71 transformers in violation)	0	0	TRANSFORMER (0 of 71 transformers in violation)	0	0
OVERHEAD LINE (0 of 141 lines in violation)	0	0	OVERHEAD LINE (0 of 141 lines in violation)	0	0
UNDERGROUND LINE (0 of 8 lines in violation)	0	0	UNDERGROUND LINE (0 of 8 lines in violation)	0	0
TRIPLEX LINE (0 of 498 lines in violation)	0	0	TRIPLEX LINE (0 of 498 lines in violation)	0	0
VIOLATION2 TOTAL	0	0	VIOLATION2 TOTAL	0	0
NODE (0 of 147 nodes in violation)	0	0	NODE (0 of 147 nodes in violation)	0	0
TRIPLEX NODE (0 of 53 nodes in violation)	0	0	TRIPLEX NODE (0 of 53 nodes in violation)	0	0
TRIPLEX METER (0 of 504 meters in violation)	0	0	TRIPLEX METER (0 of 504 meters in violation)	0	0
COMMERCIAL METER (0 of 36 meters in violation)	0	0	COMMERCIAL METER (0 of 36 meters in violation)	0	0
VIOLATION3 TOTAL	0	0	VIOLATION3 TOTAL	0	0
TRIPLEX NODE (0 of 53 nodes in violation)	0	0	TRIPLEX NODE (0 of 53 nodes in violation)	0	0
TRIPLEX METER (0 of 504 meters in violation)	0	0	TRIPLEX METER (0 of 504 meters in violation)	0	0
COMMERCIAL METER (0 of 36 meters in violation)	0	0	COMMERCIAL METER (0 of 36 meters in violation)	0	0
VIOLATION4 TOTAL	0	0	VIOLATION4 TOTAL	0	0
VIOLATION5 TOTAL	0	0	VIOLATION5 TOTAL	0	0
VIOLATION6 TOTAL (0 of 6 inverters in violation)	0	0	VIOLATION6 TOTAL (0 of 6 inverters in violation)	0	0
VIOLATION7 TOTAL	0	0	VIOLATION7 TOTAL	0	0
TRIPLEX METER (0 of 504 meters in violation)	0	0	TRIPLEX METER (0 of 504 meters in violation)	0	0
COMMERCIAL METER (0 of 36 meters in violation)	0	0	COMMERCIAL METER (0 of 36 meters in violation)	0	0
VIOLATION8 TOTAL	0	0	VIOLATION8 TOTAL	0	0

Table 4.3: Circuit 6 violations before and after manual changes

6					
Summer			Fall		
	Original	Corrected		Original	Corrected
VIOLATION1 TOTAL	41,033	0	VIOLATION1 TOTAL	31,181	0
TRANSFORMER (0 of 356 transformers in violation)	0	0	TRANSFORMER (0 of 356 transformers in violation)	0	0
OVERHEAD LINE (5 of 444 lines in violation)	41,033	0	OVERHEAD LINE (6 of 444 lines in violation)	31,181	0
UNDERGROUND LINE (0 of 221 lines in violation)	0	0	UNDERGROUND LINE (0 of 221 lines in violation)	0	0
TRIPLEX LINE (0 of 1291 lines in violation)	0	0	TRIPLEX LINE (0 of 1291 lines in violation)	0	0
VIOLATION2 TOTAL	0	0	VIOLATION2 TOTAL	0	0
NODE (0 of 698 nodes in violation)	0	0	NODE (0 of 698 nodes in violation)	0	0
TRIPLEX NODE (0 of 262 nodes in violation)	0	0	TRIPLEX NODE (0 of 262 nodes in violation)	0	0
TRIPLEX METER (0 of 1296 meters in violation)	0	0	TRIPLEX METER (0 of 1296 meters in violation)	0	0
COMMERCIAL METER (0 of 298 meters in violation)	0	0	COMMERCIAL METER (0 of 298 meters in violation)	0	0
VIOLATION3 TOTAL	0	0	VIOLATION3 TOTAL	0	0
TRIPLEX NODE (0 of 262 nodes in violation)	0	0	TRIPLEX NODE (0 of 262 nodes in violation)	0	0
TRIPLEX METER (0 of 1296 meters in violation)	0	0	TRIPLEX METER (0 of 1296 meters in violation)	0	0
COMMERCIAL METER (0 of 298 meters in violation)	0	0	COMMERCIAL METER (0 of 298 meters in violation)	0	0
VIOLATION4 TOTAL	0	0	VIOLATION4 TOTAL	0	0
VIOLATION5 TOTAL	0	0	VIOLATION5 TOTAL	0	0
VIOLATION6 TOTAL (0 of 5 inverters in violation)	0	0	VIOLATION6 TOTAL (0 of 5 inverters in violation)	0	0
VIOLATION7 TOTAL	0	0	VIOLATION7 TOTAL	0	0
TRIPLEX METER (0 of 1296 meters in violation)	0	0	TRIPLEX METER (0 of 1296 meters in violation)	0	0
COMMERCIAL METER (0 of 298 meters in violation)	0	0	COMMERCIAL METER (0 of 298 meters in violation)	0	0
VIOLATION8 TOTAL	229	235	VIOLATION8 TOTAL	209	212
Spring			Winter		
	Original	Corrected		Original	Corrected
VIOLATION1 TOTAL	30,836	0	VIOLATION1 TOTAL	25,925	0
TRANSFORMER (0 of 356 transformers in violation)	0	0	TRANSFORMER (0 of 356 transformers in violation)	0	0
OVERHEAD LINE (3 of 444 lines in violation)	30,836	0	OVERHEAD LINE (3 of 444 lines in violation)	25,925	0
UNDERGROUND LINE (0 of 221 lines in violation)	0	0	UNDERGROUND LINE (0 of 221 lines in violation)	0	0
TRIPLEX LINE (0 of 1291 lines in violation)	0	0	TRIPLEX LINE (0 of 1291 lines in violation)	0	0
VIOLATION2 TOTAL	0	0	VIOLATION2 TOTAL	0	0
NODE (0 of 698 nodes in violation)	0	0	NODE (0 of 698 nodes in violation)	0	0
TRIPLEX NODE (0 of 262 nodes in violation)	0	0	TRIPLEX NODE (0 of 262 nodes in violation)	0	0
TRIPLEX METER (0 of 1296 meters in violation)	0	0	TRIPLEX METER (0 of 1296 meters in violation)	0	0
COMMERCIAL METER (0 of 298 meters in violation)	0	0	COMMERCIAL METER (0 of 298 meters in violation)	0	0
VIOLATION3 TOTAL	0	0	VIOLATION3 TOTAL	0	0
TRIPLEX NODE (0 of 262 nodes in violation)	0	0	TRIPLEX NODE (0 of 262 nodes in violation)	0	0
TRIPLEX METER (0 of 1296 meters in violation)	0	0	TRIPLEX METER (0 of 1296 meters in violation)	0	0
COMMERCIAL METER (0 of 298 meters in violation)	0	0	COMMERCIAL METER (0 of 298 meters in violation)	0	0
VIOLATION4 TOTAL	0	0	VIOLATION4 TOTAL	0	0
VIOLATION5 TOTAL	0	0	VIOLATION5 TOTAL	0	0
VIOLATION6 TOTAL (0 of 5 inverters in violation)	0	0	VIOLATION6 TOTAL (0 of 5 inverters in violation)	0	0
VIOLATION7 TOTAL	0	0	VIOLATION7 TOTAL	0	0
TRIPLEX METER (0 of 1296 meters in violation)	0	0	TRIPLEX METER (0 of 1296 meters in violation)	0	0
COMMERCIAL METER (0 of 298 meters in violation)	0	0	COMMERCIAL METER (0 of 298 meters in violation)	0	0
VIOLATION8 TOTAL	575	576	VIOLATION8 TOTAL	56	56

Table 4.4: Circuit 11 violations before and after manual changes

11					
Summer			Fall		
	Original	Corrected		Original	Corrected
VIOLATION1 TOTAL	56,172	0	VIOLATION1 TOTAL	35,651	0
TRANSFORMER (0 of 260 transformers in violation)	0	0	TRANSFORMER (0 of 260 transformers in violation)	0	0
OVERHEAD LINE (9 of 163 lines in violation)	52,902	0	OVERHEAD LINE (6 of 163 lines in violation)	35,651	0
UNDERGROUND LINE (1 of 199 lines in violation)	3,270	0	UNDERGROUND LINE (0 of 199 lines in violation)	0	0
TRIPLEX LINE (0 of 0 lines in violation)	0	0	TRIPLEX LINE (0 of 0 lines in violation)	0	0
VIOLATION2 TOTAL	0	0	VIOLATION2 TOTAL	0	0
NODE (0 of 427 nodes in violation)	0	0	NODE (0 of 427 nodes in violation)	0	0
TRIPLEX NODE (0 of 204 nodes in violation)	0	0	TRIPLEX NODE (0 of 204 nodes in violation)	0	0
TRIPLEX METER (0 of 0 meters in violation)	0	0	TRIPLEX METER (0 of 0 meters in violation)	0	0
COMMERCIAL METER (0 of 145 meters in violation)	0	0	COMMERCIAL METER (0 of 145 meters in violation)	0	0
VIOLATION3 TOTAL	570	71	VIOLATION3 TOTAL	24	0
TRIPLEX NODE (0 of 204 nodes in violation)	0	0	TRIPLEX NODE (0 of 204 nodes in violation)	0	0
TRIPLEX METER (0 of 0 meters in violation)	0	0	TRIPLEX METER (0 of 0 meters in violation)	0	0
COMMERCIAL METER (5/2 of 145 meters in violation)	570	71	COMMERCIAL METER (1/1 of 145 meters in violation)	24	0
VIOLATION4 TOTAL	0	0	VIOLATION4 TOTAL	0	0
VIOLATION5 TOTAL	0	0	VIOLATION5 TOTAL	0	0
VIOLATION6 TOTAL (0 of 0 inverters in violation)	0	0	VIOLATION6 TOTAL (0 of 0 inverters in violation)	0	0
VIOLATION7 TOTAL	0	0	VIOLATION7 TOTAL	0	0
TRIPLEX METER (0 of 0 meters in violation)	0	0	TRIPLEX METER (0 of 0 meters in violation)	0	0
COMMERCIAL METER (0 of 145 meters in violation)	0	0	COMMERCIAL METER (0 of 145 meters in violation)	0	0
VIOLATION8 TOTAL	5,998	2,351	VIOLATION8 TOTAL	6,361	3,361
Spring			Winter		
	Original	Corrected		Original	Corrected
VIOLATION1 TOTAL	30,492	0	VIOLATION1 TOTAL	33,042	0
TRANSFORMER (0 of 260 transformers in violation)	0	0	TRANSFORMER (0 of 260 transformers in violation)	0	0
OVERHEAD LINE (6 of 163 lines in violation)	30,492	0	OVERHEAD LINE (6 of 163 lines in violation)	33,042	0
UNDERGROUND LINE (0 of 199 lines in violation)	0	0	UNDERGROUND LINE (0 of 199 lines in violation)	0	0
TRIPLEX LINE (0 of 0 lines in violation)	0	0	TRIPLEX LINE (0 of 0 lines in violation)	0	0
VIOLATION2 TOTAL	0	0	VIOLATION2 TOTAL	0	0
NODE (0 of 427 nodes in violation)	0	0	NODE (0 of 427 nodes in violation)	0	0
TRIPLEX NODE (0 of 204 nodes in violation)	0	0	TRIPLEX NODE (0 of 204 nodes in violation)	0	0
TRIPLEX METER (0 of 0 meters in violation)	0	0	TRIPLEX METER (0 of 0 meters in violation)	0	0
COMMERCIAL METER (0 of 145 meters in violation)	0	0	COMMERCIAL METER (0 of 145 meters in violation)	0	0
VIOLATION3 TOTAL	0	0	VIOLATION3 TOTAL	0	0
TRIPLEX NODE (0 of 204 nodes in violation)	0	0	TRIPLEX NODE (0 of 204 nodes in violation)	0	0
TRIPLEX METER (0 of 0 meters in violation)	0	0	TRIPLEX METER (0 of 0 meters in violation)	0	0
COMMERCIAL METER (0 of 145 meters in violation)	0	0	COMMERCIAL METER (0 of 145 meters in violation)	0	0
VIOLATION4 TOTAL	0	0	VIOLATION4 TOTAL	0	0
VIOLATION5 TOTAL	0	0	VIOLATION5 TOTAL	0	0
VIOLATION6 TOTAL (0 of 0 inverters in violation)	0	0	VIOLATION6 TOTAL (0 of 0 inverters in violation)	0	0
VIOLATION7 TOTAL	0	0	VIOLATION7 TOTAL	0	0
TRIPLEX METER (0 of 0 meters in violation)	0	0	TRIPLEX METER (0 of 0 meters in violation)	0	0
COMMERCIAL METER (0 of 145 meters in violation)	0	0	COMMERCIAL METER (0 of 145 meters in violation)	0	0
VIOLATION8 TOTAL	6,781	4,021	VIOLATION8 TOTAL	6,418	4,193

Table 4.5: Circuit 5 violations before and after manual changes

5					
Summer			Fall		
	Original	Corrected		Original	Corrected
VIOLATION1 TOTAL	126,389	0	VIOLATION1 TOTAL	89,258	0
TRANSFORMER (0 of 123 transformers in violation)	0	0	TRANSFORMER (0 of 123 transformers in violation)	0	0
OVERHEAD LINE (7 of 171 lines in violation)	126,389	0	OVERHEAD LINE (8 of 171 lines in violation)	89,258	0
UNDERGROUND LINE (0 of 34 lines in violation)	0	0	UNDERGROUND LINE (0 of 34 lines in violation)	0	0
TRIPLEX LINE (0 of 138 lines in violation)	0	0	TRIPLEX LINE (0 of 138 lines in violation)	0	0
VIOLATION2 TOTAL	0	0	VIOLATION2 TOTAL	0	0
NODE (0 of 207 nodes in violation)	0	0	NODE (0 of 207 nodes in violation)	0	0
TRIPLEX NODE (0 of 84 nodes in violation)	0	0	TRIPLEX NODE (0 of 84 nodes in violation)	0	0
TRIPLEX METER (0 of 139 meters in violation)	0	0	TRIPLEX METER (0 of 139 meters in violation)	0	0
COMMERCIAL METER (0 of 90 meters in violation)	0	0	COMMERCIAL METER (0 of 90 meters in violation)	0	0
VIOLATION3 TOTAL	672	0	VIOLATION3 TOTAL	252	0
TRIPLEX NODE (0 of 84 nodes in violation)	0	0	TRIPLEX NODE (0 of 84 nodes in violation)	0	0
TRIPLEX METER (0 of 139 meters in violation)	0	0	TRIPLEX METER (0 of 139 meters in violation)	0	0
COMMERCIAL METER (3 of 90 meters in violation)	672	0	COMMERCIAL METER (3 of 90 meters in violation)	252	0
VIOLATION4 TOTAL	0	0	VIOLATION4 TOTAL	0	0
VIOLATION5 TOTAL	0	0	VIOLATION5 TOTAL	0	0
VIOLATION6 TOTAL (0 of 1 inverters in violation)	0	0	VIOLATION6 TOTAL (0 of 1 inverters in violation)	0	0
VIOLATION7 TOTAL	28,992	0	VIOLATION7 TOTAL	20,463	0
TRIPLEX METER (0 of 139 meters in violation)	0	0	TRIPLEX METER (0 of 139 meters in violation)	0	0
COMMERCIAL METER (3 of 90 meters in violation)	28,992	0	COMMERCIAL METER (3 of 90 meters in violation)	20,463	0
VIOLATION8 TOTAL	0	0	VIOLATION8 TOTAL	0	0
Spring			Winter		
	Original	Corrected		Original	Corrected
VIOLATION1 TOTAL	89,710	0	VIOLATION1 TOTAL	81,316	0
TRANSFORMER (0 of 123 transformers in violation)	0	0	TRANSFORMER (0 of 123 transformers in violation)	0	0
OVERHEAD LINE (7 of 171 lines in violation)	89,710	0	OVERHEAD LINE (7 of 171 lines in violation)	81,316	0
UNDERGROUND LINE (0 of 34 lines in violation)	0	0	UNDERGROUND LINE (0 of 34 lines in violation)	0	0
TRIPLEX LINE (0 of 138 lines in violation)	0	0	TRIPLEX LINE (0 of 138 lines in violation)	0	0
VIOLATION2 TOTAL	0	0	VIOLATION2 TOTAL	0	0
NODE (0 of 207 nodes in violation)	0	0	NODE (0 of 207 nodes in violation)	0	0
TRIPLEX NODE (0 of 84 nodes in violation)	0	0	TRIPLEX NODE (0 of 84 nodes in violation)	0	0
TRIPLEX METER (0 of 139 meters in violation)	0	0	TRIPLEX METER (0 of 139 meters in violation)	0	0
COMMERCIAL METER (0 of 90 meters in violation)	0	0	COMMERCIAL METER (0 of 90 meters in violation)	0	0
VIOLATION3 TOTAL	475	0	VIOLATION3 TOTAL	441	0
TRIPLEX NODE (0 of 84 nodes in violation)	0	0	TRIPLEX NODE (0 of 84 nodes in violation)	0	0
TRIPLEX METER (0 of 139 meters in violation)	0	0	TRIPLEX METER (0 of 139 meters in violation)	0	0
COMMERCIAL METER (3 of 90 meters in violation)	475	0	COMMERCIAL METER (1 of 90 meters in violation)	441	0
VIOLATION4 TOTAL	0	0	VIOLATION4 TOTAL	0	0
VIOLATION5 TOTAL	0	0	VIOLATION5 TOTAL	0	0
VIOLATION6 TOTAL (0 of 1 inverters in violation)	0	0	VIOLATION6 TOTAL (0 of 1 inverters in violation)	0	0
VIOLATION7 TOTAL	19,753	0	VIOLATION7 TOTAL	19,153	0
TRIPLEX METER (0 of 139 meters in violation)	0	0	TRIPLEX METER (0 of 139 meters in violation)	0	0
COMMERCIAL METER (3 of 90 meters in violation)	19,753	0	COMMERCIAL METER (3 of 90 meters in violation)	19,153	0
VIOLATION8 TOTAL	0	0	VIOLATION8 TOTAL	0	0

Table 4.6: Circuit 24 violations before and after manual changes

24					
Summer			Fall		
	Original	Corrected		Original	Corrected
VIOLATION1 TOTAL	73,813	0	VIOLATION1 TOTAL	14,148	0
TRANSFORMER (10 of 189 transformers in violation)	30,999	0	TRANSFORMER (0 of 189 transformers in violation)	0	0
OVERHEAD LINE (7 of 250 lines in violation)	42,814	0	OVERHEAD LINE (3 of 250 lines in violation)	14,148	0
UNDERGROUND LINE (0 of 7 lines in violation)	0	0	UNDERGROUND LINE (0 of 7 lines in violation)	0	0
TRIPLEX LINE (0 of 66 lines in violation)	0	0	TRIPLEX LINE (0 of 66 lines in violation)	0	0
VIOLATION2 TOTAL	0	0	VIOLATION2 TOTAL	0	0
NODE (0 of 281 nodes in violation)	0	0	NODE (0 of 281 nodes in violation)	0	0
TRIPLEX NODE (0 of 135 nodes in violation)	0	0	TRIPLEX NODE (0 of 135 nodes in violation)	0	0
TRIPLEX METER (0 of 68 meters in violation)	0	0	TRIPLEX METER (0 of 68 meters in violation)	0	0
COMMERCIAL METER (0 of 66 meters in violation)	0	0	COMMERCIAL METER (0 of 66 meters in violation)	0	0
VIOLATION3 TOTAL	980	0	VIOLATION3 TOTAL	69	0
TRIPLEX NODE (0 of 135 nodes in violation)	0	0	TRIPLEX NODE (0 of 135 nodes in violation)	0	0
TRIPLEX METER (0 of 68 meters in violation)	0	0	TRIPLEX METER (0 of 68 meters in violation)	0	0
COMMERCIAL METER (2 of 66 meters in violation)	980	0	COMMERCIAL METER (1 of 66 meters in violation)	69	0
VIOLATION4 TOTAL	0	0	VIOLATION4 TOTAL	0	0
VIOLATION5 TOTAL	0	0	VIOLATION5 TOTAL	0	0
VIOLATION6 TOTAL (0 of 2 inverters in violation)	0	0	VIOLATION6 TOTAL (0 of 2 inverters in violation)	0	0
VIOLATION7 TOTAL	17,440	0	VIOLATION7 TOTAL	2,705	0
TRIPLEX METER (0 of 68 meters in violation)	0	0	TRIPLEX METER (0 of 68 meters in violation)	0	0
COMMERCIAL METER (3 of 66 meters in violation)	17,440	0	COMMERCIAL METER (2 of 66 meters in violation)	2,705	0
VIOLATION8 TOTAL	0	0	VIOLATION8 TOTAL	0	0
Spring			Winter		
	Original	Corrected		Original	Corrected
VIOLATION1 TOTAL	25,258	0	VIOLATION1 TOTAL	27,944	0
TRANSFORMER (0 of 189 transformers in violation)	0	0	TRANSFORMER (0 of 189 transformers in violation)	0	0
OVERHEAD LINE (5 of 250 lines in violation)	25,258	0	OVERHEAD LINE (5 of 250 lines in violation)	27,944	0
UNDERGROUND LINE (0 of 7 lines in violation)	0	0	UNDERGROUND LINE (0 of 7 lines in violation)	0	0
TRIPLEX LINE (0 of 66 lines in violation)	0	0	TRIPLEX LINE (0 of 66 lines in violation)	0	0
VIOLATION2 TOTAL	0	0	VIOLATION2 TOTAL	0	0
NODE (0 of 281 nodes in violation)	0	0	NODE (0 of 281 nodes in violation)	0	0
TRIPLEX NODE (0 of 135 nodes in violation)	0	0	TRIPLEX NODE (0 of 135 nodes in violation)	0	0
TRIPLEX METER (0 of 68 meters in violation)	0	0	TRIPLEX METER (0 of 68 meters in violation)	0	0
COMMERCIAL METER (0 of 66 meters in violation)	0	0	COMMERCIAL METER (0 of 66 meters in violation)	0	0
VIOLATION3 TOTAL	315	0	VIOLATION3 TOTAL	409	0
TRIPLEX NODE (0 of 135 nodes in violation)	0	0	TRIPLEX NODE (0 of 135 nodes in violation)	0	0
TRIPLEX METER (0 of 68 meters in violation)	0	0	TRIPLEX METER (0 of 68 meters in violation)	0	0
COMMERCIAL METER (1 of 66 meters in violation)	315	0	COMMERCIAL METER (1 of 66 meters in violation)	409	0
VIOLATION4 TOTAL	0	0	VIOLATION4 TOTAL	0	0
VIOLATION5 TOTAL	0	0	VIOLATION5 TOTAL	0	0
VIOLATION6 TOTAL (0 of 2 inverters in violation)	0	0	VIOLATION6 TOTAL (0 of 2 inverters in violation)	0	0
VIOLATION7 TOTAL	11,340	0	VIOLATION7 TOTAL	11,700	0
TRIPLEX METER (0 of 68 meters in violation)	0	0	TRIPLEX METER (0 of 68 meters in violation)	0	0
COMMERCIAL METER (2 of 66 meters in violation)	11,340	0	COMMERCIAL METER (2 of 66 meters in violation)	11,700	0
VIOLATION8 TOTAL	0	0	VIOLATION8 TOTAL	0	0

Table 4.7: Circuit 22 violations before and after manual changes

22					
Summer			Fall		
	Original	Corrected		Original	Corrected
VIOLATION1 TOTAL	0	0	VIOLATION1 TOTAL	0	0
TRANSFORMER (0 of 118 transformers in violation)	0	0	TRANSFORMER (0 of 118 transformers in violation)	0	0
OVERHEAD LINE (0 of 183 lines in violation)	0	0	OVERHEAD LINE (0 of 183 lines in violation)	0	0
UNDERGROUND LINE (0 of 4 lines in violation)	0	0	UNDERGROUND LINE (0 of 4 lines in violation)	0	0
TRIPLEX LINE (0 of 971 lines in violation)	0	0	TRIPLEX LINE (0 of 971 lines in violation)	0	0
VIOLATION2 TOTAL	0	0	VIOLATION2 TOTAL	0	0
NODE (0 of 206 nodes in violation)	0	0	NODE (0 of 206 nodes in violation)	0	0
TRIPLEX NODE (0 of 110 nodes in violation)	0	0	TRIPLEX NODE (0 of 110 nodes in violation)	0	0
TRIPLEX METER (0 of 984 meters in violation)	0	0	TRIPLEX METER (0 of 984 meters in violation)	0	0
COMMERCIAL METER (0 of 9 meters in violation)	0	0	COMMERCIAL METER (0 of 9 meters in violation)	0	0
VIOLATION3 TOTAL	56	0	VIOLATION3 TOTAL	1,778	0
TRIPLEX NODE (1 of 110 nodes in violation)	13	0	TRIPLEX NODE (1 of 110 nodes in violation)	268	0
TRIPLEX METER (5 of 984 meters in violation)	30	0	TRIPLEX METER (5 of 984 meters in violation)	1,245	0
COMMERCIAL METER (1 of 9 meters in violation)	13	0	COMMERCIAL METER (1 of 9 meters in violation)	265	0
VIOLATION4 TOTAL	0	0	VIOLATION4 TOTAL	0	0
VIOLATION5 TOTAL	0	0	VIOLATION5 TOTAL	0	0
VIOLATION6 TOTAL (0 of 13 inverters in violation)	0	0	VIOLATION6 TOTAL (0 of 13 inverters in violation)	0	0
VIOLATION7 TOTAL	0	0	VIOLATION7 TOTAL	0	0
TRIPLEX METER (0 of 984 meters in violation)	0	0	TRIPLEX METER (0 of 984 meters in violation)	0	0
COMMERCIAL METER (0 of 9 meters in violation)	0	0	COMMERCIAL METER (0 of 9 meters in violation)	0	0
VIOLATION8 TOTAL	0	0	VIOLATION8 TOTAL	0	0
Spring			Winter		
	Original	Corrected		Original	Corrected
VIOLATION1 TOTAL	0	0	VIOLATION1 TOTAL	0	0
TRANSFORMER (0 of 118 transformers in violation)	0	0	TRANSFORMER (0 of 118 transformers in violation)	0	0
OVERHEAD LINE (0 of 183 lines in violation)	0	0	OVERHEAD LINE (0 of 183 lines in violation)	0	0
UNDERGROUND LINE (0 of 4 lines in violation)	0	0	UNDERGROUND LINE (0 of 4 lines in violation)	0	0
TRIPLEX LINE (0 of 971 lines in violation)	0	0	TRIPLEX LINE (0 of 971 lines in violation)	0	0
VIOLATION2 TOTAL	0	0	VIOLATION2 TOTAL	0	0
NODE (0 of 206 nodes in violation)	0	0	NODE (0 of 206 nodes in violation)	0	0
TRIPLEX NODE (0 of 110 nodes in violation)	0	0	TRIPLEX NODE (0 of 110 nodes in violation)	0	0
TRIPLEX METER (0 of 984 meters in violation)	0	0	TRIPLEX METER (0 of 984 meters in violation)	0	0
COMMERCIAL METER (0 of 9 meters in violation)	0	0	COMMERCIAL METER (0 of 9 meters in violation)	0	0
VIOLATION3 TOTAL	0	0	VIOLATION3 TOTAL	0	0
TRIPLEX NODE (0 of 110 nodes in violation)	0	0	TRIPLEX NODE (0 of 110 nodes in violation)	0	0
TRIPLEX METER (0 of 984 meters in violation)	0	0	TRIPLEX METER (0 of 984 meters in violation)	0	0
COMMERCIAL METER (0 of 9 meters in violation)	0	0	COMMERCIAL METER (0 of 9 meters in violation)	0	0
VIOLATION4 TOTAL	0	0	VIOLATION4 TOTAL	0	0
VIOLATION5 TOTAL	0	0	VIOLATION5 TOTAL	0	0
VIOLATION6 TOTAL (0 of 13 inverters in violation)	0	0	VIOLATION6 TOTAL (0 of 13 inverters in violation)	0	0
VIOLATION7 TOTAL	0	0	VIOLATION7 TOTAL	0	0
TRIPLEX METER (0 of 984 meters in violation)	0	0	TRIPLEX METER (0 of 984 meters in violation)	0	0
COMMERCIAL METER (0 of 9 meters in violation)	0	0	COMMERCIAL METER (0 of 9 meters in violation)	0	0
VIOLATION8 TOTAL	0	0	VIOLATION8 TOTAL	0	0

Table 4.8: Circuit 4 violations before and after manual changes

4					
Summer			Fall		
	Original	Corrected		Original	Corrected
VIOLATION1 TOTAL	0	0	VIOLATION1 TOTAL	0	0
TRANSFORMER (0 of 347 transformers in violation)	0	0	TRANSFORMER (0 of 347 transformers in violation)	0	0
OVERHEAD LINE (0 of 354 lines in violation)	0	0	OVERHEAD LINE (0 of 354 lines in violation)	0	0
UNDERGROUND LINE (0 of 301 lines in violation)	0	0	UNDERGROUND LINE (0 of 301 lines in violation)	0	0
TRIPLEX LINE (0 of 2512 lines in violation)	0	0	TRIPLEX LINE (0 of 2512 lines in violation)	0	0
VIOLATION2 TOTAL	0	0	VIOLATION2 TOTAL	0	0
NODE (0 of 954 nodes in violation)	0	0	NODE (0 of 954 nodes in violation)	0	0
TRIPLEX NODE (0 of 304 nodes in violation)	0	0	TRIPLEX NODE (0 of 304 nodes in violation)	0	0
TRIPLEX METER (0 of 2540 meters in violation)	0	0	TRIPLEX METER (0 of 2540 meters in violation)	0	0
COMMERCIAL METER (0 of 107 meters in violation)	0	0	COMMERCIAL METER (0 of 107 meters in violation)	0	0
VIOLATION3 TOTAL	31	31	VIOLATION3 TOTAL	0	0
TRIPLEX NODE (0 of 304 nodes in violation)	0	0	TRIPLEX NODE (0 of 304 nodes in violation)	0	0
TRIPLEX METER (17/17 of 2540 meters in violation)	31	31	TRIPLEX METER (0 of 2540 meters in violation)	0	0
COMMERCIAL METER (0 of 107 meters in violation)	0	0	COMMERCIAL METER (0 of 107 meters in violation)	0	0
VIOLATION4 TOTAL	0	0	VIOLATION4 TOTAL	0	0
VIOLATION5 TOTAL	0	0	VIOLATION5 TOTAL	0	0
VIOLATION6 TOTAL (0 of 28 inverters in violation)	0	0	VIOLATION6 TOTAL (0 of 28 inverters in violation)	0	0
VIOLATION7 TOTAL	0	0	VIOLATION7 TOTAL	0	0
TRIPLEX METER (0 of 2540 meters in violation)	0	0	TRIPLEX METER (0 of 2540 meters in violation)	0	0
COMMERCIAL METER (0 of 107 meters in violation)	0	0	COMMERCIAL METER (0 of 107 meters in violation)	0	0
VIOLATION8 TOTAL	0	0	VIOLATION8 TOTAL	657	657
Spring			Winter		
	Original	Corrected		Original	Corrected
VIOLATION1 TOTAL	0	0	VIOLATION1 TOTAL	0	0
TRANSFORMER (0 of 347 transformers in violation)	0	0	TRANSFORMER (0 of 347 transformers in violation)	0	0
OVERHEAD LINE (0 of 354 lines in violation)	0	0	OVERHEAD LINE (0 of 354 lines in violation)	0	0
UNDERGROUND LINE (0 of 301 lines in violation)	0	0	UNDERGROUND LINE (0 of 301 lines in violation)	0	0
TRIPLEX LINE (0 of 2512 lines in violation)	0	0	TRIPLEX LINE (0 of 2512 lines in violation)	0	0
VIOLATION2 TOTAL	0	0	VIOLATION2 TOTAL	0	0
NODE (0 of 954 nodes in violation)	0	0	NODE (0 of 954 nodes in violation)	0	0
TRIPLEX NODE (0 of 304 nodes in violation)	0	0	TRIPLEX NODE (0 of 304 nodes in violation)	0	0
TRIPLEX METER (0 of 2540 meters in violation)	0	0	TRIPLEX METER (0 of 2540 meters in violation)	0	0
COMMERCIAL METER (0 of 107 meters in violation)	0	0	COMMERCIAL METER (0 of 107 meters in violation)	0	0
VIOLATION3 TOTAL	0	0	VIOLATION3 TOTAL	0	0
TRIPLEX NODE (0 of 304 nodes in violation)	0	0	TRIPLEX NODE (0 of 304 nodes in violation)	0	0
TRIPLEX METER (0 of 2540 meters in violation)	0	0	TRIPLEX METER (0 of 2540 meters in violation)	0	0
COMMERCIAL METER (0 of 107 meters in violation)	0	0	COMMERCIAL METER (0 of 107 meters in violation)	0	0
VIOLATION4 TOTAL	0	0	VIOLATION4 TOTAL	0	0
VIOLATION5 TOTAL	0	0	VIOLATION5 TOTAL	0	0
VIOLATION6 TOTAL (0 of 28 inverters in violation)	0	0	VIOLATION6 TOTAL (0 of 28 inverters in violation)	0	0
VIOLATION7 TOTAL	0	0	VIOLATION7 TOTAL	0	0
TRIPLEX METER (0 of 2540 meters in violation)	0	0	TRIPLEX METER (0 of 2540 meters in violation)	0	0
COMMERCIAL METER (0 of 107 meters in violation)	0	0	COMMERCIAL METER (0 of 107 meters in violation)	0	0
VIOLATION8 TOTAL	1,291	1,291	VIOLATION8 TOTAL	4	4

Table 4.9: Circuit 21 violations before and after manual changes

21					
Summer			Fall		
	Original	Corrected		Original	Corrected
VIOLATION1 TOTAL	300	0	VIOLATION1 TOTAL	180	0
TRANSFORMER (0 of 85 transformers in violation)	0	0	TRANSFORMER (0 of 85 transformers in violation)	0	0
OVERHEAD LINE (1 of 169 lines in violation)	300	0	OVERHEAD LINE (1 of 169 lines in violation)	180	0
UNDERGROUND LINE (0 of 38 lines in violation)	0	0	UNDERGROUND LINE (0 of 38 lines in violation)	0	0
TRIPLEX LINE (0 of 1107 lines in violation)	0	0	TRIPLEX LINE (0 of 1107 lines in violation)	0	0
VIOLATION2 TOTAL	0	0	VIOLATION2 TOTAL	0	0
NODE (0 of 193 nodes in violation)	0	0	NODE (0 of 193 nodes in violation)	0	0
TRIPLEX NODE (0 of 61 nodes in violation)	0	0	TRIPLEX NODE (0 of 61 nodes in violation)	0	0
TRIPLEX METER (0 of 1108 meters in violation)	0	0	TRIPLEX METER (0 of 1108 meters in violation)	0	0
COMMERCIAL METER (0 of 80 meters in violation)	0	0	COMMERCIAL METER (0 of 80 meters in violation)	0	0
VIOLATION3 TOTAL	35	0	VIOLATION3 TOTAL	0	0
TRIPLEX NODE (0 of 61 nodes in violation)	0	0	TRIPLEX NODE (0 of 61 nodes in violation)	0	0
TRIPLEX METER (0 of 1108 meters in violation)	0	0	TRIPLEX METER (0 of 1108 meters in violation)	0	0
COMMERCIAL METER (1 of 80 meters in violation)	35	0	COMMERCIAL METER (0 of 80 meters in violation)	0	0
VIOLATION4 TOTAL	0	0	VIOLATION4 TOTAL	0	0
VIOLATION5 TOTAL	0	0	VIOLATION5 TOTAL	0	0
VIOLATION6 TOTAL (0 of 1 inverters in violation)	0	0	VIOLATION6 TOTAL (0 of 1 inverters in violation)	0	0
VIOLATION7 TOTAL	240	0	VIOLATION7 TOTAL	82	0
TRIPLEX METER (0 of 1108 meters in violation)	0	0	TRIPLEX METER (0 of 1108 meters in violation)	0	0
COMMERCIAL METER (1 of 80 meters in violation)	240	0	COMMERCIAL METER (1 of 80 meters in violation)	82	0
VIOLATION8 TOTAL	0	0	VIOLATION8 TOTAL	0	0
Spring			Winter		
	Original	Corrected		Original	Corrected
VIOLATION1 TOTAL	60	0	VIOLATION1 TOTAL	60	0
TRANSFORMER (0 of 85 transformers in violation)	0	0	TRANSFORMER (0 of 85 transformers in violation)	0	0
OVERHEAD LINE (1 of 169 lines in violation)	60	0	OVERHEAD LINE (1 of 169 lines in violation)	60	0
UNDERGROUND LINE (0 of 38 lines in violation)	0	0	UNDERGROUND LINE (0 of 38 lines in violation)	0	0
TRIPLEX LINE (0 of 1107 lines in violation)	0	0	TRIPLEX LINE (0 of 1107 lines in violation)	0	0
VIOLATION2 TOTAL	0	0	VIOLATION2 TOTAL	0	0
NODE (0 of 193 nodes in violation)	0	0	NODE (0 of 193 nodes in violation)	0	0
TRIPLEX NODE (0 of 61 nodes in violation)	0	0	TRIPLEX NODE (0 of 61 nodes in violation)	0	0
TRIPLEX METER (0 of 1108 meters in violation)	0	0	TRIPLEX METER (0 of 1108 meters in violation)	0	0
COMMERCIAL METER (0 of 80 meters in violation)	0	0	COMMERCIAL METER (0 of 80 meters in violation)	0	0
VIOLATION3 TOTAL	0	0	VIOLATION3 TOTAL	0	0
TRIPLEX NODE (0 of 61 nodes in violation)	0	0	TRIPLEX NODE (0 of 61 nodes in violation)	0	0
TRIPLEX METER (0 of 1108 meters in violation)	0	0	TRIPLEX METER (0 of 1108 meters in violation)	0	0
COMMERCIAL METER (0 of 80 meters in violation)	0	0	COMMERCIAL METER (0 of 80 meters in violation)	0	0
VIOLATION4 TOTAL	0	0	VIOLATION4 TOTAL	0	0
VIOLATION5 TOTAL	0	0	VIOLATION5 TOTAL	0	0
VIOLATION6 TOTAL (0 of 1 inverters in violation)	0	0	VIOLATION6 TOTAL (0 of 1 inverters in violation)	0	0
VIOLATION7 TOTAL	0	0	VIOLATION7 TOTAL	0	0
TRIPLEX METER (0 of 1108 meters in violation)	0	0	TRIPLEX METER (0 of 1108 meters in violation)	0	0
COMMERCIAL METER (0 of 80 meters in violation)	0	0	COMMERCIAL METER (0 of 80 meters in violation)	0	0
VIOLATION8 TOTAL	0	0	VIOLATION8 TOTAL	0	0

Table 4.10: Circuit 29 violations before and after manual changes

29					
Summer			Fall		
	Original	Corrected		Original	Corrected
VIOLATION1 TOTAL	13,217	0	VIOLATION1 TOTAL	0	0
TRANSFORMER (0 of 205 transformers in violation)	0	0	TRANSFORMER (0 of 205 transformers in violation)	0	0
OVERHEAD LINE (3 of 108 lines in violation)	13,217	0	OVERHEAD LINE (0 of 108 lines in violation)	0	0
UNDERGROUND LINE (0 of 378 lines in violation)	0	0	UNDERGROUND LINE (0 of 378 lines in violation)	0	0
TRIPLEX LINE (0 of 1453 lines in violation)	0	0	TRIPLEX LINE (0 of 1453 lines in violation)	0	0
VIOLATION2 TOTAL	0	0	VIOLATION2 TOTAL	0	0
NODE (0 of 803 nodes in violation)	0	0	NODE (0 of 803 nodes in violation)	0	0
TRIPLEX NODE (0 of 153 nodes in violation)	0	0	TRIPLEX NODE (0 of 153 nodes in violation)	0	0
TRIPLEX METER (0 of 1468 meters in violation)	0	0	TRIPLEX METER (0 of 1468 meters in violation)	0	0
COMMERCIAL METER (0 of 100 meters in violation)	0	0	COMMERCIAL METER (0 of 100 meters in violation)	0	0
VIOLATION3 TOTAL	167,102	58	VIOLATION3 TOTAL	0	0
TRIPLEX NODE (56 of 153 nodes in violation)	12,172	0	TRIPLEX NODE (0 of 153 nodes in violation)	0	0
TRIPLEX METER (538/15 of 1468 meters in violation)	152,376	58	TRIPLEX METER (0 of 1468 meters in violation)	0	0
COMMERCIAL METER (12 of 100 meters in violation)	2,554	0	COMMERCIAL METER (0 of 100 meters in violation)	0	0
VIOLATION4 TOTAL	0	0	VIOLATION4 TOTAL	0	0
VIOLATION5 TOTAL	0	0	VIOLATION5 TOTAL	0	0
VIOLATION6 TOTAL (0 of 15 inverters in violation)	0	0	VIOLATION6 TOTAL (0 of 15 inverters in violation)	0	0
VIOLATION7 TOTAL	0	0	VIOLATION7 TOTAL	0	0
TRIPLEX METER (0 of 1468 meters in violation)	0	0	TRIPLEX METER (0 of 1468 meters in violation)	0	0
COMMERCIAL METER (0 of 100 meters in violation)	0	0	COMMERCIAL METER (0 of 100 meters in violation)	0	0
VIOLATION8 TOTAL	0	0	VIOLATION8 TOTAL	2,794	1,040
Spring			Winter		
	Original	Corrected		Original	Corrected
VIOLATION1 TOTAL	0	0	VIOLATION1 TOTAL	0	0
TRANSFORMER (0 of 205 transformers in violation)	0	0	TRANSFORMER (0 of 205 transformers in violation)	0	0
OVERHEAD LINE (0 of 108 lines in violation)	0	0	OVERHEAD LINE (0 of 108 lines in violation)	0	0
UNDERGROUND LINE (0 of 378 lines in violation)	0	0	UNDERGROUND LINE (0 of 378 lines in violation)	0	0
TRIPLEX LINE (0 of 1453 lines in violation)	0	0	TRIPLEX LINE (0 of 1453 lines in violation)	0	0
VIOLATION2 TOTAL	0	0	VIOLATION2 TOTAL	0	0
NODE (0 of 803 nodes in violation)	0	0	NODE (0 of 803 nodes in violation)	0	0
TRIPLEX NODE (0 of 153 nodes in violation)	0	0	TRIPLEX NODE (0 of 153 nodes in violation)	0	0
TRIPLEX METER (0 of 1468 meters in violation)	0	0	TRIPLEX METER (0 of 1468 meters in violation)	0	0
COMMERCIAL METER (0 of 100 meters in violation)	0	0	COMMERCIAL METER (0 of 100 meters in violation)	0	0
VIOLATION3 TOTAL	0	0	VIOLATION3 TOTAL	356	0
TRIPLEX NODE (0 of 153 nodes in violation)	0	0	TRIPLEX NODE (0 of 153 nodes in violation)	0	0
TRIPLEX METER (0 of 1468 meters in violation)	0	0	TRIPLEX METER (35 of 1468 meters in violation)	356	0
COMMERCIAL METER (0 of 100 meters in violation)	0	0	COMMERCIAL METER (0 of 100 meters in violation)	0	0
VIOLATION4 TOTAL	0	0	VIOLATION4 TOTAL	0	0
VIOLATION5 TOTAL	0	0	VIOLATION5 TOTAL	0	0
VIOLATION6 TOTAL (0 of 15 inverters in violation)	0	0	VIOLATION6 TOTAL (0 of 15 inverters in violation)	0	0
VIOLATION7 TOTAL	0	0	VIOLATION7 TOTAL	0	0
TRIPLEX METER (0 of 1468 meters in violation)	0	0	TRIPLEX METER (0 of 1468 meters in violation)	0	0
COMMERCIAL METER (0 of 100 meters in violation)	0	0	COMMERCIAL METER (0 of 100 meters in violation)	0	0
VIOLATION8 TOTAL	729	807	VIOLATION8 TOTAL	2,969	0

Table 4.11: Circuit 17 violations before and after manual changes

17					
Summer			Fall		
	Original	Corrected		Original	Corrected
VIOLATION1 TOTAL	55,255	0	VIOLATION1 TOTAL	44,076	0
TRANSFORMER (0 of 257 transformers in violation)	0	0	TRANSFORMER (0 of 257 transformers in violation)	0	0
OVERHEAD LINE (7 of 558 lines in violation)	55,255	0	OVERHEAD LINE (9 of 558 lines in violation)	44,076	0
UNDERGROUND LINE (0 of 145 lines in violation)	0	0	UNDERGROUND LINE (0 of 145 lines in violation)	0	0
TRIPLEX LINE (0 of 261 lines in violation)	0	0	TRIPLEX LINE (0 of 261 lines in violation)	0	0
VIOLATION2 TOTAL	0	0	VIOLATION2 TOTAL	0	0
NODE (0 of 428 nodes in violation)	0	0	NODE (0 of 428 nodes in violation)	0	0
TRIPLEX NODE (0 of 183 nodes in violation)	0	0	TRIPLEX NODE (0 of 183 nodes in violation)	0	0
TRIPLEX METER (0 of 262 meters in violation)	0	0	TRIPLEX METER (0 of 262 meters in violation)	0	0
COMMERCIAL METER (0 of 530 meters in violation)	0	0	COMMERCIAL METER (0 of 530 meters in violation)	0	0
VIOLATION3 TOTAL	25,035	0	VIOLATION3 TOTAL	3,064	0
TRIPLEX NODE (9 of 183 nodes in violation)	601	0	TRIPLEX NODE (0 of 183 nodes in violation)	0	0
TRIPLEX METER (0 of 262 meters in violation)	0	0	TRIPLEX METER (0 of 262 meters in violation)	0	0
COMMERCIAL METER (112 of 530 meters in violation)	24,434	0	COMMERCIAL METER (18 of 530 meters in violation)	3,064	0
VIOLATION4 TOTAL	0	0	VIOLATION4 TOTAL	0	0
VIOLATION5 TOTAL	0	0	VIOLATION5 TOTAL	0	0
VIOLATION6 TOTAL (0 of 1 inverters in violation)	0	0	VIOLATION6 TOTAL (0 of 1 inverters in violation)	0	0
VIOLATION7 TOTAL	16,143	0	VIOLATION7 TOTAL	17,981	0
TRIPLEX METER (0 of 262 meters in violation)	0	0	TRIPLEX METER (0 of 262 meters in violation)	0	0
COMMERCIAL METER (1 of 530 meters in violation)	16,143	0	COMMERCIAL METER (1 of 530 meters in violation)	17,981	0
VIOLATION8 TOTAL	5,404	0	VIOLATION8 TOTAL	3,012	0
Spring			Winter		
	Original	Corrected		Original	Corrected
VIOLATION1 TOTAL	54,188	0	VIOLATION1 TOTAL	40,431	0
TRANSFORMER (0 of 257 transformers in violation)	0	0	TRANSFORMER (0 of 257 transformers in violation)	0	0
OVERHEAD LINE (7 of 558 lines in violation)	54,188	0	OVERHEAD LINE (6 of 558 lines in violation)	40,431	0
UNDERGROUND LINE (0 of 145 lines in violation)	0	0	UNDERGROUND LINE (0 of 145 lines in violation)	0	0
TRIPLEX LINE (0 of 261 lines in violation)	0	0	TRIPLEX LINE (0 of 261 lines in violation)	0	0
VIOLATION2 TOTAL	0	0	VIOLATION2 TOTAL	0	0
NODE (0 of 428 nodes in violation)	0	0	NODE (0 of 428 nodes in violation)	0	0
TRIPLEX NODE (0 of 183 nodes in violation)	0	0	TRIPLEX NODE (0 of 183 nodes in violation)	0	0
TRIPLEX METER (0 of 262 meters in violation)	0	0	TRIPLEX METER (0 of 262 meters in violation)	0	0
COMMERCIAL METER (0 of 530 meters in violation)	0	0	COMMERCIAL METER (0 of 530 meters in violation)	0	0
VIOLATION3 TOTAL	4,079	0	VIOLATION3 TOTAL	609	0
TRIPLEX NODE (0 of 183 nodes in violation)	0	0	TRIPLEX NODE (0 of 183 nodes in violation)	0	0
TRIPLEX METER (0 of 262 meters in violation)	0	0	TRIPLEX METER (0 of 262 meters in violation)	0	0
COMMERCIAL METER (14 of 530 meters in violation)	4,079	0	COMMERCIAL METER (2 of 530 meters in violation)	609	0
VIOLATION4 TOTAL	0	0	VIOLATION4 TOTAL	0	0
VIOLATION5 TOTAL	0	0	VIOLATION5 TOTAL	0	0
VIOLATION6 TOTAL (0 of 1 inverters in violation)	0	0	VIOLATION6 TOTAL (0 of 1 inverters in violation)	0	0
VIOLATION7 TOTAL	17,400	0	VIOLATION7 TOTAL	16,543	0
TRIPLEX METER (0 of 262 meters in violation)	0	0	TRIPLEX METER (0 of 262 meters in violation)	0	0
COMMERCIAL METER (1 of 530 meters in violation)	17,400	0	COMMERCIAL METER (1 of 530 meters in violation)	16,543	0
VIOLATION8 TOTAL	3,009	60	VIOLATION8 TOTAL	5,295	379

Table 4.12: Circuit 7 violations before and after manual changes

7					
Summer			Fall		
	Original	Corrected		Original	Corrected
VIOLATION1 TOTAL	120,212	0	VIOLATION1 TOTAL	58,146	0
TRANSFORMER (0 of 144 transformers in violation)	0	0	TRANSFORMER (0 of 144 transformers in violation)	0	0
OVERHEAD LINE (12 of 149 lines in violation)	120,212	0	OVERHEAD LINE (7 of 149 lines in violation)	58,146	0
UNDERGROUND LINE (0 of 162 lines in violation)	0	0	UNDERGROUND LINE (0 of 162 lines in violation)	0	0
TRIPLEX LINE (0 of 338 lines in violation)	0	0	TRIPLEX LINE (0 of 338 lines in violation)	0	0
VIOLATION2 TOTAL	0	0	VIOLATION2 TOTAL	0	0
NODE (0 of 367 nodes in violation)	0	0	NODE (0 of 367 nodes in violation)	0	0
TRIPLEX NODE (0 of 105 nodes in violation)	0	0	TRIPLEX NODE (0 of 105 nodes in violation)	0	0
TRIPLEX METER (0 of 341 meters in violation)	0	0	TRIPLEX METER (0 of 341 meters in violation)	0	0
COMMERCIAL METER (0 of 147 meters in violation)	0	0	COMMERCIAL METER (0 of 147 meters in violation)	0	0
VIOLATION3 TOTAL	1,773	189	VIOLATION3 TOTAL	1,186	0
TRIPLEX NODE (0 of 105 nodes in violation)	0	0	TRIPLEX NODE (0 of 105 nodes in violation)	0	0
TRIPLEX METER (0 of 341 meters in violation)	0	1	TRIPLEX METER (0 of 341 meters in violation)	0	0
COMMERCIAL METER (2/1 of 147 meters in violation)	1,773	188	COMMERCIAL METER (1 of 147 meters in violation)	1,186	0
VIOLATION4 TOTAL	0	0	VIOLATION4 TOTAL	0	0
VIOLATION5 TOTAL	0	0	VIOLATION5 TOTAL	0	0
VIOLATION6 TOTAL (0 of 3 inverters in violation)	0	0	VIOLATION6 TOTAL (0 of 3 inverters in violation)	0	0
VIOLATION7 TOTAL	17,434	0	VIOLATION7 TOTAL	13,930	0
TRIPLEX METER (0 of 341 meters in violation)	0	0	TRIPLEX METER (0 of 341 meters in violation)	0	0
COMMERCIAL METER (1 of 147 meters in violation)	17,434	0	COMMERCIAL METER (1 of 147 meters in violation)	13,930	0
VIOLATION8 TOTAL	0	0	VIOLATION8 TOTAL	0	0
Spring			Winter		
	Original	Corrected		Original	Corrected
VIOLATION1 TOTAL	36,267	0	VIOLATION1 TOTAL	37,066	0
TRANSFORMER (0 of 144 transformers in violation)	0	0	TRANSFORMER (0 of 144 transformers in violation)	0	0
OVERHEAD LINE (7 of 149 lines in violation)	36,267	0	OVERHEAD LINE (7 of 149 lines in violation)	37,066	0
UNDERGROUND LINE (0 of 162 lines in violation)	0	0	UNDERGROUND LINE (0 of 162 lines in violation)	0	0
TRIPLEX LINE (0 of 338 lines in violation)	0	0	TRIPLEX LINE (0 of 338 lines in violation)	0	0
VIOLATION2 TOTAL	0	0	VIOLATION2 TOTAL	0	0
NODE (0 of 367 nodes in violation)	0	0	NODE (0 of 367 nodes in violation)	0	0
TRIPLEX NODE (0 of 105 nodes in violation)	0	0	TRIPLEX NODE (0 of 105 nodes in violation)	0	0
TRIPLEX METER (0 of 341 meters in violation)	0	0	TRIPLEX METER (0 of 341 meters in violation)	0	0
COMMERCIAL METER (0 of 147 meters in violation)	0	0	COMMERCIAL METER (0 of 147 meters in violation)	0	0
VIOLATION3 TOTAL	1,275	0	VIOLATION3 TOTAL	1,147	0
TRIPLEX NODE (0 of 105 nodes in violation)	0	0	TRIPLEX NODE (0 of 105 nodes in violation)	0	0
TRIPLEX METER (0 of 341 meters in violation)	0	0	TRIPLEX METER (0 of 341 meters in violation)	0	0
COMMERCIAL METER (1 of 147 meters in violation)	1,275	0	COMMERCIAL METER (1 of 147 meters in violation)	1,147	0
VIOLATION4 TOTAL	0	0	VIOLATION4 TOTAL	0	0
VIOLATION5 TOTAL	0	0	VIOLATION5 TOTAL	0	0
VIOLATION6 TOTAL (0 of 3 inverters in violation)	0	0	VIOLATION6 TOTAL (0 of 3 inverters in violation)	0	0
VIOLATION7 TOTAL	15,563	0	VIOLATION7 TOTAL	14,790	0
TRIPLEX METER (0 of 341 meters in violation)	0	0	TRIPLEX METER (0 of 341 meters in violation)	0	0
COMMERCIAL METER (1 of 147 meters in violation)	15,563	0	COMMERCIAL METER (1 of 147 meters in violation)	14,790	0
VIOLATION8 TOTAL	0	0	VIOLATION8 TOTAL	0	0

Table 4.13: Circuit 8 violations before and after manual changes

8					
Summer			Fall		
	Original	Corrected		Original	Corrected
VIOLATION1 TOTAL	34,489	0	VIOLATION1 TOTAL	17,832	0
TRANSFORMER (0 of 261 transformers in violation)	0	0	TRANSFORMER (0 of 261 transformers in violation)	0	0
OVERHEAD LINE (4 of 357 lines in violation)	34,489	0	OVERHEAD LINE (1 of 357 lines in violation)	17,832	0
UNDERGROUND LINE (0 of 96 lines in violation)	0	0	UNDERGROUND LINE (0 of 96 lines in violation)	0	0
TRIPLEX LINE (0 of 1409 lines in violation)	0	0	TRIPLEX LINE (0 of 1409 lines in violation)	0	0
VIOLATION2 TOTAL	0	0	VIOLATION2 TOTAL	0	0
NODE (0 of 569 nodes in violation)	0	0	NODE (0 of 569 nodes in violation)	0	0
TRIPLEX NODE (0 of 235 nodes in violation)	0	0	TRIPLEX NODE (0 of 235 nodes in violation)	0	0
TRIPLEX METER (0 of 1424 meters in violation)	0	0	TRIPLEX METER (0 of 1424 meters in violation)	0	0
COMMERCIAL METER (0 of 62 meters in violation)	0	0	COMMERCIAL METER (0 of 62 meters in violation)	0	0
VIOLATION3 TOTAL	11,487	4,354	VIOLATION3 TOTAL	29	0
TRIPLEX NODE (13/6 of 235 nodes in violation)	586	57	TRIPLEX NODE (0 of 235 nodes in violation)	0	0
TRIPLEX METER (149/108 of 1424 meters in violation)	10,676	4,297	TRIPLEX METER (0 of 1424 meters in violation)	0	0
COMMERCIAL METER (2 of 62 meters in violation)	225	0	COMMERCIAL METER (1 of 62 meters in violation)	29	0
VIOLATION4 TOTAL	0	0	VIOLATION4 TOTAL	0	0
VIOLATION5 TOTAL	0	0	VIOLATION5 TOTAL	0	0
VIOLATION6 TOTAL (0 of 15 inverters in violation)	0	0	VIOLATION6 TOTAL (0 of 15 inverters in violation)	0	0
VIOLATION7 TOTAL	0	0	VIOLATION7 TOTAL	0	0
TRIPLEX METER (0 of 1424 meters in violation)	0	0	TRIPLEX METER (0 of 1424 meters in violation)	0	0
COMMERCIAL METER (0 of 62 meters in violation)	0	0	COMMERCIAL METER (0 of 62 meters in violation)	0	0
VIOLATION8 TOTAL	953	14	VIOLATION8 TOTAL	737	147
Spring			Winter		
	Original	Corrected		Original	Corrected
VIOLATION1 TOTAL	11,489	0	VIOLATION1 TOTAL	10,283	0
TRANSFORMER (0 of 261 transformers in violation)	0	0	TRANSFORMER (0 of 261 transformers in violation)	0	0
OVERHEAD LINE (1 of 357 lines in violation)	11,489	0	OVERHEAD LINE (1 of 357 lines in violation)	10,283	0
UNDERGROUND LINE (0 of 96 lines in violation)	0	0	UNDERGROUND LINE (0 of 96 lines in violation)	0	0
TRIPLEX LINE (0 of 1409 lines in violation)	0	0	TRIPLEX LINE (0 of 1409 lines in violation)	0	0
VIOLATION2 TOTAL	0	0	VIOLATION2 TOTAL	0	0
NODE (0 of 569 nodes in violation)	0	0	NODE (0 of 569 nodes in violation)	0	0
TRIPLEX NODE (0 of 235 nodes in violation)	0	0	TRIPLEX NODE (0 of 235 nodes in violation)	0	0
TRIPLEX METER (0 of 1424 meters in violation)	0	0	TRIPLEX METER (0 of 1424 meters in violation)	0	0
COMMERCIAL METER (0 of 62 meters in violation)	0	0	COMMERCIAL METER (0 of 62 meters in violation)	0	0
VIOLATION3 TOTAL	0	0	VIOLATION3 TOTAL	0	0
TRIPLEX NODE (0 of 235 nodes in violation)	0	0	TRIPLEX NODE (0 of 235 nodes in violation)	0	0
TRIPLEX METER (0 of 1424 meters in violation)	0	0	TRIPLEX METER (0 of 1424 meters in violation)	0	0
COMMERCIAL METER (0 of 62 meters in violation)	0	0	COMMERCIAL METER (0 of 62 meters in violation)	0	0
VIOLATION4 TOTAL	0	0	VIOLATION4 TOTAL	0	0
VIOLATION5 TOTAL	0	0	VIOLATION5 TOTAL	0	0
VIOLATION6 TOTAL (0 of 15 inverters in violation)	0	0	VIOLATION6 TOTAL (0 of 15 inverters in violation)	0	0
VIOLATION7 TOTAL	0	0	VIOLATION7 TOTAL	0	0
TRIPLEX METER (0 of 1424 meters in violation)	0	0	TRIPLEX METER (0 of 1424 meters in violation)	0	0
COMMERCIAL METER (0 of 62 meters in violation)	0	0	COMMERCIAL METER (0 of 62 meters in violation)	0	0
VIOLATION8 TOTAL	5,149	3,661	VIOLATION8 TOTAL	4,256	2,959

Table 4.14: Circuit 2 violations before and after manual changes

2					
Summer			Fall		
	Original	Corrected		Original	Corrected
VIOLATION1 TOTAL	112,500	0	VIOLATION1 TOTAL	74,869	0
TRANSFORMER (0 of 97 transformers in violation)	0	0	TRANSFORMER (0 of 97 transformers in violation)	0	0
OVERHEAD LINE (11 of 92 lines in violation)	112,500	0	OVERHEAD LINE (10 of 92 lines in violation)	74,869	0
UNDERGROUND LINE (0 of 106 lines in violation)	0	0	UNDERGROUND LINE (0 of 106 lines in violation)	0	0
TRIPLEX LINE (0 of 0 lines in violation)	0	0	TRIPLEX LINE (0 of 0 lines in violation)	0	0
VIOLATION2 TOTAL	0	0	VIOLATION2 TOTAL	0	0
NODE (0 of 251 nodes in violation)	0	0	NODE (0 of 251 nodes in violation)	0	0
TRIPLEX NODE (0 of 68 nodes in violation)	0	0	TRIPLEX NODE (0 of 68 nodes in violation)	0	0
TRIPLEX METER (0 of 0 meters in violation)	0	0	TRIPLEX METER (0 of 0 meters in violation)	0	0
COMMERCIAL METER (0 of 68 meters in violation)	0	0	COMMERCIAL METER (0 of 68 meters in violation)	0	0
VIOLATION3 TOTAL	2,852	0	VIOLATION3 TOTAL	574	0
TRIPLEX NODE (0 of 68 nodes in violation)	0	0	TRIPLEX NODE (0 of 68 nodes in violation)	0	0
TRIPLEX METER (0 of 0 meters in violation)	0	0	TRIPLEX METER (0 of 0 meters in violation)	0	0
COMMERCIAL METER (10 of 68 meters in violation)	2,852	0	COMMERCIAL METER (6 of 68 meters in violation)	574	0
VIOLATION4 TOTAL	0	0	VIOLATION4 TOTAL	0	0
VIOLATION5 TOTAL	0	0	VIOLATION5 TOTAL	0	0
VIOLATION6 TOTAL (0 of 0 inverters in violation)	0	0	VIOLATION6 TOTAL (0 of 0 inverters in violation)	0	0
VIOLATION7 TOTAL	0	0	VIOLATION7 TOTAL	0	0
TRIPLEX METER (0 of 0 meters in violation)	0	0	TRIPLEX METER (0 of 0 meters in violation)	0	0
COMMERCIAL METER (0 of 68 meters in violation)	0	0	COMMERCIAL METER (0 of 68 meters in violation)	0	0
VIOLATION8 TOTAL	5,227	0	VIOLATION8 TOTAL	6,528	0
Spring			Winter		
	Original	Corrected		Original	Corrected
VIOLATION1 TOTAL	75,623	0	VIOLATION1 TOTAL	84,818	0
TRANSFORMER (0 of 97 transformers in violation)	0	0	TRANSFORMER (0 of 97 transformers in violation)	0	0
OVERHEAD LINE (10 of 92 lines in violation)	75,623	0	OVERHEAD LINE (8 of 92 lines in violation)	84,818	0
UNDERGROUND LINE (0 of 106 lines in violation)	0	0	UNDERGROUND LINE (0 of 106 lines in violation)	0	0
TRIPLEX LINE (0 of 0 lines in violation)	0	0	TRIPLEX LINE (0 of 0 lines in violation)	0	0
VIOLATION2 TOTAL	0	0	VIOLATION2 TOTAL	0	0
NODE (0 of 251 nodes in violation)	0	0	NODE (0 of 251 nodes in violation)	0	0
TRIPLEX NODE (0 of 68 nodes in violation)	0	0	TRIPLEX NODE (0 of 68 nodes in violation)	0	0
TRIPLEX METER (0 of 0 meters in violation)	0	0	TRIPLEX METER (0 of 0 meters in violation)	0	0
COMMERCIAL METER (0 of 68 meters in violation)	0	0	COMMERCIAL METER (0 of 68 meters in violation)	0	0
VIOLATION3 TOTAL	1,318	0	VIOLATION3 TOTAL	3,283	0
TRIPLEX NODE (0 of 68 nodes in violation)	0	0	TRIPLEX NODE (20 of 68 nodes in violation)	1,182	0
TRIPLEX METER (0 of 0 meters in violation)	0	0	TRIPLEX METER (0 of 0 meters in violation)	0	0
COMMERCIAL METER (7 of 68 meters in violation)	1,318	0	COMMERCIAL METER (10 of 68 meters in violation)	2,101	0
VIOLATION4 TOTAL	0	0	VIOLATION4 TOTAL	0	0
VIOLATION5 TOTAL	0	0	VIOLATION5 TOTAL	0	0
VIOLATION6 TOTAL (0 of 0 inverters in violation)	0	0	VIOLATION6 TOTAL (0 of 0 inverters in violation)	0	0
VIOLATION7 TOTAL	0	0	VIOLATION7 TOTAL	0	0
TRIPLEX METER (0 of 0 meters in violation)	0	0	TRIPLEX METER (0 of 0 meters in violation)	0	0
COMMERCIAL METER (0 of 68 meters in violation)	0	0	COMMERCIAL METER (0 of 68 meters in violation)	0	0
VIOLATION8 TOTAL	6,951	0	VIOLATION8 TOTAL	6,067	0

Table 4.15: Circuit 3 violations before and after manual changes

3					
Summer			Fall		
	Original	Corrected		Original	Corrected
VIOLATION1 TOTAL	13,491	0	VIOLATION1 TOTAL	2,625	0
TRANSFORMER (0 of 325 transformers in violation)	0	0	TRANSFORMER (0 of 325 transformers in violation)	0	0
OVERHEAD LINE (4 of 128 lines in violation)	10,997	0	OVERHEAD LINE (2 of 128 lines in violation)	2,625	0
UNDERGROUND LINE (5 of 324 lines in violation)	2,494	0	UNDERGROUND LINE (0 of 324 lines in violation)	0	0
TRIPLEX LINE (0 of 2961 lines in violation)	0	0	TRIPLEX LINE (0 of 2961 lines in violation)	0	0
VIOLATION2 TOTAL	0	0	VIOLATION2 TOTAL	0	0
NODE (0 of 795 nodes in violation)	0	0	NODE (0 of 795 nodes in violation)	0	0
TRIPLEX NODE (0 of 203 nodes in violation)	0	0	TRIPLEX NODE (0 of 203 nodes in violation)	0	0
TRIPLEX METER (0 of 3039 meters in violation)	0	0	TRIPLEX METER (0 of 3039 meters in violation)	0	0
COMMERCIAL METER (0 of 132 meters in violation)	0	0	COMMERCIAL METER (0 of 132 meters in violation)	0	0
VIOLATION3 TOTAL	225,245	0	VIOLATION3 TOTAL	6	0
TRIPLEX NODE (59 of 203 nodes in violation)	13,550	0	TRIPLEX NODE (0 of 203 nodes in violation)	0	0
TRIPLEX METER (879 of 3039 meters in violation)	207,452	0	TRIPLEX METER (0 of 3039 meters in violation)	0	0
COMMERCIAL METER (21 of 132 meters in violation)	4,243	0	COMMERCIAL METER (1 of 132 meters in violation)	6	0
VIOLATION4 TOTAL	0	0	VIOLATION4 TOTAL	0	0
VIOLATION5 TOTAL	0	0	VIOLATION5 TOTAL	0	0
VIOLATION6 TOTAL (0 of 78 inverters in violation)	0	0	VIOLATION6 TOTAL (0 of 78 inverters in violation)	0	0
VIOLATION7 TOTAL	3,112	0	VIOLATION7 TOTAL	272	0
TRIPLEX METER (0 of 3039 meters in violation)	0	0	TRIPLEX METER (0 of 3039 meters in violation)	0	0
COMMERCIAL METER (1 of 132 meters in violation)	3,112	0	COMMERCIAL METER (1 of 132 meters in violation)	272	0
VIOLATION8 TOTAL	0	0	VIOLATION8 TOTAL	0	0
Spring			Winter		
	Original	Corrected		Original	Corrected
VIOLATION1 TOTAL	2,025	0	VIOLATION1 TOTAL	1,997	0
TRANSFORMER (0 of 325 transformers in violation)	0	0	TRANSFORMER (0 of 325 transformers in violation)	0	0
OVERHEAD LINE (1 of 128 lines in violation)	2,025	0	OVERHEAD LINE (1 of 128 lines in violation)	1,997	0
UNDERGROUND LINE (0 of 324 lines in violation)	0	0	UNDERGROUND LINE (0 of 324 lines in violation)	0	0
TRIPLEX LINE (0 of 2961 lines in violation)	0	0	TRIPLEX LINE (0 of 2961 lines in violation)	0	0
VIOLATION2 TOTAL	0	0	VIOLATION2 TOTAL	0	0
NODE (0 of 795 nodes in violation)	0	0	NODE (0 of 795 nodes in violation)	0	0
TRIPLEX NODE (0 of 203 nodes in violation)	0	0	TRIPLEX NODE (0 of 203 nodes in violation)	0	0
TRIPLEX METER (0 of 3039 meters in violation)	0	0	TRIPLEX METER (0 of 3039 meters in violation)	0	0
COMMERCIAL METER (0 of 132 meters in violation)	0	0	COMMERCIAL METER (0 of 132 meters in violation)	0	0
VIOLATION3 TOTAL	0	0	VIOLATION3 TOTAL	0	0
TRIPLEX NODE (0 of 203 nodes in violation)	0	0	TRIPLEX NODE (0 of 203 nodes in violation)	0	0
TRIPLEX METER (0 of 3039 meters in violation)	0	0	TRIPLEX METER (0 of 3039 meters in violation)	0	0
COMMERCIAL METER (0 of 132 meters in violation)	0	0	COMMERCIAL METER (0 of 132 meters in violation)	0	0
VIOLATION4 TOTAL	0	0	VIOLATION4 TOTAL	0	0
VIOLATION5 TOTAL	0	0	VIOLATION5 TOTAL	0	0
VIOLATION6 TOTAL (0 of 78 inverters in violation)	0	0	VIOLATION6 TOTAL (0 of 78 inverters in violation)	0	0
VIOLATION7 TOTAL	180	0	VIOLATION7 TOTAL	0	0
TRIPLEX METER (0 of 3039 meters in violation)	0	0	TRIPLEX METER (0 of 3039 meters in violation)	0	0
COMMERCIAL METER (1 of 132 meters in violation)	180	0	COMMERCIAL METER (0 of 132 meters in violation)	0	0
VIOLATION8 TOTAL	0	0	VIOLATION8 TOTAL	0	0

Table 4.16:Summary of changes made to each circuit

Feeder #	Change Made
23	Increased the size of 8 secondary service drops
	Increased rating of 1 secondary service transformer
19	No manual changes made
6	Increased the size of 5 secondary service drops
11	Increased the thermal rating on 1 primary conductor
	Increased the size of 10 secondary service drops
	Changed the capacitor settings for 2 capacitors
5	Increased the thermal rating on 1 primary conductor
	Increased the size of 7 secondary service drops
	Increased rating of 2 secondary service transformers
	Removed the secondary drop for a 2500 MVA load
24	Increased the size of 7 secondary service drops
	Increased rating of 10 secondary service transformers
22	No manual changes made
4	No manual changes made
21	Increased the size of 1 secondary service drop
29	Increased the size of 4 secondary service drops
	Increased the swing node voltage by 2.0%
17	Increased the size of 11 secondary service drops
	Increased rating of 1 secondary service transformer
	Removed the secondary drop for a 1500 MVA load
	Changed the capacitor settings for 2 capacitors
	Increased the swing node voltage by 3.0%
7	Increased the size of 12 secondary service drops
	Increased rating of 1 secondary service transformer
8	Corrected the nominal votlage of a secondary from 120 to 208
	Increased the size of 4 secondary service drops
2	Changed the capacitor settings for 2 capacitors
	Increased the size of 11 secondary service drops
3	Changed the capacitor settings for 2 capacitors
	Increased the thermal rating on 3 primary conductors
	Increased the size of 4 secondary service drops
	Increased the swing node voltage by 3.0%