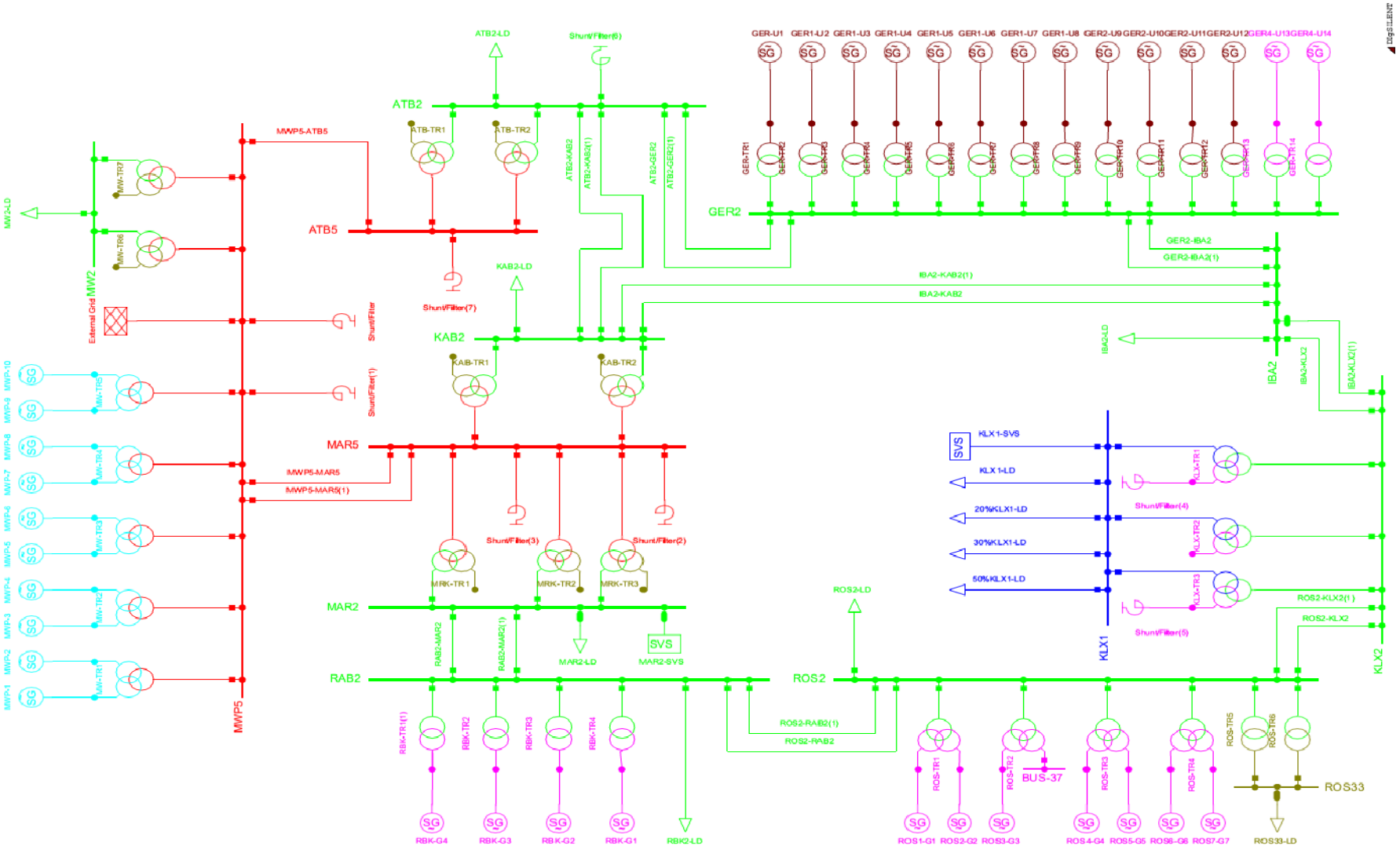


Figure 4.1: 14bus Sudanese national grid

4.3 Steady State Operation:

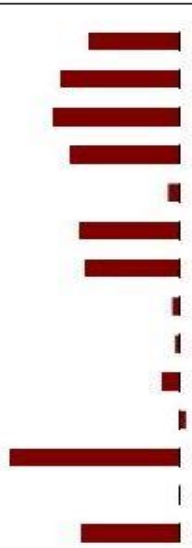
Table 4.2: voltage profile of steady state operation of 14bus Sudanese national grid

Load Flow Calculation — Complete System Report: Voltage Profiles

Grid: 16 Bus Sudanese Grid | System Stage: 16 Bus Sudanese | Study Case: Study Case | Annex: / 1

	rtd.V [kV]	Bus - voltage [p.u.]	[kV]	[deg]
ROS2	220.00	0.972	213.84	-13.50
MAR2	220.00	0.963	211.87	-7.82
KLX2	220.00	0.961	211.45	-8.98
IBA2	220.00	0.967	212.64	-8.18
ATB5	500.00	0.996	497.94	-3.91
MAR5	500.00	0.969	484.70	-6.89
KAB2	220.00	0.971	213.66	-7.38
ATB2	220.00	0.997	219.39	-4.66
GER2	220.00	0.998	219.62	-5.16
MW2	220.00	0.994	218.75	-0.52
RAB2	220.00	1.002	220.39	-5.01
KLX1	110.00	0.948	104.30	-10.49
MWP5	500.00	1.000	500.00	0.00
ROS33	33.00	0.970	32.01	-13.69

Voltage - Deviation [%]: -10 -5 0 +5 +10



- observe that voltage levels within the specified limit

4.4 Case One: Sync M/C out of Service:

4.4.1 Discussion and Generalization:

According to simulation results the particulate outage of each sync M/C alone has insignificant impact, hence voltage profile remains within the specified limit, GER- U14, ROS- U5, And RAB- U4 have been taken as an example to simplify that.

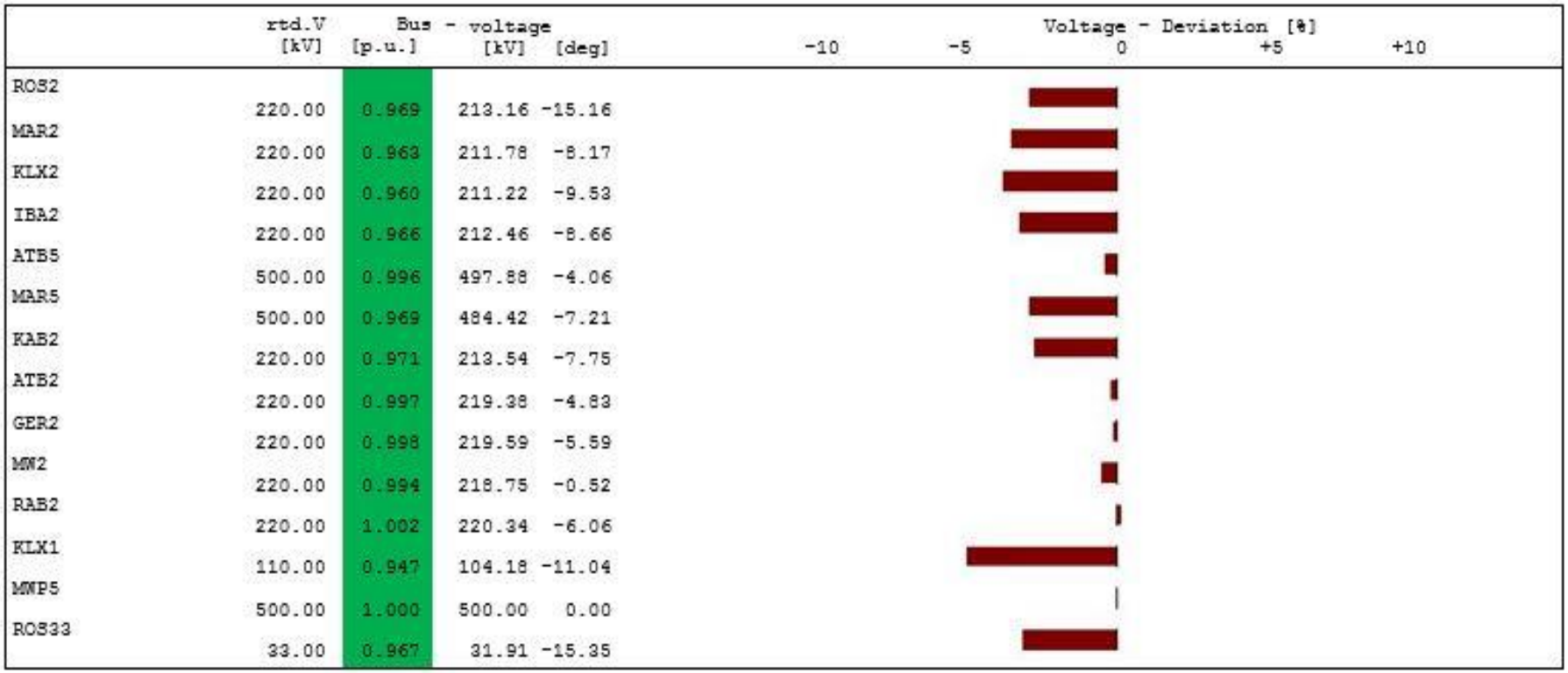
4.4.2 GER- U14 Sync M/C machine out of service:

Table 4.3: voltage profile when GER- U14 out of service

	rtd.V [kV]	Bus -voltage [p.u.]	[kV]	[deg]	Voltage - Deviation [%] -10 -5 0 +5 +10
ROS2	220.00	0.972	213.83	-13.83	
MAR2	220.00	0.963	211.84	-8.04	
KLX2	220.00	0.961	211.44	-9.35	
IBA2	220.00	0.967	212.63	-8.55	
ATB5	500.00	0.996	497.92	-4.07	
MAR5	500.00	0.969	484.63	-7.10	
KAB2	220.00	0.971	213.66	-7.64	
ATB2	220.00	0.997	219.40	-4.85	
GER2	220.00	0.998	219.56	-5.74	
MW2	220.00	0.994	218.75	-0.52	
RAB2	220.00	1.002	220.39	-5.29	
KLX1	110.00	0.948	104.29	-10.86	
MWP5	500.00	1.000	500.00	0.00	
ROS33	33.00	0.970	32.01	-14.02	

4.4.3 ROS U5 Sync M/C out of Service:

Table 4.4: voltage profile when ROS U5 out of service

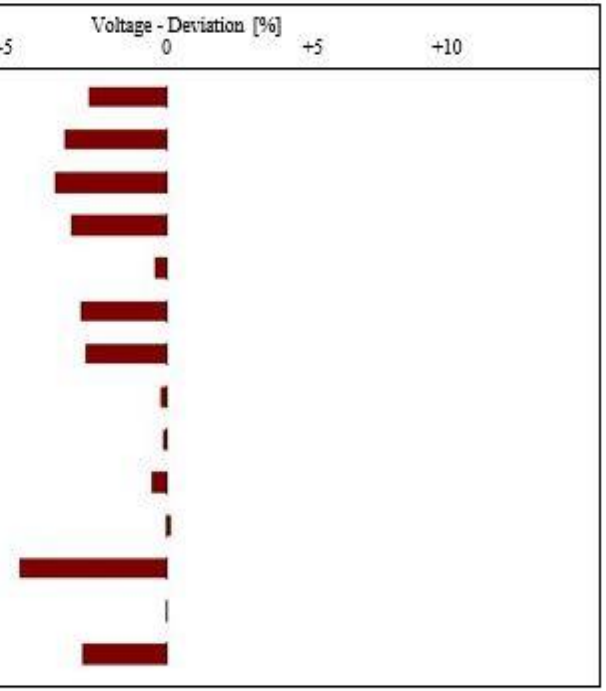


	rtd.V [kV]	Bus - voltage [p.u.]	[kV]	[deg]
ROS2	220.00	0.969	213.16	-15.16
MAR2	220.00	0.963	211.78	-8.17
KLX2	220.00	0.960	211.22	-9.53
IBA2	220.00	0.966	212.46	-8.66
ATB5	500.00	0.996	497.88	-4.06
MAR5	500.00	0.969	484.42	-7.21
KAB2	220.00	0.971	213.54	-7.75
ATB2	220.00	0.997	219.38	-4.83
GER2	220.00	0.998	219.59	-5.59
MW2	220.00	0.994	218.75	-0.52
RAB2	220.00	1.002	220.34	-6.06
KLX1	110.00	0.947	104.18	-11.04
MWP5	500.00	1.000	500.00	0.00
ROS33	33.00	0.967	31.91	-15.35

4.4.4 RAB- U4 Sync M/C out of Service:

Table 4.5: voltage profile when RAB- U4 out of service

	rtd.V [kV]	Bus [p.u.]	- voltage [kV]	[deg]
ROS2	220.00	0.972	213.83	-16.31
MAR2	220.00	0.963	211.85	-8.85
KLX2	220.00	0.960	211.27	-10.16
IBA2	220.00	0.966	212.48	-9.27
ATB5	500.00	0.996	497.86	-4.26
MAR5	500.00	0.969	484.40	-7.79
KAB2	220.00	0.971	213.54	-8.32
ATB2	220.00	0.997	219.40	-5.07
GER2	220.00	0.998	219.59	-6.12
MW2	220.00	0.994	218.75	-0.52
RAB2	220.00	1.001	220.30	-9.76
KLX1	110.00	0.947	104.20	-11.67
MWP5	500.00	1.000	500.00	0.00
ROS33	33.00	0.970	32.01	-16.50



4.5 Case Two: T.L out of service:

4.5.1 Discussion and Generalization:

According to simulation results the particular outage of each T.L alone has insignificant impact, hence voltage profile remains within the specified limit, MW5-MAR5 T.L, IBA2-KLX2 T.L have been taken as an example to simplify that.

4.5.2 MW5-MAR5 T.L out of Service:

Table 4.6: voltage profile when MW5-MAR5 T.L out of service

	rtd.V [kV]	Bus - voltage [p.u.]	[kV]	[deg]	Voltage - Deviation [%] −10 −5 0 +5 +10
ROS2	220.00	0.968	213.02	-18.89	
MAR2	220.00	0.923	203.06	-13.03	
KLX2	220.00	0.938	206.46	-13.84	
IBA2	220.00	0.943	207.48	-12.98	
ATB5	500.00	0.988	494.03	-5.59	
MAR5	500.00	0.929	464.27	-12.02	
KAB2	220.00	0.937	206.08	-12.22	
ATB2	220.00	0.989	217.59	-6.67	
GER2	220.00	0.994	218.78	-9.60	
MW2	220.00	0.994	218.75	-0.52	
RAB2	220.00	1.000	219.96	-10.51	
KLX1	110.00	0.925	101.77	-15.42	
MWP5	500.00	1.000	500.00	0.00	
ROS33	33.00	0.966	31.89	-19.08	

4.5.3 IBA2-KLX2 T.L out of Service:

Table 4.7: voltage profile when IBA2-KLX2 T.L out of service

	rtd.V [kV]	Bus [p.u.]	-voltage [kV]	[deg]	Voltage - Deviation[%] -10 -5 0 +5 +10
ROS2	220.00	0.971	213.64	-14.13	
MAR2	220.00	0.963	211.87	-7.85	
KLX2	220.00	0.956	210.24	-9.76	
IBA2	220.00	0.966	212.59	-8.17	
ATB5	500.00	0.996	497.93	-3.91	
MAR5	500.00	0.969	484.66	-6.91	
KAB2	220.00	0.971	213.62	-7.38	
ATB2	220.00	0.997	219.38	-4.66	
GER2	220.00	0.998	219.61	-5.15	
MW2	220.00	0.994	218.75	-0.52	
RAB2	220.00	1.002	220.38	-5.36	
KLX1	110.00	0.943	103.68	-11.28	
MWP5	500.00	1.000	500.00	0.00	
ROS33	33.00	0.969	31.98	-14.32	

4.6 Case Three: Load out of service:

4.6.1 Discussion and Generalization:

This case causes voltage profile moves towards the positive limit; because the total load decreases.

According to simulation results the particular outage of each load alone has insignificant impact, hence voltage profile remains within the specified limit, MAR2 load has been taken as an example to simplify that.

4.6.2 MAR2 load out of Service:

Table 4.8: voltage profile when MAR2 load out of service

	rtd.V [kV]	Bus - voltage [p.u.]	[kV]	[deg]	Voltage - Deviation [%] −10 −5 0 +5 +10
MAR2	220.00	0.975	214.58	-8.33	
KLX2	220.00	1.009	221.94	-2.19	
IBA2	220.00	0.982	216.01	-4.55	
ATB5	220.00	0.988	217.36	-3.82	
MAR5	500.00	1.002	500.84	-2.36	
KAB2	500.00	1.007	503.61	-2.28	
ATB2	220.00	1.003	220.61	-3.00	
GER2	220.00	1.003	220.72	-2.80	
MW2	220.00	1.002	220.36	-1.12	
RAB2	220.00	0.994	218.75	-0.52	
KLX1	220.00	1.004	220.88	0.59	
MWP5	110.00	0.969	106.61	-6.00	
ROS33	500.00	1.000	500.00	0.00	
	33.00	0.973	32.12	-8.52	

4.7 Case Four: Load Increasing:

4.7.1 Discussion and Generalization:

This case causes voltage profile moves towards the negative limit; because the total load increases.

According to simulation results Load increasing by 20%, 30%, and 50% of each load alone has insignificant impact, hence the voltage profile remains within the specified limit, KLX1 load have been taken as an example to simplify that.

4.7.2 20% Increasing in KLX1 Load:

Table 4.9: voltage profile within the when 20% load increasing in KLX1 load

	rtd.V [kV]	Bus - voltage [p.u.]	[kV]	[deg]	Voltage - Deviation [%] -10 -5 0 +5 +10
ROS2	220.00	0.971	213.63	-14.29	
MAR2	220.00	0.960	211.31	-8.25	
KLX2	220.00	0.955	210.16	-9.80	
IBA2	220.00	0.962	211.66	-8.90	
ATB5	500.00	0.995	497.60	-4.13	
MAR5	500.00	0.967	483.38	-7.30	
KAB2	220.00	0.968	213.00	-7.89	
ATB2	220.00	0.997	219.24	-4.92	
GER2	220.00	0.998	219.47	-5.82	
MW2	220.00	0.994	218.75	-0.52	
RAB2	220.00	1.002	220.36	-5.64	
KLX1	110.00	0.939	103.34	-11.64	
MWP5	500.00	1.000	500.00	0.00	
ROS33	33.00	0.969	31.98	-14.48	

4.7.3 30% Increasing in KLX1 Load:

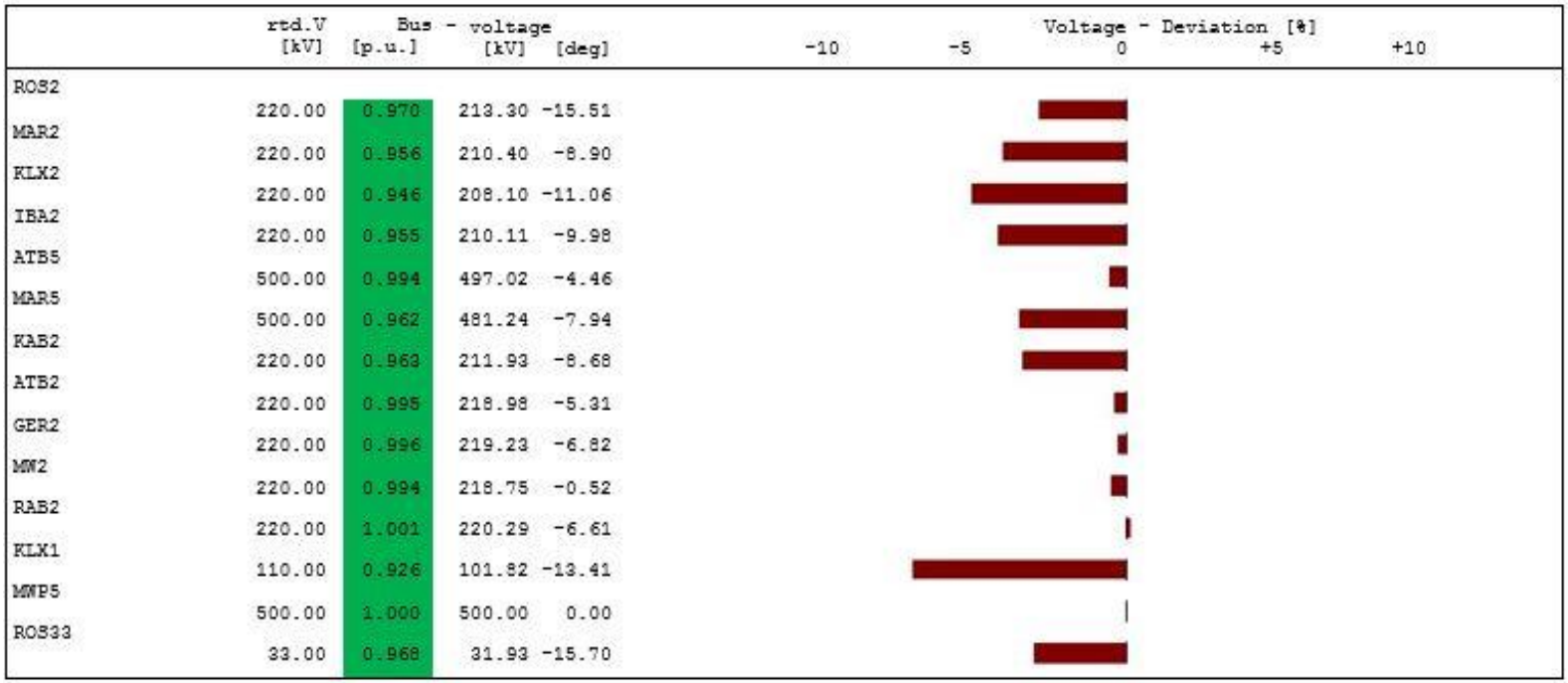
Table 4.10: voltage profile when 30% load increasing in KLX1 load

	rtd.V [kV]	Bus - voltage [p.u.]	[kV]	[deg]	Voltage - Deviation [%] −10 −5 0 +5 +10
ROS2	220.00	0.971	213.52	-14.69	
MAR2	220.00	0.959	211.01	-8.46	
KLX2	220.00	0.952	209.49	-10.22	
IBA2	220.00	0.960	211.16	-9.25	
ATB5	500.00	0.995	497.41	-4.24	
MAR5	500.00	0.965	482.69	-7.51	
KAB2	220.00	0.967	212.65	-8.15	
ATB2	220.00	0.996	219.16	-5.05	
GER2	220.00	0.997	219.39	-6.15	
MW2	220.00	0.994	218.75	-0.52	
RAB2	220.00	1.002	220.34	-5.96	
KLX1	110.00	0.935	102.84	-12.23	
MWP5	500.00	1.000	500.00	0.00	
ROS33	33.00	0.969	31.96	-14.89	

- Observe that voltage profile remains within specified limit when 30% increasing in KLX1 load.

4.7.4 50% Increasing in KLX1 load:

Table 4.11: voltage profile when 50%load increasing



	rtd.V [kV]	Bus - voltage [p.u.]	[kV]	[deg]
ROS2	220.00	0.970	213.30	-15.51
MAR2	220.00	0.956	210.40	-8.90
KLX2	220.00	0.946	208.10	-11.06
IBA2	220.00	0.955	210.11	-9.98
ATB5	500.00	0.994	497.02	-4.46
MAR5	500.00	0.962	481.24	-7.94
KAB2	220.00	0.963	211.93	-8.68
ATB2	220.00	0.995	218.98	-5.31
GER2	220.00	0.996	219.23	-6.82
MW2	220.00	0.994	218.75	-0.52
RAB2	220.00	1.001	220.29	-6.61
KLX1	110.00	0.926	101.82	-13.41
MWP5	500.00	1.000	500.00	0.00
ROS33	33.00	0.968	31.93	-15.70

Voltage - Deviation [%]: -10, -5, 0, +5, +10

- Observe that voltage profile remains within specified limit when 50% increasing in KLX1 load.

4.8 Compensation Using SVC System:

This part is to study the effect of SVC in voltage improvement considering two cases as following:

4.8.1 SVC Effect when MW5-MAR5 T.L out of Service:

Table 4.12: voltage profile when MW5-MAR5 T.L out of service without using SVC

	rtd.V [kV]	Bus - voltage [p.u.]	[kV]	[deg]	Voltage - Deviation [θ] -10 -5 0 +5 +10
ROS2	220.00	0.968	213.02	-18.89	
MAR2	220.00	0.923	203.06	-13.03	
KLX2	220.00	0.938	206.46	-13.84	
IBA2	220.00	0.943	207.48	-12.98	
ATB5	500.00	0.988	494.03	-5.59	
MAR5	500.00	0.929	464.27	-12.02	
KAB2	220.00	0.937	206.08	-12.22	
ATB2	220.00	0.989	217.59	-6.67	
GER2	220.00	0.994	218.78	-9.60	
MW2	220.00	0.994	218.75	-0.52	
RAB2	220.00	1.000	219.96	-10.51	
KLX1	110.00	0.925	101.77	-15.42	
MWP5	500.00	1.000	500.00	0.00	
ROS33	33.00	0.966	31.89	-19.08	

- Observe that MAR2, MAR5, KLX1, KLX2, KAB2, and IBA2 buses represent the weak buses.

Table 4.13: voltage profile when MW5-MAR5 T.L out of service using SVC

	rtd.V [kV]	Bus - voltage [p.u.]	[kV]	[deg]	Voltage - Deviation [%] -10 -5 0 +5 +10
ROS2	220.00	0.977	214.93	-18.09	
MAR2	220.00	0.950	209.08	-12.83	
KLX2	220.00	0.993	218.57	-13.91	
IBA2	220.00	0.985	216.77	-12.95	
ATB5	500.00	0.995	497.62	-5.51	
MAR5	500.00	0.956	478.23	-11.88	
KAB2	220.00	0.969	213.21	-12.08	
ATB2	220.00	0.998	219.46	-6.55	
GER2	220.00	1.001	220.20	-9.27	
MW2	220.00	0.994	218.75	-0.52	
RAB2	220.00	1.001	220.33	-9.84	
KLX1	110.00	1.018	111.99	-15.27	
MWP5	500.00	1.000	500.00	0.00	
ROS33	33.00	0.975	32.17	-18.27	

- Observe that MAR2, MAR5, KLX1, KLX2, KAB2, and IBA2 buses have been improved to acceptable voltage limit when using SVC.

4.8.2 SVC Effect when MAR2 load out of Service:

Table 4.14 voltage profile when MAR2 load out of service without using SVC

	rtd.V [kV]	Bus - voltage [p.u.]	[kV]	[deg]	Voltage - Deviation [%] -10 -5 0 +5 +10
ROS2	220.00	0.975	214.58	-8.33	
MAR2	220.00	1.009	221.94	-2.19	
KLX2	220.00	0.982	216.01	-4.55	
IBA2	220.00	0.988	217.36	-3.82	
ATB5	500.00	1.002	500.84	-2.36	
MAR5	500.00	1.007	503.61	-2.28	
KAB2	220.00	1.003	220.61	-3.00	
ATB2	220.00	1.003	220.72	-2.80	
GER2	220.00	1.002	220.36	-1.12	
MW2	220.00	0.994	218.75	-0.52	
RAB2	220.00	1.004	220.88	0.59	
KLX1	110.00	0.969	106.61	-6.00	
MWP5	500.00	1.000	500.00	0.00	
ROS33	33.00	0.973	32.12	-8.52	

- Observe that voltage profile moved towards the positive limit.

Table 4.15: voltage profile when MAR2 load out of service using SVC

	rtd.V [kV]	Bus – voltage [p.u.]	[kV]	[deg]	Voltage – Deviation [%] −10 −5 0 +5 +10
ROS2	220.00	0.975	214.45	-8.40	
MAR2	220.00	1.000	220.00	-2.16	
KLX2	220.00	0.978	215.22	-4.57	
IBA2	220.00	0.984	216.54	-3.82	
ATB5	500.00	1.001	500.29	-2.37	
MAR5	500.00	1.000	500.21	-2.25	
KAB2	220.00	0.997	219.39	-2.97	
ATB2	220.00	1.002	220.44	-2.81	
GER2	220.00	1.001	220.23	-1.16	
MW2	220.00	0.994	218.75	-0.52	
RAB2	220.00	1.004	220.78	0.53	
KLX1	110.00	0.966	106.21	-6.02	
MWP5	500.00	1.000	500.00	0.00	
ROS33	33.00	0.973	32.10	-8.59	

- Observe that MAR2, MAR5, ATB5, and KAB2 buses have been improved to acceptable voltage limit when using SVC.