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VOLTAGE LEVEL IMPROVEMENT OF KHARTOUM LOCAL MARKET 110kV SUBSTATION

[Mohamed.M.K.Boshara]

Abstract— **The main goal of this study is to improve the voltage at Khartoum Local Market 110kV substation as one of substations of Khartoum Ring Network. Static VAR Compensator has been used to contribute to the improvement of the decline in the voltage at the substation resulting from the different operating conditions. ETAP software has been used in the analysis to determine the effectiveness of this technique in the improvement process.**

The results obtained were satisfactory and as expected.

Keywords— Voltage level improvement, Static VAR compensator, Reduction of system losses, ETAP software.

I. Introduction

Demands on electrical transmission system are increasing every day because of the increasing number of customers. Absence of long term planning and the necessity to provide open access to customers, all together have resulted in diminished security and poor quality of supply [1]. However, the electric power system is an exceedingly nonlinear system that operates in changing environmental conditions. Loads, generator outputs, topology, and key operating parameters change continually [2]. All this lead to decrease of voltage in the network. Static VAR Compensator is one of the techniques used to provide solution to this problem.
Static VAR Compensator can be linked to the terminal substation in the power distribution system to reduce the reactive power, enhance the power factor, decrease the distribution system losses and reduce the damages brought on by frequent switching-in of capacitor banks [3].

II. Khartoum Network Substations

Khartoum Ring Network contains Seventeen substations. The total length of the Ring is 232km, double circuited. Six of these substations are among the nine substations in SUDAN Grid which have or suggested to connect Static VAR Compensator, because Ring thus have problems of voltage level decrease. One of them is local Market 110kV substation. In this study it is suggested to connect static VAR compensator at this substation and study the feasibility of improvement in the voltage level.
Local Market Substation contains two transformers with a capacity of 100MVA each. Each is supplied by two-lines are line from Kilo-X 110kV substation and the other line from Shagara 110kV substation [4]. The total load in the substation is 110.4MW. The substation feeds loads in the industrial area south of Khartoum, as well as supplying residential and commercial loads. Figure (1) refers to the single line diagram of the substation.

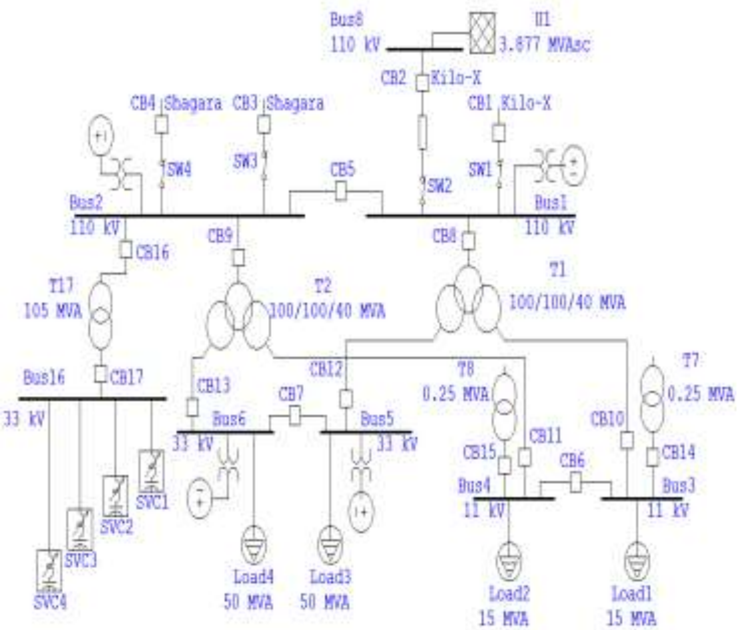

Figure (1): Single Line Diagram of Local Market Substation with SVC.

A. Static VAR Compensators

Static VAR Compensators (SVCs) are shunt linked static generators and/or absorbers of reactive power whose outputs are varied in order to control specific parameters of the electrical power system [5]. They are electrical devices for giving quick-acting reactive power compensation on high voltage transmission systems and thus can contribute to the improvement of the voltage profiles in the transient state and subsequently, they can improve the quality and of the electric supply [6].

Mohamed .M. Boshara (Auther)
Faculty of Engineering / University of Medical Sciences and Technology (UMST).
Sudan.

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B. Method

During the peak load, the load increases and the voltage decreases, so in this case the capacitor starts to work, because this decreasing affects the efficiency of the substation transformers.

When the load decreases, the voltage increases and the reactor starts to work to solve this problem, because the increase in the voltage affects the cables and insulations. Thus this above process is accomplished by Static VAR Compensator (SVC), which comprises both capacitors and reactors.

III. Implementation of ETAP Software

ETAP software is used in this study, because of its efficiency, accuracy and simplicity**.**

The basic data of the substations is as follows:

- Load 110.4MW.
- Power factor 0.85.
- Short circuit current for110kV bus**:**

$I_{1-p} = 22.67\angle -83.3$**,** $I_{3-P} = 20.35\angle -83.4$

From the data given, it is necessary to calculate some of the required parameters of the lines coming into the substation from other stations so as to know the amount of power drawn from them.

$$X/R = \tan\Phi \quad \ldots\ldots (1)$$

- Values of (X/R) for 3-phase and 1-phase are**:**

$X/R_{(3-ph)} = \tan(-83.4) = -8.643^0.$

$X/R_{(1-ph)} = \tan(-83.3) = -8.513^0.$

- Value of MVA for both, 1-phase and 3-phase are**:**

MVA (3-ph) = $\sqrt{3}$*110*20.35=3.877MVA

MVA (1-ph) = MVA (3-ph)/3=1.292MVA

For load busses:

$$P=S+jQ \quad \ldots\ldots (2)$$

$P=S\cos\Phi \rightarrow S=P/\cos\Phi=110.4/0.85$

$$S=129.5\approx 130\text{MVA} \quad \ldots\ldots (3)$$

- 130 MVA from Equation (3) refers to apparent power (S) in MVA. It has been computed to be 130MVA, using Pf = 0.85.This apparent power has been divided among feeders with voltage level 33kV and11kV as follows:

Feeder	Voltage Load in kV	Apparent Power in MVA
Feeder-1	33	50
Feeder-2	33	50
Feeder-3	11	15
Feeder-4	11	15

A. Static VAR Compensator Models

There are three types of control models in ETAP software. These are variable impendence type, current source type and voltage source type. In addition, ETAP program has two important values of parameters for static VAR compensator, capacitive load **(Q_C)** and inductive load **(Q_L)**. In this study only one of these types is used for controlling the static VAR compensator. Table (1) refers to the maximum and minimum value of capacitive and inductive loads. The maximum voltage taken is10% above the rated voltage.

Table (1): Values of capacitive and inductive loads.

	Maximum Value	**Minimum Value**	**Unit**
Q_L	30	0	MVAr
Q_C	70	62.08	MVAr

IV. RESEULTS OF LOAD FLOW

A. Result of Load Flow without SVC

Table (2): Critical Report without SVC.

Bus No (3-Ø)	**Condition**	**Rating / Limit**	**Operation**	**% Operation**
Bus-3	Under Voltage	11.00 kV	10.156	92.3
Bus-4	Under Voltage	11.00 kV	10.153	92.3
Bus-5	Under Voltage	33.00 kV	30.840	93.5
Bus-6	Under Voltage	33.00 kV	30.830	93.4

Table (3): Total Generation and Demand (Load).

	MW	**Mvar**	**MVA**	**PF%**
Swing Buses	108.791	81.195	135.75	80.14 lagg
Non-Swing Buses	0.000	0.000	0.000	
Total Demand	108.791	81.195	135.75	85.00 lagg
Total Motor Load	88.400	54.785	104.00	85.00 lag
Total Static Load	19.189	11.892	22.575	80.14 lagg
Total Constant Load	0.000	0.000	0.000	0.000
Total Generic Load	0.000	0.000	0.000	0.000
Apparent Losses	1.202	14.518		
System Mismatch	0.000	0.000	0.000	

Going through tables (2), (3) it is noted that there is a clear voltage drop before using SVC. The voltage registered at 33kV bus bar and 11kV bus bar is 30.84kV and 10.156kV respectively .So there is a real need to use SVC at this substation to correct the voltage level to its nominal voltage values.

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B. Result of Load Flow with SVC

Table (4): Critical Report with SVC at the maximum voltage.

Bus No (3-Ø)	Condition	Rating/ Limit	Operation	% Operation
Bus-1	Over Voltage	110.00 kV	119.916	109.0
Bus-2	Over Voltage	110.00 kV	119.916	109.0
Bus-8	Over Voltage	110.00 kV	121.000	110.0

Table (5): Marginal Report with SVC at the maximum voltage.

Bus No (3-Ø)	Condition	Rating/ Limit	Operation	% Operation
Bus-16	Over Voltage	33.00 kV	34.430	104.3
Bus-3	Over Voltage	11.00 kV	11.279	102.5
Bus-4	Over Voltage	11.00 kV	11.276	102.5
Bus-5	Over Voltage	33.00 kV	34.185	103.6
Bus-6	Over Voltage	33.00 kV	34.176	103.6

Table (6): Total Generation and Demand (load) at the maximum voltage.

	MW	Mvar	MVA	PF%
Swing Buses	113.543	134.334	175.891	64.55 lagg
Non-Swing Buses	0.000	0.000	0.000	
Total Demand	113.543	134.334	175.891	64.55 lagg
Total Motor Load	88.400	54.795	104.005	85.00 lagg
Total Static Load	23.599	63.961	68.176	34.61 lagg
Total Constant Load	0.000	0.000	0.000	0.000
Total Generic Load	0.000	0.000	0.000	0.000
Apparent Losses	1.544	15.577		
System Mismatch	0.000	0.010		

Table (7): Critical Report with SVC at the minimum voltage.

Bus No (3-Ø)	Condition	Rating/ Limit	Operatio n	% Operation
Bus-1	Under Voltage	110.000 kV	90.053	81.9
Bus-2	Under Voltage	110.000 kV	90.053	81.9
Bus-3	Under Voltage	11.000 kV	8.093	73.6
Bus-4	Under Voltage	11.000 kV	8.093	73.5
Bus-5	Under Voltage	33.000 kV	24.715	74.9
Bus-6	Under Voltage	33.000 kV	24.703	74.9
Bus-8	Under Voltage	110.000 kV	90.000	81.8
T17	**Over Load**	105.000 MVA	132.399	126.1

Table (8): Marginal Report with SVC at the minimum voltage.

Bus No (3-Ø)	Condition	Rating / Limit	Operation	% Operation
Bus-16	Under Voltage	33.000 kV	31.530	95.5

Table (9): Total Generation and Demand (load) at the minimum voltage.

	MW	Mvar	MVA	PF%
Swing Buses	105.048	-31.526	109.677	95.78 lead
Non-Swing Buses	0.000	0.000	0.000	
Total Demand	105.048	-31.526	109.677	95.78 lead
Total Motor Load	88.400	54.776	103.995	85.00 lead
Total Static Load	12.290	-124.77	125.376	9.80 lead
Total Constant Load	0.000	0.000	0.000	
Total Generic Load	0.000	0.000	0.000	
Apparent Losses	4.358	38.471		
System Mismatch	0.000	0.010		

Results in tables No (4), (5) and (6), show that there is an improvement in the substation voltage profile when (-10%) inductive MVAR has been absorbed to the system. The voltage has improved to 110kV at110kV bus bar, 34.18kV at 33kV and 11.27kV at 11kV bus bar.

The results in tables No (7), (8) and (9), show that there is an improvement in the substation voltage profile to its nominal values when (+10%) capacitive MVAR has been injected to the system. The voltage has been improved to 33kV instead of 24.72kV and 11kV instead of 8.093kV.

IV. CONCLUSION

In this study, the system under consideration has been simulated using ETAP software under the following assumptions:

- Local Market substation 110kV bus bar voltage will increase to a maximum value of 121kV (i.e. +10%).
- Local Market substation 110kV bus bar voltage will drop to a minimum value of 90kv (i.e.–10%).

After connection of static VAR compensator**:** Under maximum voltage assumption (i.e. 121kV) the bus bar has been improved to the nominal voltage value of (110kV) due to absorption of inductive load (-MVAr) by the action of the static VAR compensator connection. Under minimum voltage assumption (i.e. 90kV) the bus bar voltage has been improved to the nominal operating value of 110kv due to injection of capacitive load (+MVAr).

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V. Further Work

It is recommended to use SVC as reactive power compensator in this case study, because it is economically and technically feasible. Moreover, SVC is a static machine which means free maintenance and no fuel consumption, simplicity and flexibility in operation. SVC can be used as one package in both high/low voltage cases of the power system.

Studies are recommended to be conducted in other substations in the SUDAN Grid to improve the voltage profile of the system and accordingly reduce the energy losses.

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About Author :

Mohamed Mukhtar Khalil Boshara was born in El fasher/ Sudan, on May 28, 1988. He received B.sc degree in Electrical and Electronics from University of Nyala, in 2013. He got M.sc degree in Electrical Power Engineering from University of Khartoum in 2015. Currently lecturer in Department of Electrical Engineering at University of Medical Sciences and Technology / Sudan.