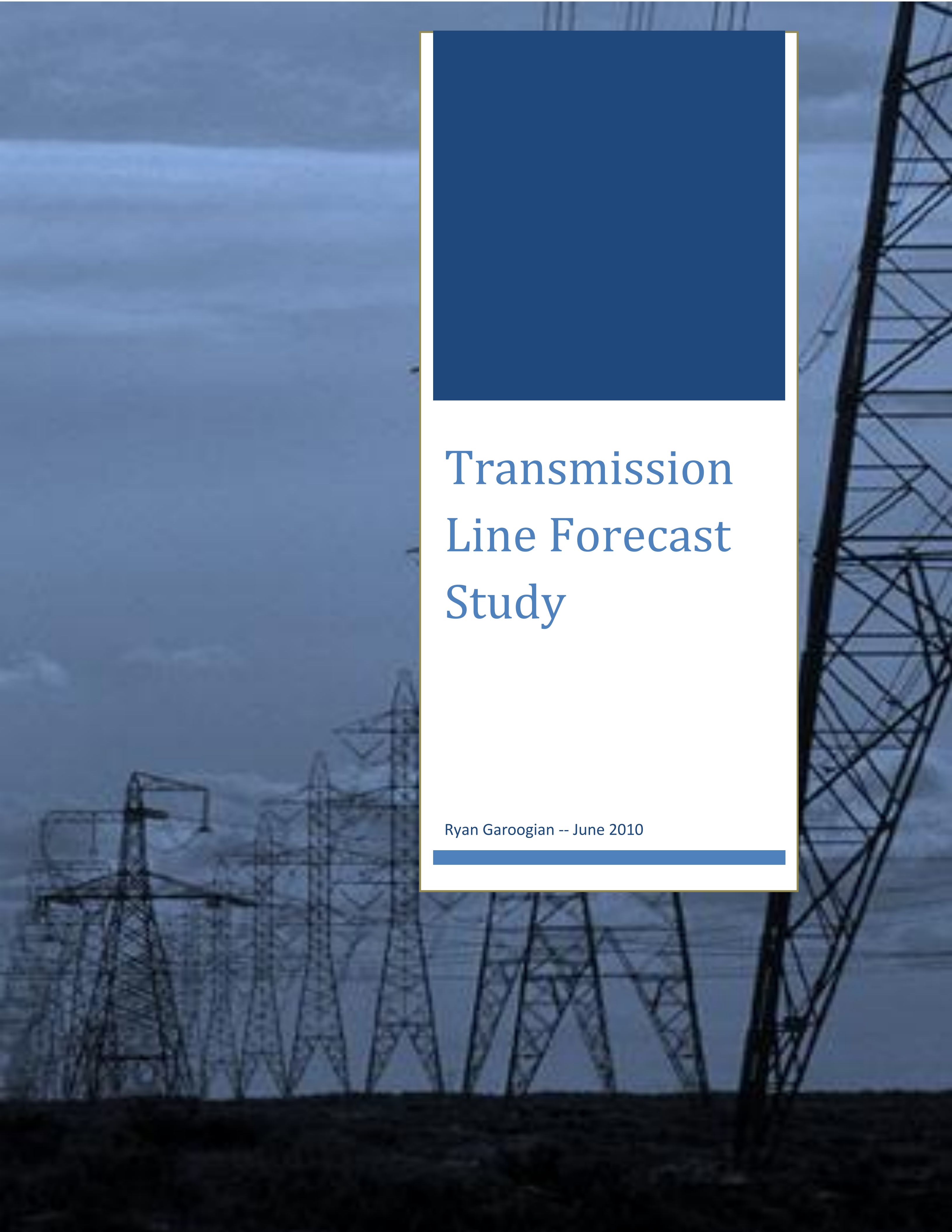

Transmission Line Forecast Study

Ryan Garoogian -- June 2010

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Acknowledgements

I would first like to thank my family for all the encouragement and support through this whole project. I would like to thank my advisor Dr. Ali Shaban for his support and guidance throughout the project. He was an invaluable resource and knowledge base for which this project would not be possible without.

Abstract

Load forecasting is the procedure to predict future loading conditions on a power system. Using simulation software such as ETAP you are able to predict abnormal voltage conditions, overloading of certain equipment, as well as determine protective equipment from short circuit studies. This study consisted of a 115kV loop network with multiple loading busses and one infinite bus. There was no separate generation other than the infinite bus. As load increased from forecasting to the future voltage dropped. To restore voltage levels capacitors were added at strategic points in the system to boost the voltage back up. Preparing yourself for the future in power systems is crucial to be able to efficiently and safely run the system.

Introduction

This transmission line forecast study deals with a subsystem of 115kV lines interconnected to each other with loading at different parts of the system. Transmission line loading data begins in the year 2010 and is then extrapolated linearly to the future every year for ten years. Power load flow is conducted on the circuit for years 2010, 2015, and 2020. Requirements that must be met at every time period are the voltage levels must be within 2% of the nominal value for normal operating conditions as well as 5% of the nominal value for N-1 contingencies and no part of the circuit can be overloaded. N-1 contingencies hypothesizes that one section of the circuit will go out of service and the system needs to maintain the requirements for those conditions. Running short circuit analysis is also a key part of a transmission line study which will give short circuit duty at each bus so protection devices can be added to the system with the correct settings in place to efficiently and safely protect the system. For this system directional overcurrent relay protection is used with coordination between two devices. The relays at each load will be set to trip first and coordination will be done between those along the transmission line to maintain proper protection.

Background

Electric utilities most precious asset is there infrastructure. Transmission Line systems are the backbone of that infrastructure and in turn require a great amount of resources maintaining the system. As systems grow it is vital that you plan ahead and try and hypothesize where future loads might appear. Being able to forecast future loading into the system will prepare you to correctly and efficiently run the system.

The basics of a power system include generation and loads with paths to those loads which in this report are transmission lines. Power flows from the generation to the loads and along the way there are losses which cause voltage drop in the circuit as well as power loss as a form of thermal losses.

Performing a forecast study includes future loading as well as additions of generation. In this study only additional loading is taken into consideration. When additional loading occurs, equipment can become overloaded and must be upgraded to meet the demand or power must be redistributed at various places to relieve that part of the system. You must also take into account that as current is flowing through these lines there is a small amount of inductance and or capacitance in the line which will change the voltage levels at different points in the system. Lines with too much inductance through a section of the line, the voltage level at the end of that section will decrease. Lines with too much capacitance in the line, voltage will decrease.

In a transmission system there is a standard for voltage levels that must be met. These levels are voltages within 2% of the nominal value for normal operating conditions and 5% of nominal value for N-1 Contingencies condition. N-1 Contingencies is a situation where a section of the system goes out of service but since the system is all interconnected the power will be directed around to supply the loads. When a line goes out of service, power flow changes drastically and Utilities are given a little more leeway in maintaining voltage levels for these cases.

In a power system you must also take into account for equipment failure or malfunction as well as abnormalities in the system. When a fault occurs on the system there is an extremely low impedance path to ground. The ground is for all practical purposes an infinite load which demands an infinite source. As the fault occurs the generation must supply that load which pushes an extreme amount of current through the system to the point of the fault. These fault currents can be in the order of 20-30 times the normal operating currents. Equipment specifications should be chosen that meet or exceed the requirements for fault that is predicted on the system. Running a short circuit duty cycle for the system will hypothesize the

fault current at every point in the system which will give an idea of how to properly construct the system.

In order to minimize the duration for faults, power systems maintain complex and redundant protection schemes for their system. The basic protection for a power system is a radial system where power is only flowing in one direction. In this scheme one will only need to sense the current and if it is much greater than the pickup current a relay will activate and will take that part of the circuit out of service until the fault has been cleared. In a transmission system it is exponentially more complex as power can flow in either direction so one must be able to sense which direction the fault is at so you can efficiently and quickly remove part of the system where the fault originates. Various protection schemes include directional overcurrent which sense the current in one direction, impedance or distance relay which calculates the impedance of the line and when a fault occurs that impedance drastically decreases, pilot protection which communicates with other relays to figure out where the fault is.

Project Goals:

1. To extrapolate future loading based on past loading trend from 2010 through 2020.
2. Model future loading in ETAP Electrical modeling software.
3. Upgrade the system to meet standards with N-1 contingencies for each transmission line.
   a. Verify standards in under voltage and over voltage.
   b. Calculate and clear load mismatches.
   c. Verify proper Reactive power.

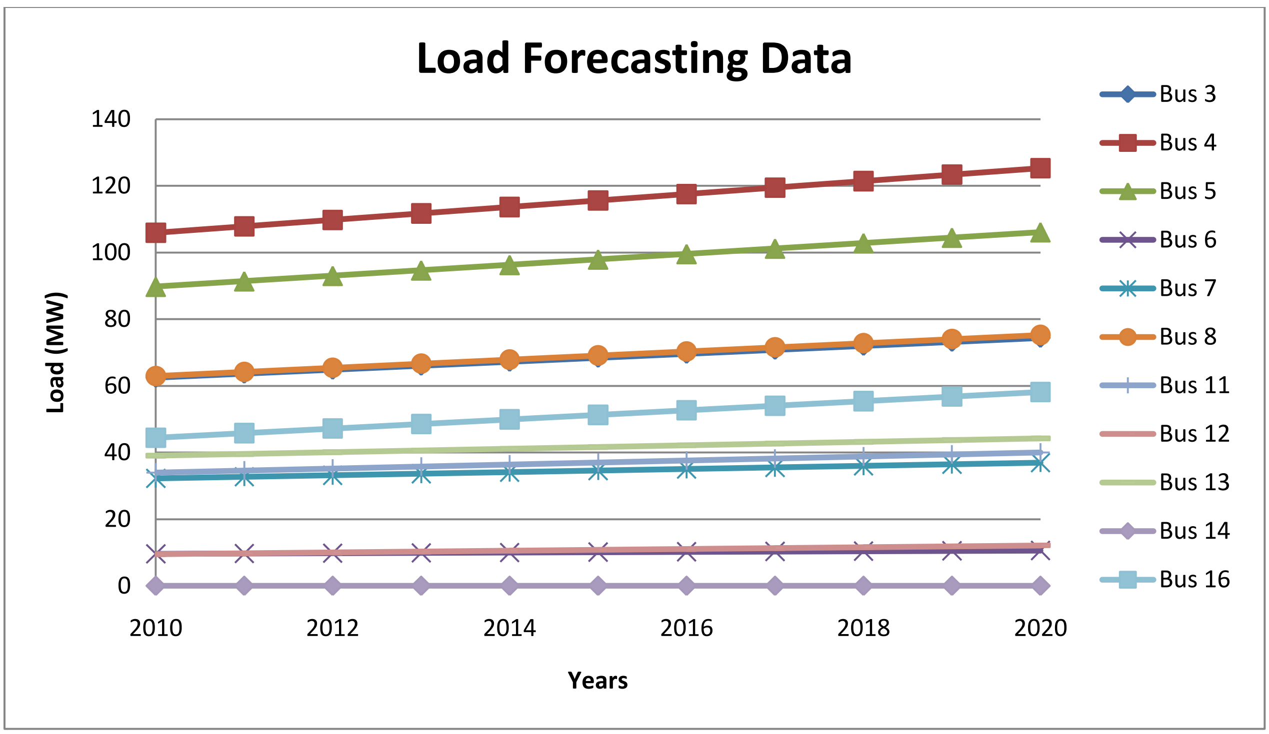
Technical Data:

- Voltage Base : 115kV
- Apparent Power Base : 100MVA
- Static Loads: MVA @ 85% Lagging
- BUS 1 : Swing Bus
- Average line length : 5.56 miles

Load Forecast Data:

Vista Subs	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Bus 3	62	64	65	66	67	68	70	71	72	73	74
Bus 4	106	108	110	112	114	116	118	119	121	123	125
Bus 5	90	91	93	95	96	98	100	101	103	104	106
Bus 6	10	10	10	10	10	10	10	10	10	10	11
Bus 7	32	33	33	34	34	35	35	36	36	36	37
Bus 8	63	64	65	67	68	69	70	72	73	74	75
Bus 11	34	35	35	36	36	37	38	38	39	39	40
Bus 12	9	10	10	10	11	11	11	11	12	12	12
Bus 13	39	40	40	41	41	42	42	43	43	44	44
Bus 16	44	46	47	49	50	51	53	54	55	57	58

Table 1 - Loading data forecasted to 2020



Transmission Line Wire Data:

- Southwire – 650 to 653
- Southwire – 4/0-7 cu to 4/0
- Southwire – 350 to 336
- Southwire – 2/0-7 cu to 2/0
- Southwire – 4/0 ACSR/CO to 4/0 ACSR
- Southwire – 600 to 636
- Southwire – 900 to 954

One Line Diagram Total Busses 51

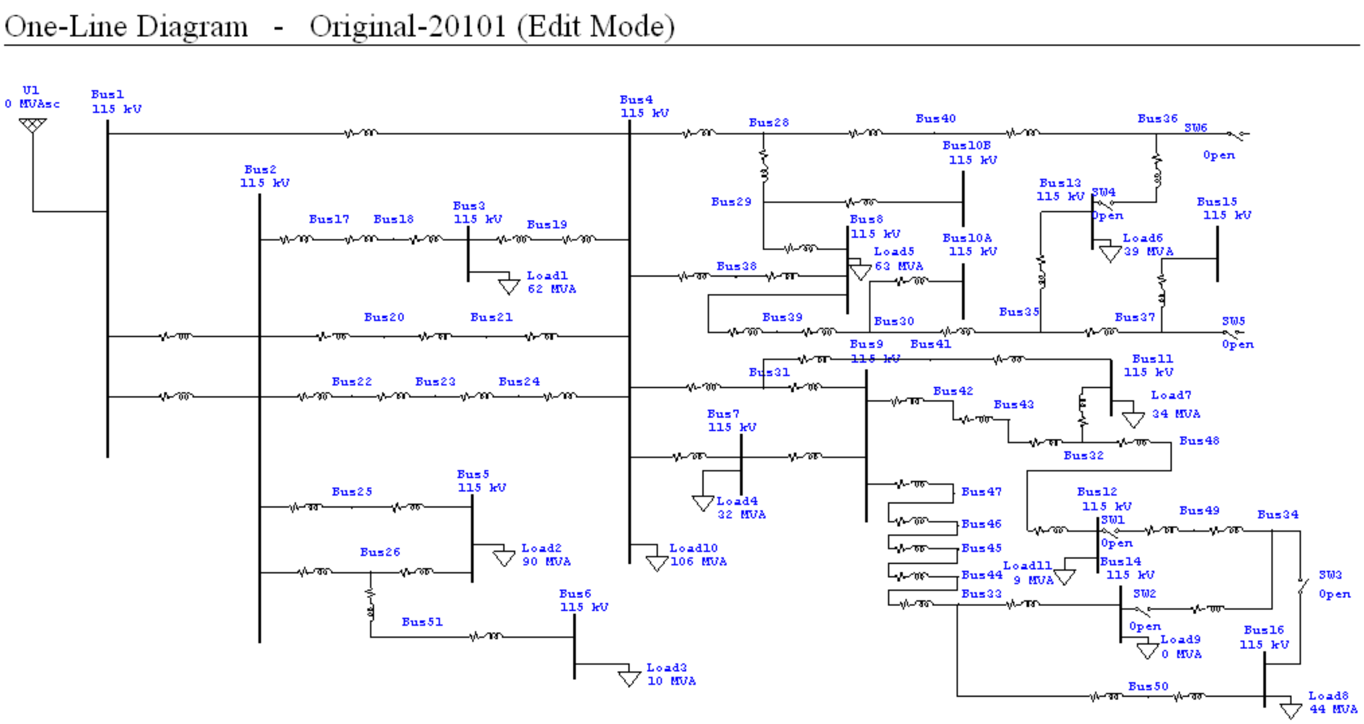


Figure 1 - One Line Diagram 51 Busses

Merging Transmission Lines to bring down the number of Busses used

- Removed Bus 17 & 18 and added then merged the Transmission Line Lengths into one.
- Removed Bus 20 & 21 and added then merged the Transmission Line Lengths into one.
- Removed Bus 22 & 23 & 24 and added then merged the Transmission Line Lengths into one.
- Removed Bus 25 & 51 and added then merged the Transmission Line Lengths into one.
- Removed Bus 47 & 46 & 45 & 44 and added then merged the Transmission Line Lengths into one.
- Removed Bus 39 and added the merged then Transmission Line Lengths into one.
- Removed Bus 41 and added the merged then Transmission Line Lengths into one.
- Removed Bus 42 & 43 and added the merged then Transmission Line Lengths into one.
- Removed Bus 46 and added the merged then Transmission Line Lengths into one.
- Removed Bus 49 and added the merged then Transmission Line Lengths into one.
- Removed Bus 10B & 10A & 15 because there was no load connected to that bus.
- Removed Bus 35 and added the merged then Transmission Line Lengths into one.

Revised One Line Diagram Total Busses 24 – Year 2010

One-Line Diagram - Revised-2010 (Edit Mode)

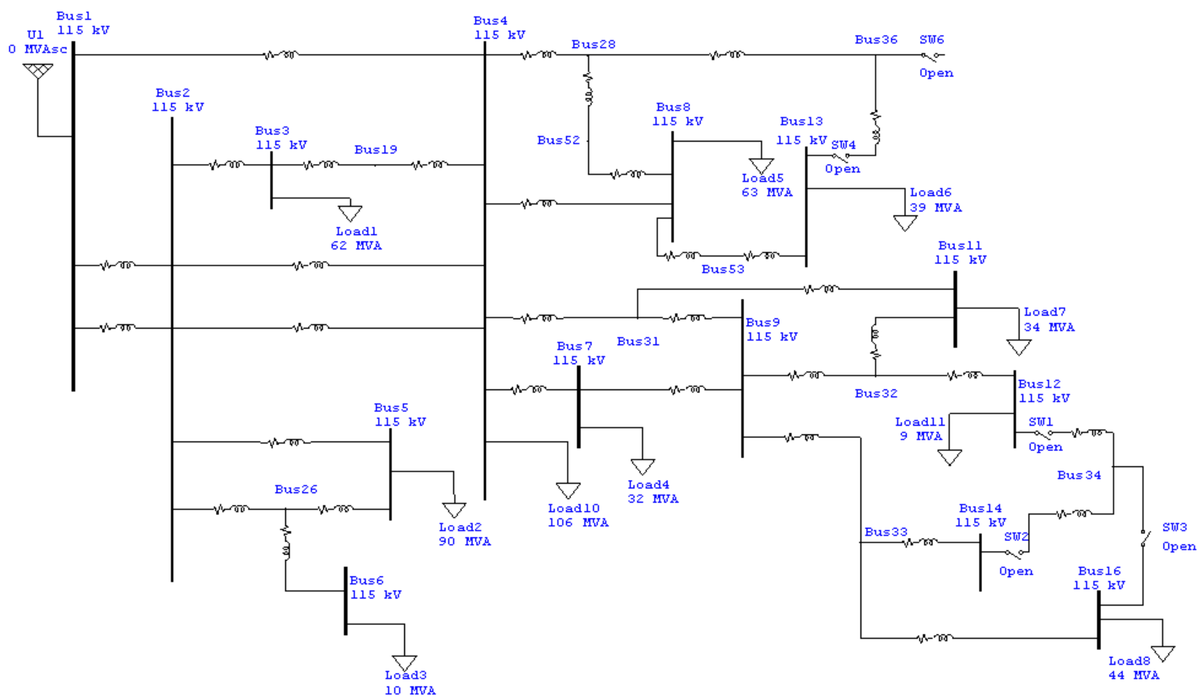


Figure 2 - One Line Diagram 24 Busses

Load Flow Analysis

We begin by running a load flow of the simplified system for the year 2010 loading conditions. In figure 3 certain busses are colored differently which states the level of voltage difference from nominal value. A bus that is red is more than 5% from the nominal value and does not meet the standard for normal operation nor N-1 contingency operation. A bus that is pink is more than 2% from the nominal value and does not meet the standard for normal operation but does meet the N-1 contingency standard for operation.

Load Flow Analysis before modifications – Year 2010

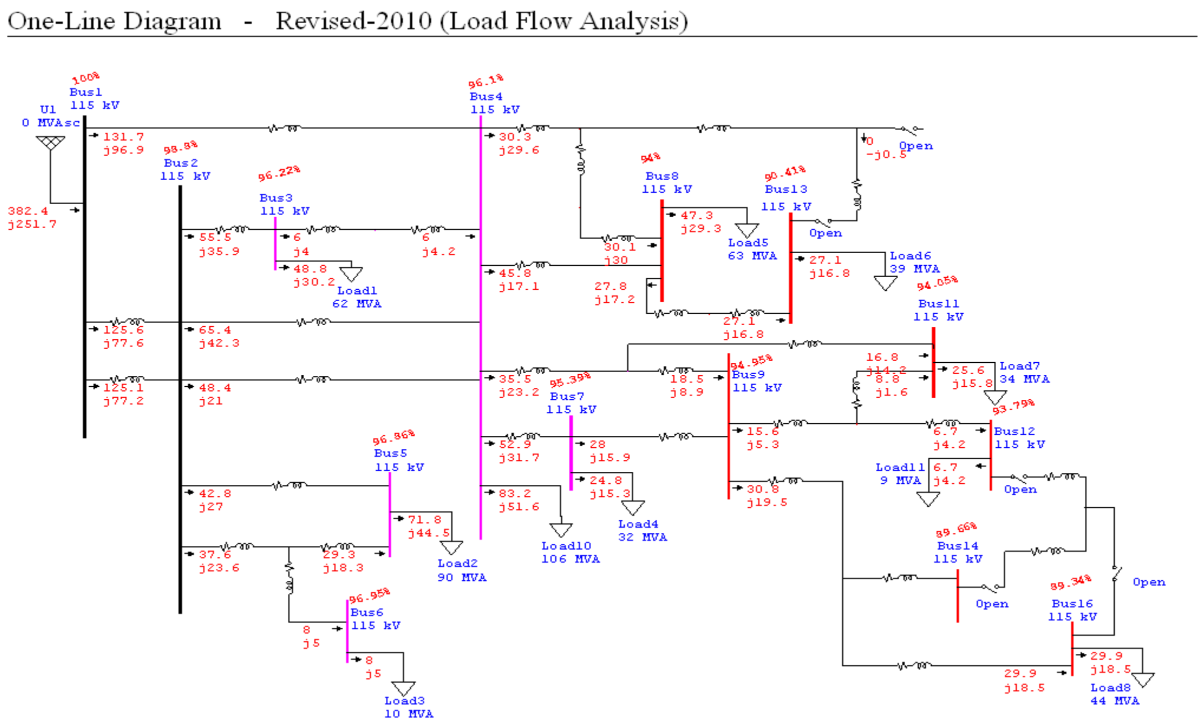


Figure 3 - Load Flow before modifications year 2010

There are many ways to try and improve the voltage levels are certain busses on the system and one of those ways is by adding capacitors to the bus to increase the voltage level at that bus. Because of the voltage sag on a couple of buses capacitors were added to the system. Even though the system is an interconnected system there are certain areas of the system that are more of a radial nature which did see more of an effect of the voltage drop that other parts of the system. Capacitors were added to the buses one by one starting at the end of the system or farthest away from the source and then load flow was ran to see how the capacitors improved the system voltage levels. Capacitors were added until every bus was over 98% for normal operating conditions and over 95% for N-1 contingencies. The capacitor with the greatest value was 50000 KVARS added to bus 4. The capacitor with the smallest value was 15000 KVARS added to bus 6.

Load Flow Analysis after modifications – Year 2010

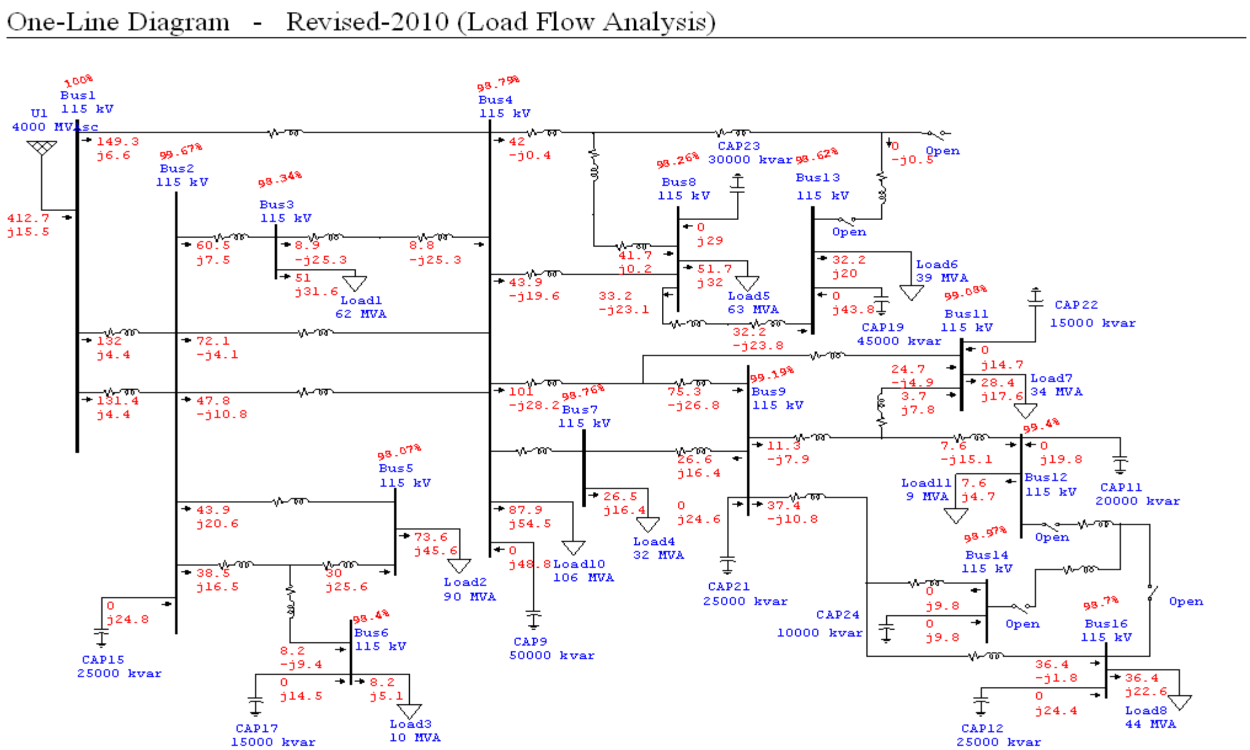


Figure 4 - Load flow after modifications year 2010

Capacitor Banks added to Busses 2, 4, 6, 8, 9, 11, 12, 13, 14, & 16

After the system was modified for normal operating conditions you must make sure the N-1 contingencies are also correct. Systematically you must go through each line and take it out of service and see how it affects the system as far as voltage levels and possible overloading is concerned. I would suggest analyzing the loading at normal operating conditions and finding the lines carrying the most current in them and taking them out first and working your way down each line with less and less current. You will find out that the line that does the most damage to the circuit if taken out of service is almost always the line with the most current or the line with the most loading in the system. Below in figure 5 is the worst case N-1 with line 1-4 taken out of service and showing how the voltage levels of the system come out with that line out of service. Since no bus voltage dropped below 95% there was no need to add additional capacitors to the system for the N-1 case.

Load Flow Analysis after modifications (N-1) Worst Case – Year 2010

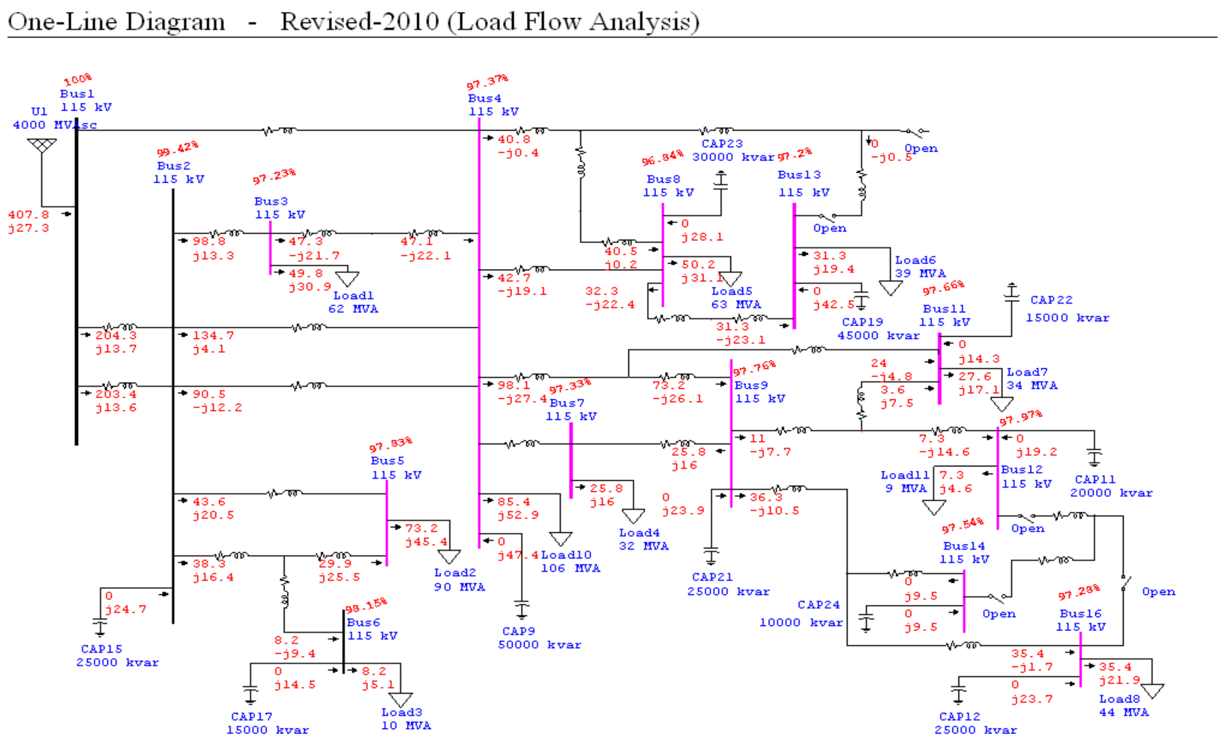


Figure 5 - Load Flow N-1 year 2010

No Capacitor banks needed to be added as the voltage didn't sag below 95% at any bus

In the year 2015 each load was increased based on the linear extrapolation of the loading data given. Load flow was again run and improvements needed to be made to meet the requirements for voltage levels for the system were done. Since capacitors from year 2010 were already in place the voltage drop was not nearly as drastic as it was in year 2010 and therefore a fewer number of capacitors were needed to increase the voltage to the required levels.

Load Flow Analysis before modifications – Year 2015

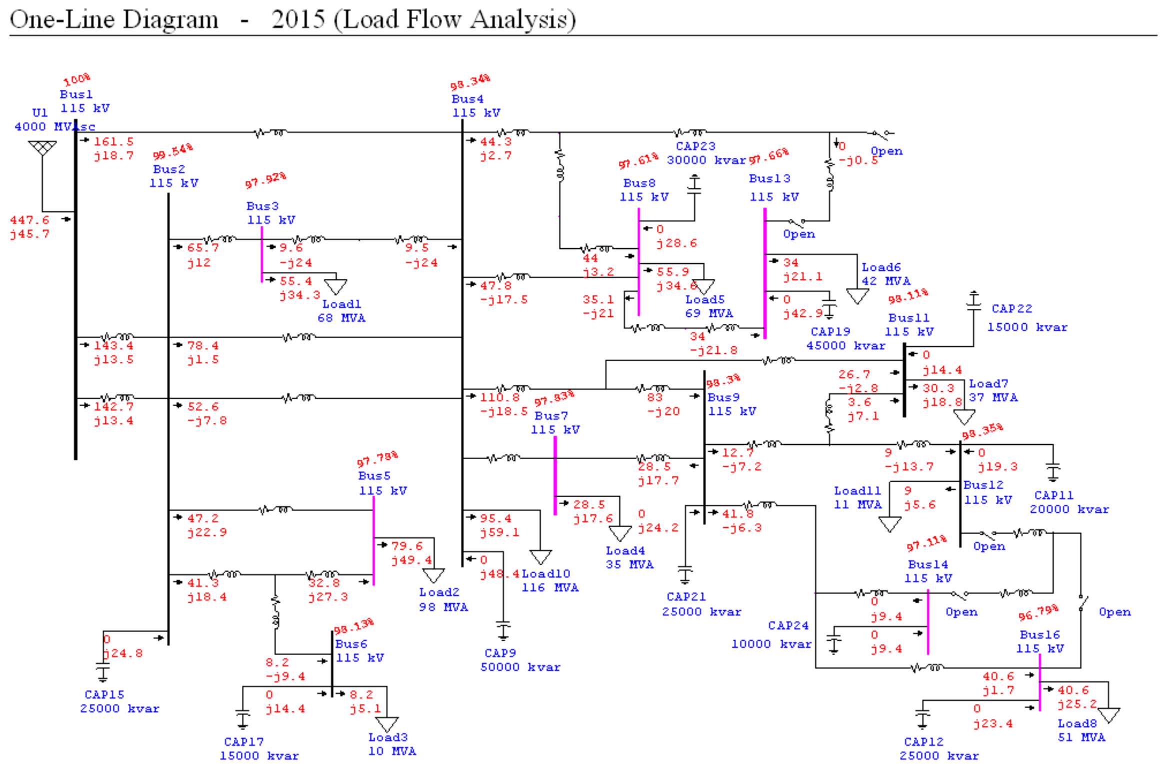


Figure 6 - Load Flow before modifications year 2015

There are many ways to try and improve the voltage levels at certain busses on the system and one of those ways is by adding capacitors to the bus to increase the voltage level at that bus. Because of the previous capacitors added to the system for year 2010 only a few capacitors were added as well as some of the capacitors were increased. Even though the system is an interconnected system there are certain areas of the system that are more of a radial nature which did see more of an effect of the voltage drop that other parts of the system. Capacitors were increased to the buses one by one starting at the end of the system or farthest away from the source and then load flow was ran to see how the capacitors improved the system voltage levels.

Load Flow Analysis after modifications – Year 2015

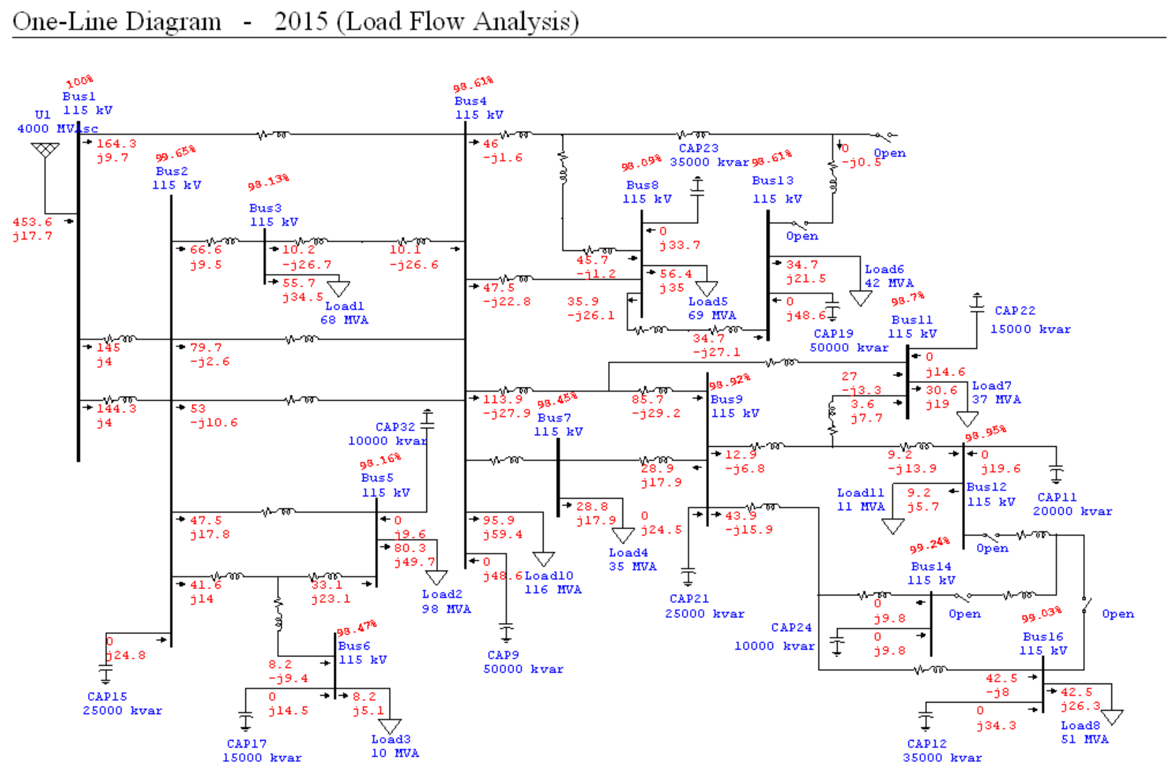


Figure 7 - Load flow after modifications year 2015

Capacitors banks added to busses 5 & increased 8, 13, 16

Again we must take into account the N-1 worst case scenario. As was the case for year 2010, there was no need to add any more capacitors for the worst case as the voltage levels did not dip below 5% of the nominal voltage levels. Again the line with the most loading current passing through it was the worst case which was from bus 1 to bus 4.

Load Flow Analysis after modifications (N-1) Worst Case – Year 2015

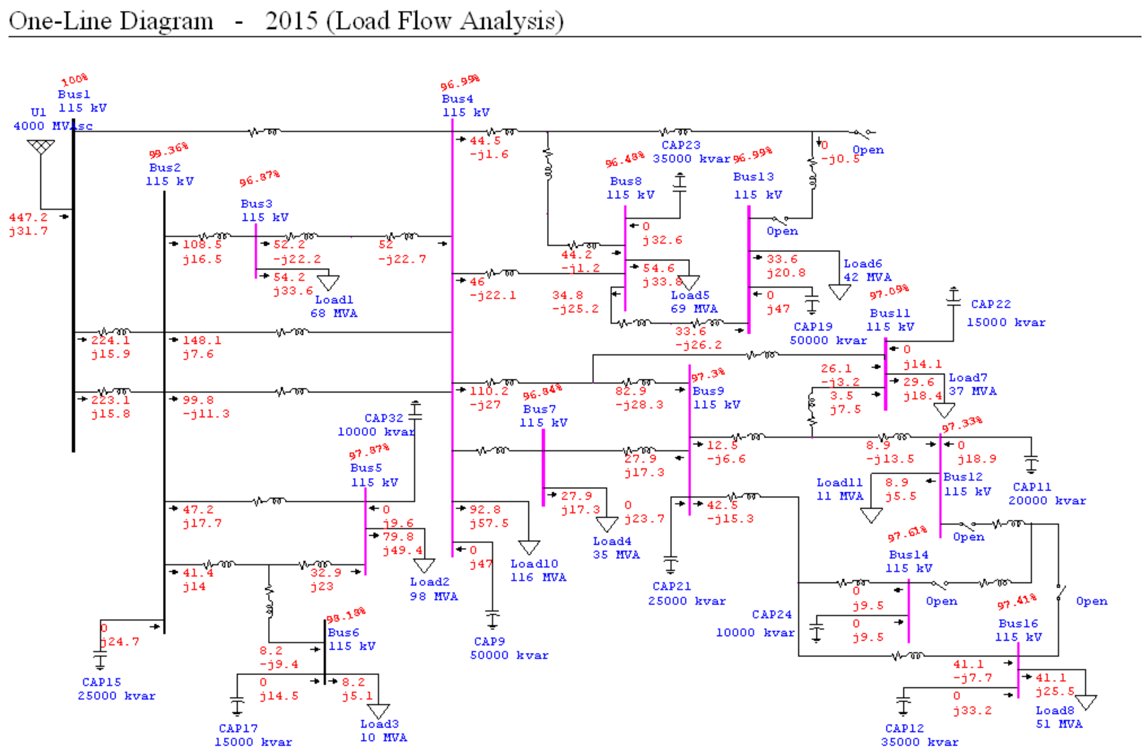


Figure 8 - Load flow N-1 year 2015

No Capacitor banks needed to be added as the voltage didn't sag below 95% at any bus

Fault Analysis

Fault analysis is run to be able to determine the maximum fault duty at each bus to be able to configure and size the equipment to be able to handle that amount of current for a short period of time. We also run short circuit analysis to determine fault current for different types of faults including three-phase, single-line,-ground line-line, and double-line-ground. This will give us pretty close approximations to be able to set up our protection to be able to sense certain currents in the line and trip the breakers at the correct time.

Fault Analysis after modifications – Duty Cycle (Data)

Below is the data for the Fault Analysis Duty Cycle. Things to note first that bus 1 has the most current flowing as that is considered the infinite bus and therefore all the generation passes through that bus. The bus with the second greatest amount of fault current was bus 2. This was due to the fact that it had two parallel lines from the infinite bus to it which increased the fault current drastically. Bus 4 was the third greatest which is a big reason why line 1-4 was the greatest trouble when completing N-1 contingency load flow analysis.

Momentary Duty Summary Report

3-Phase Fault Currents: (Prefault Voltage = 100 % of the Bus Nominal Voltage)

Bus		Device		Momentary Duty			
ID	kV	ID	Type	Symm. kA rms	X/R Ratio	Asymm. kA rms	Asymm. kA Peak
Bus1	115.000	Bus1	Bus	**20.082**	**0.6**	**20.083**	**28.579**
Bus2	115.000	Bus2	Bus	17.311	0.8	17.320	25.046
Bus3	115.000	Bus3	Bus	11.068	1.3	11.141	16.930
Bus4	115.000	Bus4	Bus	13.698	1.1	13.733	20.348
Bus5	115.000	Bus5	Bus	9.199	1.6	9.379	14.838
Bus6	115.000	Bus6	Bus	7.437	1.9	7.684	12.448
Bus7	115.000	Bus7	Bus	10.504	1.4	10.613	16.374
Bus8	115.000	Bus8	Bus	8.047	1.4	8.146	12.646
Bus9	115.000	Bus9	Bus	9.375	1.5	9.528	14.959
Bus11	115.000	Bus11	Bus	6.132	1.8	6.324	10.220
Bus12	115.000	Bus12	Bus	4.268	1.6	4.353	6.892
Bus13	115.000	Bus13	Bus	2.830	1.6	2.882	4.544
Bus14	115.000	Bus14	Bus	2.063	2.4	2.208	3.706
Bus16	115.000	Bus16	Bus	2.128	2.4	2.273	3.808
Bus19	115.000	Bus19	Bus	12.358	1.2	12.417	18.679
Bus26	115.000	Bus26	Bus	9.180	1.6	9.361	14.813
Bus28	115.000	Bus28	Bus	8.516	1.5	8.648	13.548
Bus31	115.000	Bus31	Bus	9.388	1.5	9.544	14.994
Bus32	115.000	Bus32	Bus	6.081	1.8	6.258	10.079
Bus33	115.000	Bus33	Bus	2.236	2.3	2.379	3.975
Bus36	115.000	Bus36	Bus	3.944	1.4	3.986	6.156
Bus52	115.000	Bus52	Bus	8.125	1.5	8.241	12.871
Bus53	115.000	Bus53	Bus	3.941	1.4	3.979	6.123

Table 2 - Fault Analysis Duty Cycle Data

Fault Analysis after modifications – 4 Cycles & 30 Cycles (Data)

The data below consists of fault analysis for 4 and 30 cycles as well as every type of fault that can occur on a system. With the exception of Bus 2, which had Line-Line-Ground faults as the greatest, every bus had a 3-phase fault as the fault with the most current flow. Line-Ground faults were always the fault with the lowest amount of current.

All fault currents are symmetrical momentary (1.5-4 Cycle network) values in rms kA

All fault currents are symmetrical momentary (30 Cycle network) values in rms kA

* LLG fault current is the larger of the two faulted line currents

Bus		3-Phase Fault (Year)			Line-to-Ground Fault (Year)			Line-to-Line Fault (Year)			*Line-to-Line-to-Ground (Year)		
ID	**kV**	**2010**	**2015**	**2020**	**2010**	**2015**	**2020**	**2010**	**2015**	**2020**	**2010**	**2015**	**2020**
Bus1	115.00	20.082	20.082	20.082	20.082	20.082	20.082	17.391	17.391	17.391	20.082	20.082	20.082
Bus2	115.00	17.311	17.311	17.311	15.678	15.678	15.678	14.991	14.991	14.991	**17.502**	**17.502**	**17.502**
Bus3	115.00	**11.068**	**11.068**	**11.068**	8.538	8.538	8.538	9.585	9.585	9.585	10.818	10.818	10.818
Bus4	115.00	**13.698**	**13.698**	**13.698**	11.313	11.313	11.313	11.863	11.863	11.863	13.620	13.620	13.620
Bus5	115.00	**9.199**	**9.199**	**9.199**	6.544	6.544	6.544	7.967	7.967	7.967	8.785	8.785	8.785
Bus6	115.00	**7.437**	**7.437**	**7.437**	5.072	5.072	5.072	6.441	6.441	6.441	7.014	7.014	7.014
Bus7	115.00	**5.414**	**5.414**	**5.414**	3.535	3.535	3.535	4.688	4.688	4.688	5.035	5.035	5.035
Bus8	115.00	**8.047**	**8.047**	**8.047**	5.947	5.947	5.947	6.969	6.969	6.969	7.780	7.780	7.780
Bus9	115.00	**6.781**	**6.781**	**6.781**	4.558	4.558	4.558	5.872	5.872	5.872	6.363	6.363	6.363
Bus11	115.00	**5.067**	**5.067**	**5.067**	3.355	3.355	3.355	4.388	4.388	4.388	4.737	4.737	4.737
Bus12	115.00	**3.725**	**3.725**	**3.725**	2.485	2.485	2.485	3.226	3.226	3.226	3.512	3.512	3.512
Bus13	115.00	**2.830**	**2.830**	**2.830**	1.920	1.920	1.920	2.451	2.451	2.451	2.693	2.693	2.693
Bus14	115.00	**1.897**	**1.897**	**1.897**	1.204	1.204	1.204	1.643	1.643	1.643	1.750	1.750	1.750
Bus16	115.00	**1.953**	**1.953**	**1.953**	1.242	1.242	1.242	1.691	1.691	1.691	1.802	1.802	1.802
Bus19	115.00	**12.358**	**12.358**	**12.358**	9.785	9.785	9.785	10.703	10.703	10.703	12.161	12.161	12.161
Bus26	115.00	**9.180**	**9.180**	**9.180**	6.528	6.528	6.528	7.951	7.951	7.951	8.766	8.766	8.766
Bus28	115.00	**8.516**	**8.516**	**8.516**	6.175	6.175	6.175	7.375	7.375	7.375	8.183	8.183	8.183
Bus31	115.00	**7.367**	**7.367**	**7.367**	5.015	5.015	5.015	6.380	6.380	6.380	6.940	6.940	6.940
Bus32	115.00	**5.022**	**5.022**	**5.022**	3.339	3.339	3.339	4.349	4.349	4.349	4.702	4.702	4.702
Bus33	115.00	**2.043**	**2.043**	**2.043**	1.305	1.305	1.305	1.770	1.770	1.770	1.888	1.888	1.888
Bus36	115.00	**3.944**	**3.944**	**3.944**	2.757	2.757	2.757	3.415	3.415	3.415	3.790	3.790	3.790
Bus52	115.00	**8.125**	**8.125**	**8.125**	5.931	5.931	5.931	7.036	7.036	7.036	7.825	7.825	7.825
Bus53	115.00	**3.941**	**3.941**	**3.941**	2.786	2.786	2.786	3.413	3.413	3.413	3.799	3.799	3.799

Table 3 - Fault Analysis 4 Cycle Data

Below is a table for the loading data for the year 2010. Voltages are categorized from left to right showing before/after/N-1 conditions in percentage based on the nominal voltage levels. Voltage levels highlighted in red are levels which the system cannot operate in. Voltage levels in purple are levels in which the system can operate in but not for prolonged periods of time. Voltage levels in black are levels in which the standards are met for operation. Voltages before the modifications contain both purple and red voltage levels which are fixed to being all black after modifications. N-1 conditions contain purple voltage levels which is ok as long as the N-1 case does not persist through the system for long periods of time.

Year 2010 - Loading Data

Bus ID	Nominal kV	Voltage Before	Voltage After	N-1 Condition	MW Loading	Mvar Loading
Bus1	115	100 %	100 %	100 %	412.472	12.603
Bus2	115	98.8	99.68	99.42	262.472	44.222
Bus3	115	96.22	98.37	97.23	59.808	31.603
Bus4	115	96.1	98.83	97.37	274.488	100.066
Bus5	115	96.86	98.08	97.83	73.593	45.609
Bus6	115	96.59	98.41	98.15	8.232	14.526
Bus7	115	95.39	98.82	97.33	58.514	29.816
Bus8	115	94	98.3	96.84	85.01	52.278
Bus9	115	94.59	99.24	97.76	51.621	44.571
Bus11	115	94.05	99.1	97.66	28.38	21.18
Bus12	115	93.79	99.41	97.09	7.559	19.763
Bus13	115	90.41	98.66	97.2	32.267	43.801
Bus16	115	89.34	98.75	97.28	36.474	24.381

Table 4 - Loading Data 2010

Below is a table for the loading data for the year 2015. As stated above the goal is to bring the voltage levels for every bus into the black range which is plus or minus 2% from the nominal value. Since there are capacitors from the previous 5 year forecast there are no voltage levels in red before modifications which minimizes the amount of changes needed to be made to the system. Again some capacitors were added as well as some capacitors were increased in order to bring the system to the specifications needed in voltage levels.

Year 2015 - Loading Data

Bus ID	Nominal kV	Voltage Before	Voltage After	N-1 Condition	MW Loading	Mvar Loading
Bus1	115	100 %	100 %	100 %	453.51	14.066
Bus2	115	99.54	99.67	99.36	288.269	40.742
Bus3	115	97.92	98.17	96.87	65.848	34.522
Bus4	115	98.34	98.66	96.99	303.071	104.789
Bus5	115	97.78	98.17	97.87	80.28	49.753
Bus6	115	98.13	98.49	98.19	8.244	14.549
Bus7	115	97.83	98.62	96.84	65.895	31.509
Bus8	115	97.61	98.14	96.48	92.451	59.789
Bus9	115	98.3	99.05	97.3	60.146	48.575
Bus11	115	98.11	98.78	97.09	30.69	20.951
Bus12	115	98.35	99.03	97.33	9.169	19.613
Bus13	115	97.66	98.66	96.99	34.752	48.672
Bus16	115	96.79	99.16	97.41	42.625	34.414

Table 5 - Loading Data 2015

Conclusion

Forecasting for future loading conditions is a great way to prepare yourself for the future as loading will most likely always increase and you must be able to meet demand all the time. In this study load forecasting was done for ten years into the future and corrections were made for the original year as well as every 5 years after that. From the original system there was considerable voltage sags within the system especially as you moved farther away from the infinite bus. The solution to the problem of voltage sag was to place large capacitor banks at certain locations within the system to boost the voltage at those points and obtain operational voltage levels. The process was to start farthest away from the infinite bus and add one capacitor bank at a time and re run the load flow to analyze what each did to the system. Once every bus was within 2% of the nominal voltage levels one line at a time was taken out of service and again load flow was run to see voltage levels in the system.

Short circuit analysis was run to be able to correctly size protection equipment as well as the transmission line equipment for possible fault conditions on the system. As the loading increased from the forecast there was no increase in the fault duty cycle for the system. This is due to the fact that no new generation was being added to the system which would increase the fault duty cycle. Basic overcurrent relay protection was added to the system to minimize the duration for faults that might occur on the system. Coordination for relays was made so that relays next to loads would operate the fastest and delays would be added for the subsequent relays upstream of the relays at the loads.

Overall the forecast study proves that you need to be able to predict future loading conditions to be able to efficiently and effectively run a power system in a world that is always growing. Being able to forecast this future growth will give you the knowledge you need to keep customers online and happy as well as keep everyone safe.

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Appendix

Load Flow Analysis before modifications – Year 2020

One-Line Diagram - 2020 (Load Flow Analysis)

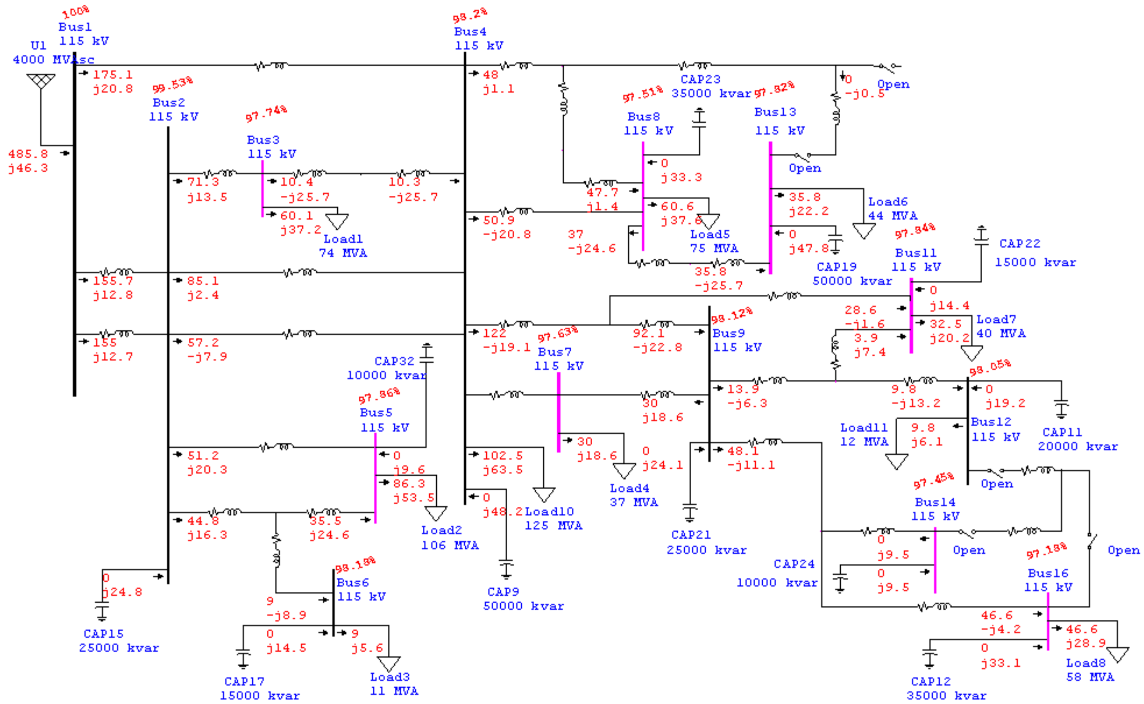

Figure 9 - Load Flow before modifications year 2010

Load Flow Analysis after modifications – Year 2020

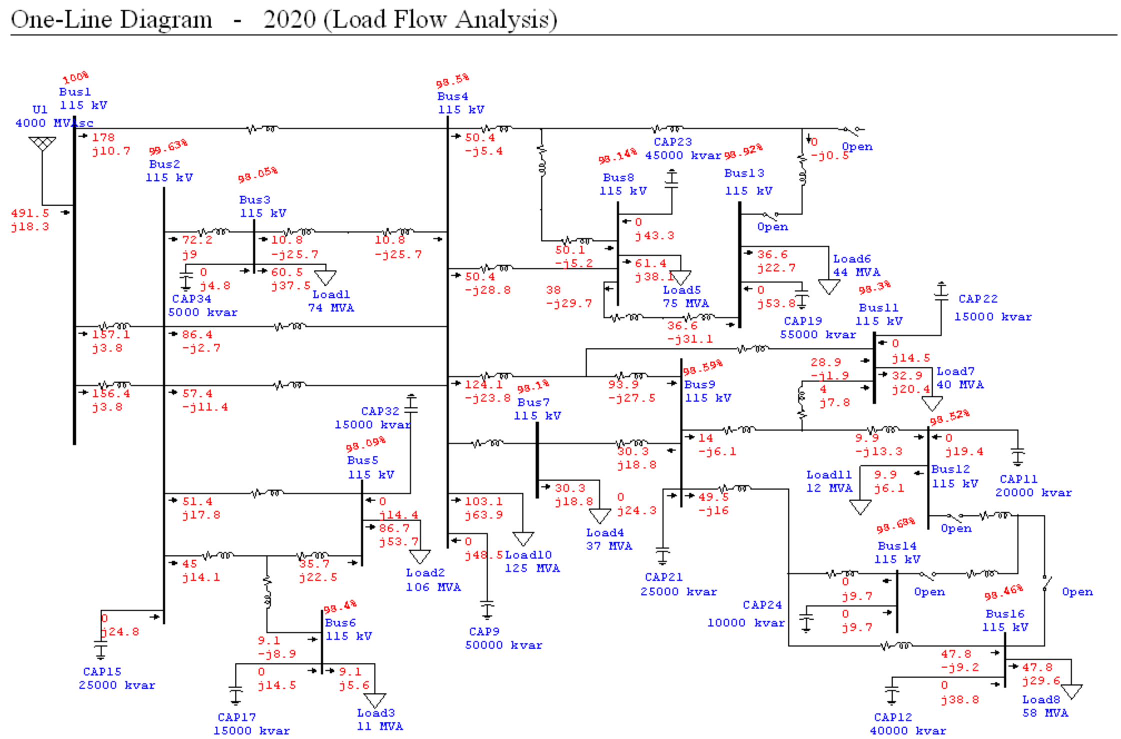

Figure 10 - Load flow after modifications year 2020

Capacitors banks added to busses 3 & increased 5, 8, 13, 16

Load Flow Analysis after modifications (N-1) Worst Case – Year 2020

One-Line Diagram - 2020 (Load Flow Analysis)

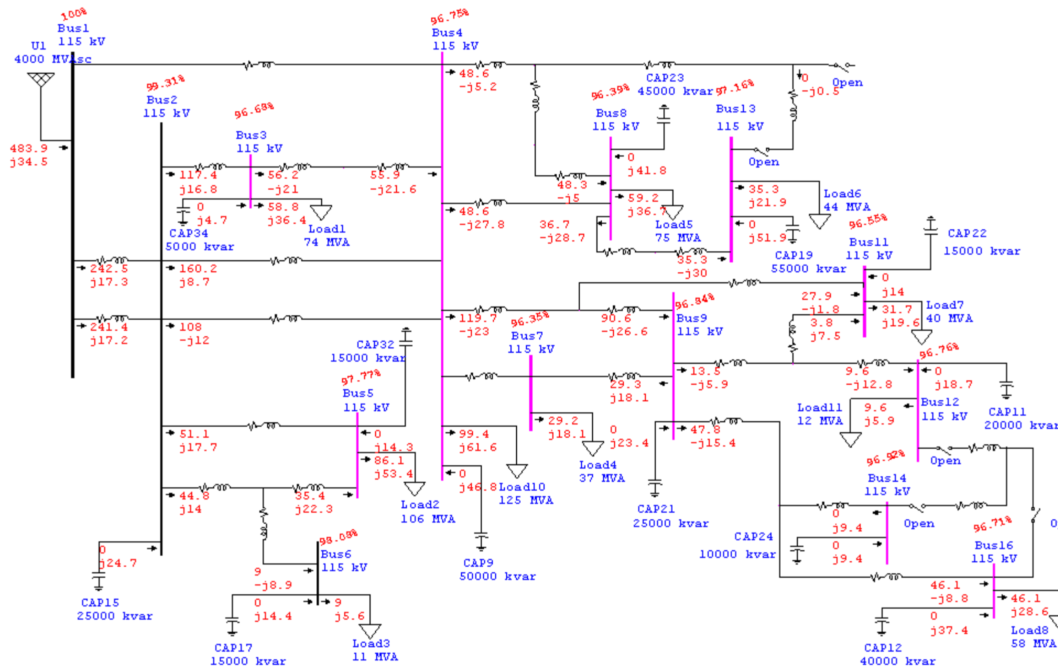

Figure 11 - Load flow N-1 year 2020

No Capacitor banks needed to be added as the voltage didn’t sag below 95% at any bus

Year 2020 - Loading Data

Bus ID	Nominal kV	Voltage Before	Voltage After	N-1 Condition	MW Loading	Mvar Loading
Bus1	115	100 %	100 %	100 %	491.464	18.257
Bus2	115	99.53	99.63	99.31	312.43	40.863
Bus3	115	97.74	98.05	96.96	71.317	37.474
Bus4	115	98.2	98.5	96.75	327.984	107.775
Bus5	115	97.86	98.09	97.77	86.696	53.729
Bus6	115	98.19	98.4	98.08	9.053	14.523
Bus7	115	97.63	98.1	96.35	30.267	18.758
Bus8	115	97.15	98.14	96.39	99.427	73.065
Bus9	115	98.12	98.59	96.84	93.879	46.334
Bus11	115	97.84	98.3	96.55	32.855	22.258
Bus12	115	98.05	98.52	96.76	9.9	19.411
Bus13	115	97.82	98.92	97.16	36.599	53.822
Bus16	115	97.18	98.46	96.71	47.796	38.78

Table 6 - Loading Data 2020

Fault Analysis after modifications (Device Duty) – Year 2010

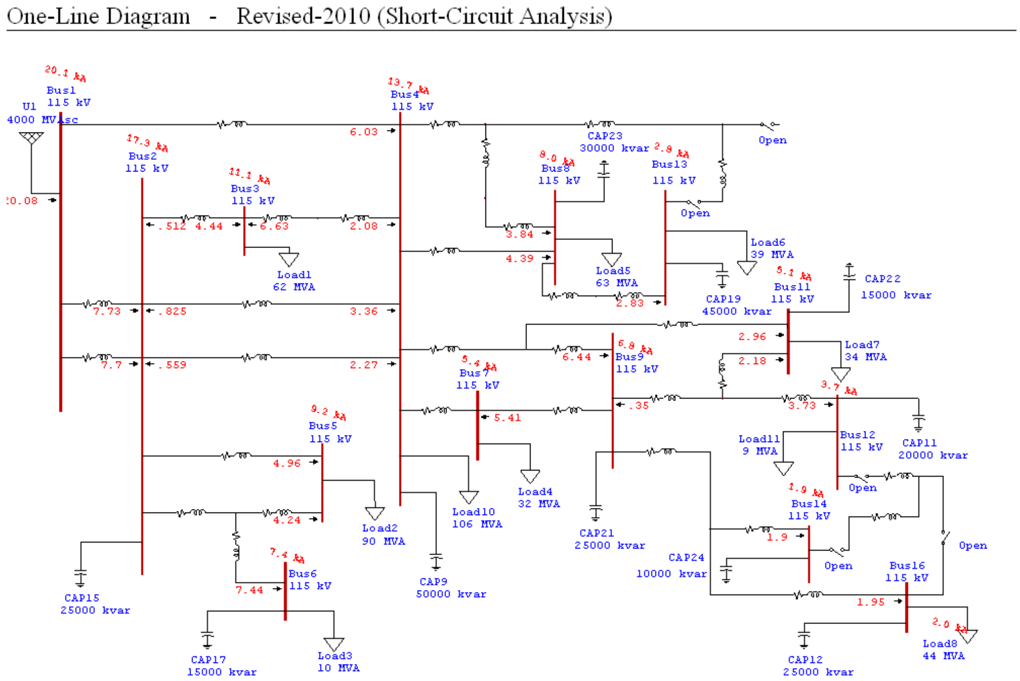

Figure 12 - Fault Analysis 2010 Device Duty

Fault Analysis after modifications (30 Cycles) – Year 2010

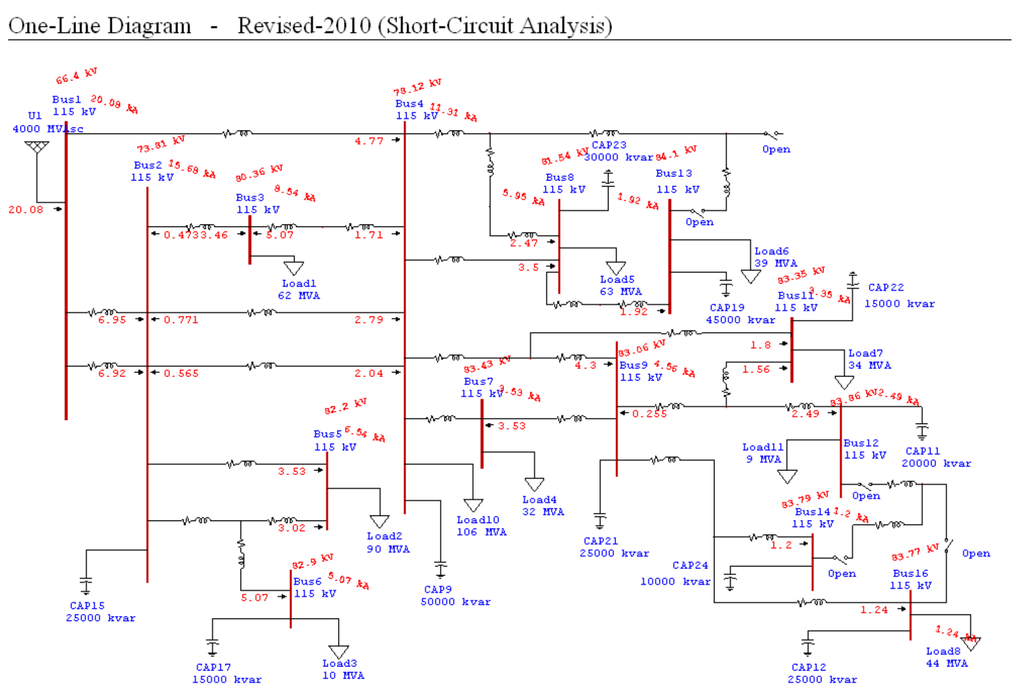

Figure 13 - Fault Analysis 2010 30 Cycles

Fault Analysis after modifications (Device Duty) – Year 2015

One-Line Diagram - 2015 (Short-Circuit Analysis)

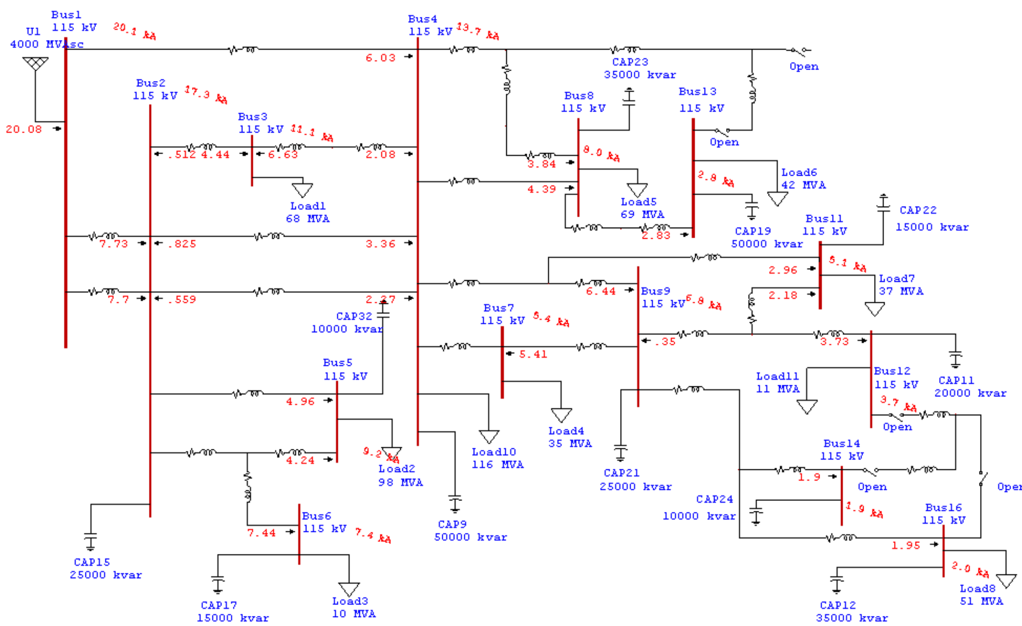

Figure 14 - Fault Analysis 2015 - Device Duty

Fault Analysis after modifications (30 Cycles) – Year 2015

One-Line Diagram - 2015 (Short-Circuit Analysis)

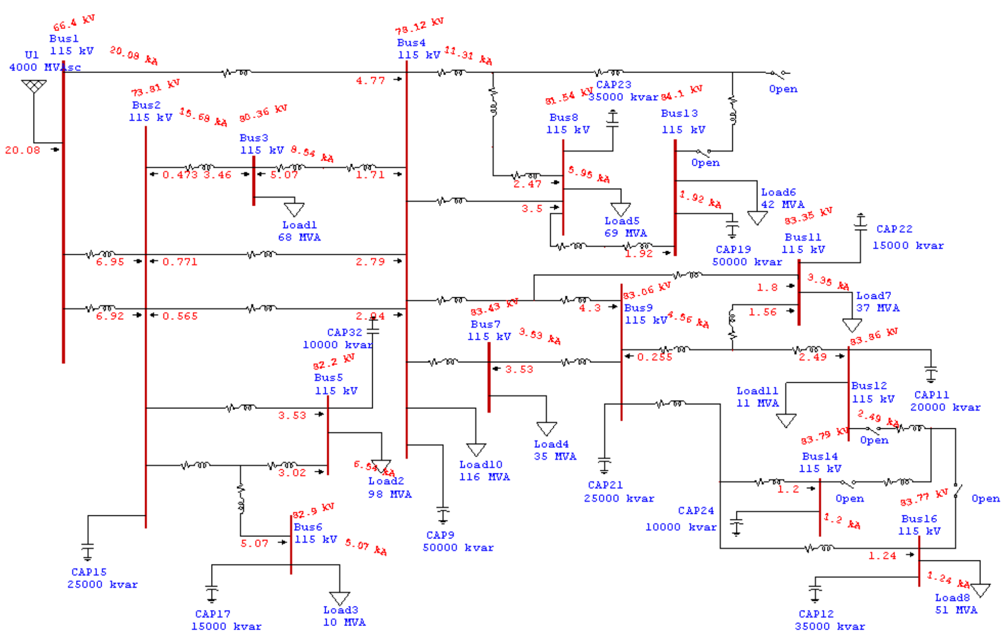

Figure 15 - Fault Analysis 2015 30 Cycles

Fault Analysis after modifications (Device Duty) – Year 2020

One-Line Diagram - 2020 (Short-Circuit Analysis)

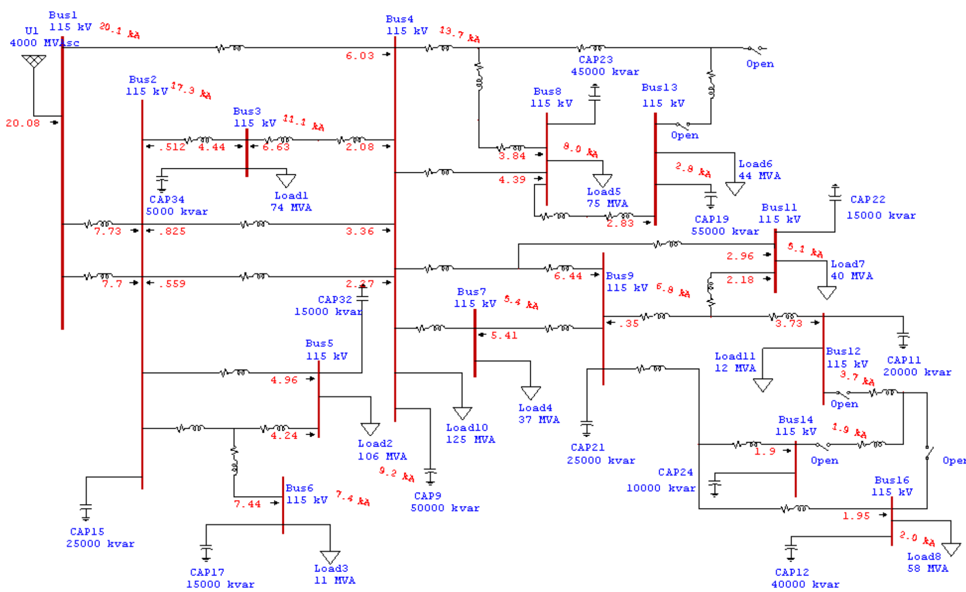

Figure 16 - Fault Analysis 2020 Device Duty

Fault Analysis after modifications (30 Cycles) – Year 2020

One-Line Diagram - 2020 (Short-Circuit Analysis)

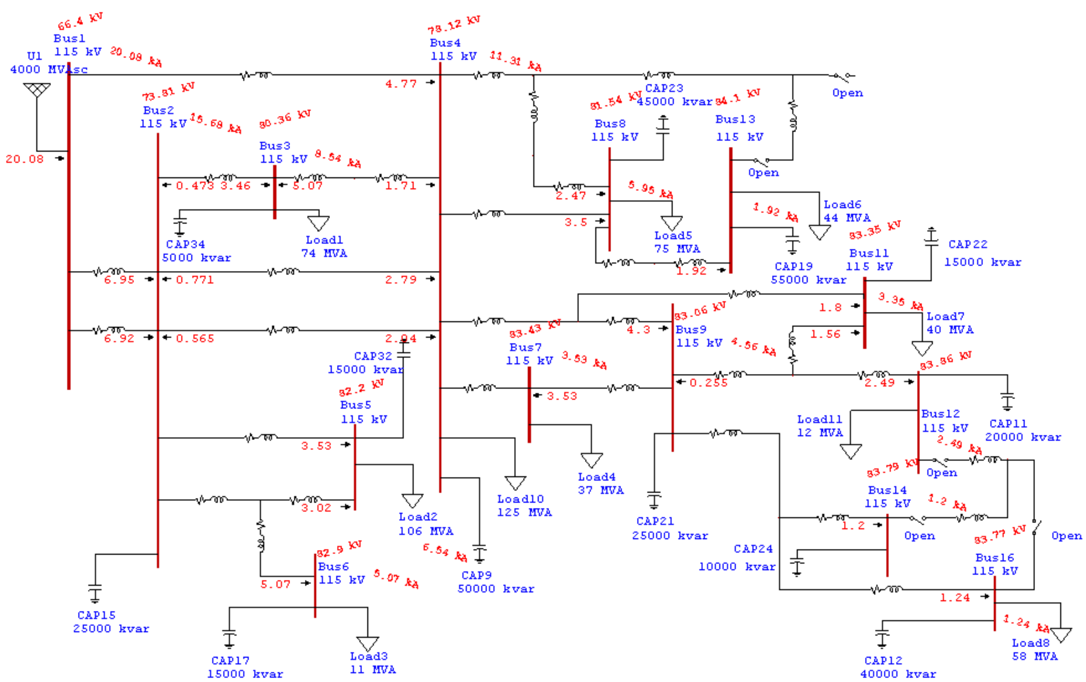

Figure 17 - Fault Analysis 2020 30 Cycles