Open Access Library Journal
2023, Volume 10, e9666
ISSN Online: 2333-9721
ISSN Print: 2333-9705

Reducing Losses in the Sudanese Power Transmission System 66 kV Sector

Ekram Osman, Mujahid Ahmed, Sufyan Al-Sadiq Suleiman Ibrahim, Helal Qahtan

Department of Electrical Engineering, Red Sea University, Port Sudan, Sudan
Email: ekramhasabo2016@gmail.com, helalqahtan770@gmail.com

How to cite this paper: Osman, E., Ahmed, M., Ibrahim, S.A.-S.S. and Qahtan, H. (2023) Reducing Losses in the Sudanese Power Transmission System 66 kV Sector. *Open Access Library Journal*, **10**: e9666.
https://doi.org/10.4236/oalib.1109666

Received: December 8, 2022
Accepted: January 28, 2023
Published: January 31, 2023

Abstract

Electricity is transmitted from the generating stations to the distribution center and consumers through transmission lines, to ensure that energy reaches consumers in the required form and quality, and losses along transmission lines must be minimized. In this project, losses were analyzed and reduced in the East network sector (66 kV) using a modern compensator Static VAR (Volt-Ampere Reactive) Compensator (SVC) and electrical network simulation in the NEPLAN program to validate its validity. In this project, three tests were carried out at different locations on the eastern grid to discover the most suitable place to place the static compensator for the best optimization of power loss. Finally, the compensator was placed in the Gedaref feeder where the best network optimization was obtained east of the sector (66 kV).

Subject Areas

Electric Engineering

Keywords

Static VAR (Volt-Ampere Reactive) Compensator (SVC), Static Synchronous Compensator (STATCOM)

1. Introduction

Electrical power is transferred from generating stations to distribution centers and consumers by transmission lines; to ensure that the capability reaches consumers in the required form and quality, the loss along the transmission lines must be minimized which are known as technical losses [1]. These technical losses in power systems are mainly due to heat dissipation caused by current passing through the conductors and magnetic losses in the transformer [2]. The types of these losses are:

- Copper losses due to loss R I2.
- Dielectric losses are caused by the effect of heating on the insulating material between the conductors.
- Induction and radiation loss produced by electromagnetic fields surrounding conductors.

Corona discharge losses occur on all transmission lines, but become more noticeable at higher voltages (345 kV and above) under moderate weather conditions [3]. Non-technical losses occur due to procedures outside the power system or due to loads and conditions that technical losses fail to take into account. They are more difficult to measure, because they are often unaccountable [4].

To increasing the transferred power from the electrical power to the maximum limits of the thermal endurance of these lines by making it dedicated only to the transfer of the effective power, and without carrying it with the reactive power. This means that it provides the addition of new lines that may need lands, towers, connectors, etc. to solve this problem devices are installed on AC power transmission lines, so they contribute flexibly and smoothly to controlling the power transmitted through AC lines, for example, they can control the reactive power transmitted through these lines and then increase the stability of the voltage of the electrical system. Synchronous generators are used for this purpose, the field current may be less than normal, and then the generators draw reactive power from the electrical network. The generators' excitation may be any field current higher than normal, and then the generators pay a reactive power that is fed into the network, but the reactive power that the generator gives or absorbs is always limited to the power of the generator according to the circuit diagram of the generator, and therefore the use of this method is considered to be of limited use [2]. Installing capacitors in series with the network in one or more locations along the transmission line to dissipate part of the inductive reactance is also a method, which theoretically allows more transmitted power and also a lower phase angle difference and therefore greater stability. In addition, the reactive power is generated by series capacitors. It increases with increasing load, thus improving voltage regulation, but the disadvantage of this method is that there is a rise in voltage with light loading, which requires the installation of parallel reactors on a continuous basis, and this will of course reduce the transmitted power, which can be increased by increasing the series capacitors, and thus reduces the importance of this method. Attention should be paid in this case to the voltage problem and the phenomenon of resonance of waves with sub-harmonic frequencies, which may lead to the breakdown of the rotating generator shaft. Parallel capacitors provide negative compensation and are either permanently connected to the transmission and distribution system or via a switch and control the voltage by modifying the network characteristics. These units together with the generation units create voltage points at specific points in the system and determine the voltage at other locations in the system. The system flows effective and reactive power through various components including reactive compensators.

The purpose of constructing this compensator near the load areas is to control the voltage, stabilize the load, reduce losses in the transmission system and ensure reasonable voltage levels during high loads. Mechanical switches are installed at major substations in the loading areas to produce reactive power and keep the voltage within the required limits. Capacitors that use mechanical switches are characterized by low cost and high speed, capacitors are usually used in parallel at the ends of high-load transmission lines, and capacitors are usually connected in parallel at low power factor loads, providing reactive power near the point where it is consumed instead of supplying it from a far place. The problem of parallel capacitors is that the reactive power they produce is proportional to the square of the voltage, and then that capacity decreases with the voltage drop at the time when it was expected to rise. There is also another problem which is that it leads to the occurrence of the phenomenon of resonance with the rest of the network at certain harmonics, which may lead to a dangerous rise in the voltage, which requires care when using these capacitors connected in parallel to prevent the occurrence of this phenomenon [5].

2. Eastern Network Sector 66 kV

The power network model used in the study was drawn by the (NEPLAN V554) program, NEPLAN Electricity is a software tool to analyses, plan, optimize and simulate electrical networks. Where the system contains four transmission lines and two transformers and contains five distribution rails.

Figure 1 shows the scheme the network under study, the system information are collected from Sudanese distribution company and then filtered it in Table 1 and Table 2 as shown below:

After modeled and analysis the network using (NEPLAN V554) program as in Figure 2, the network losses is determined as shown in Table 3.

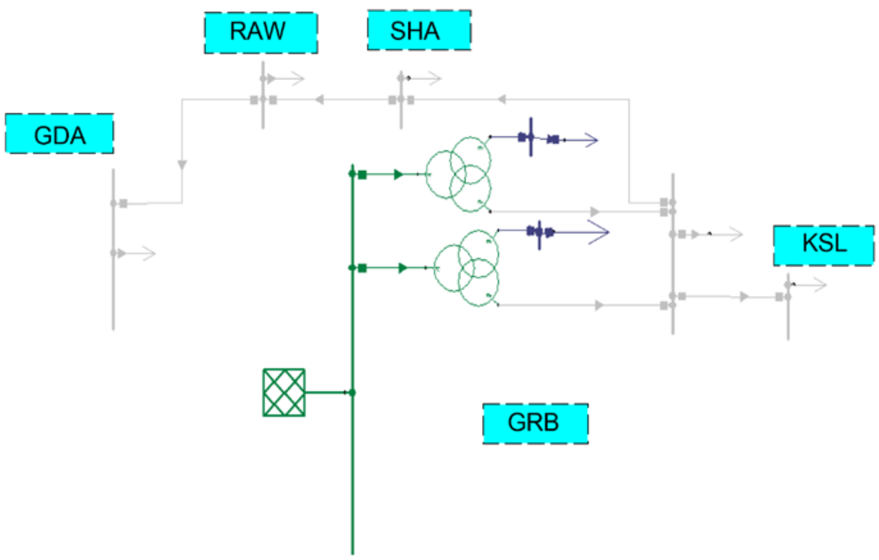

Figure 1. Sudanese network for the transmission of the 66 kV sector.

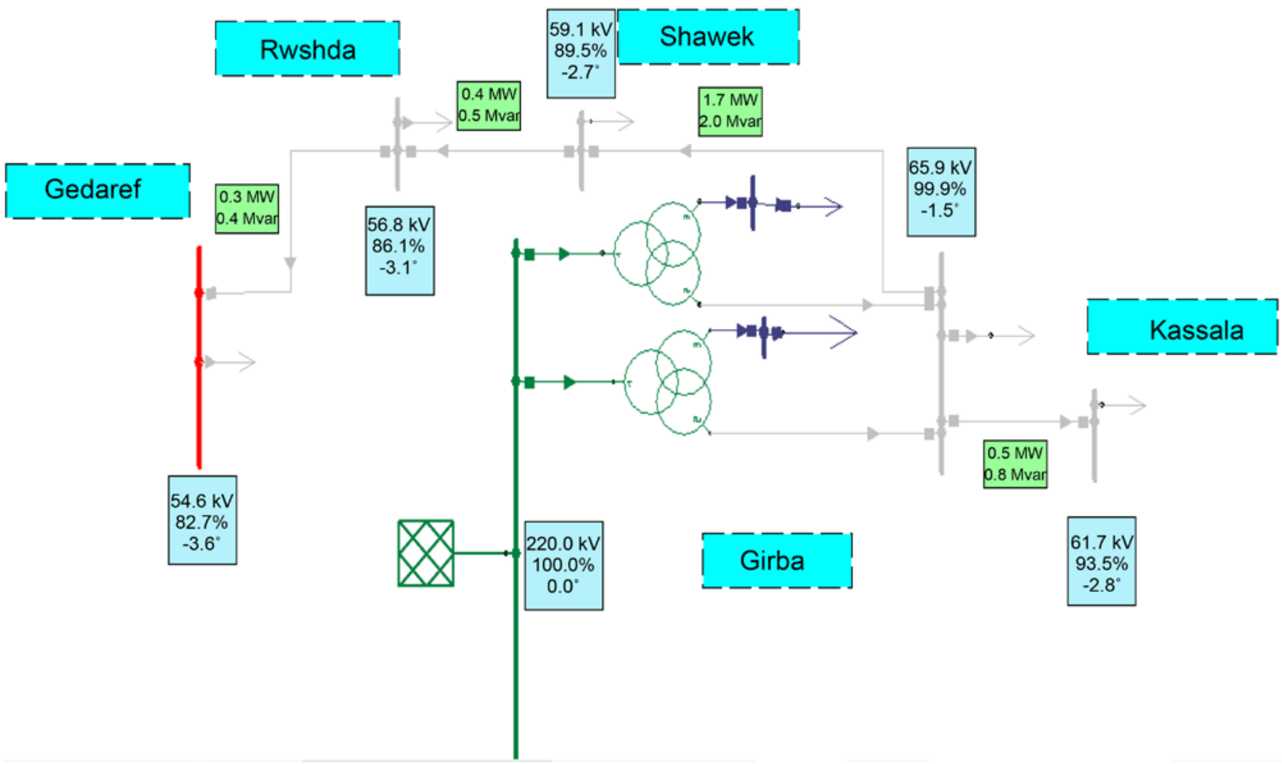

Figure 2. Network modeling without compensator.

Table 1. Transmission line transactions.

T. Line	Nominal Voltage (KV)	Length (Km)	R (Ω/km)	X (Ω/km)	C nF/km
Gedaref - Rwshda	66	38	0.348	0.397	8.96
Rwshda - Showk	66	32	0.348	0.397	8.6
Showk - El-Girba	66	70	0.348	0.397	8.96
El-Girba - Kassala	66	95	0.255	0.386	9.7

Table 2. Loads transactions.

Bus Name	Total Load (MW)
El-Girba	5
Shawek	5
Rwshda	2
Gedaref	10
Kassala	10

3. Static Var Compensators (SVC)

It is a group of electrical devices that produce reactive power without the need for auxiliary devices.

Table 3. Network losses without application (SVC).

Line Name	Real power losses (MW)
El-Girba - Shawek	1.7
Shawek - Rwshda	0.4
Rwshda - Gedaref	0.3
El-Girba - Kassala	0.5
Total losses	2.9

Before the invention of the stationary compensator devices, the power factor was compensated by a group of capacitors. The stationary compensator devices were connected directly with the power system to regulate the voltage through the transmission lines, and it is near large industrial loads to improve the quality of power and also in high industrial applications and it changes quickly and controls and the term SVC includes three types under it:

- Thyristor controlled reactor (TCR).
- Thyristor switching capacitor (TSC) assemblies.
- Thyristor switching coil (TSR) assemblies.

The first and second types are shown in Figure 3.

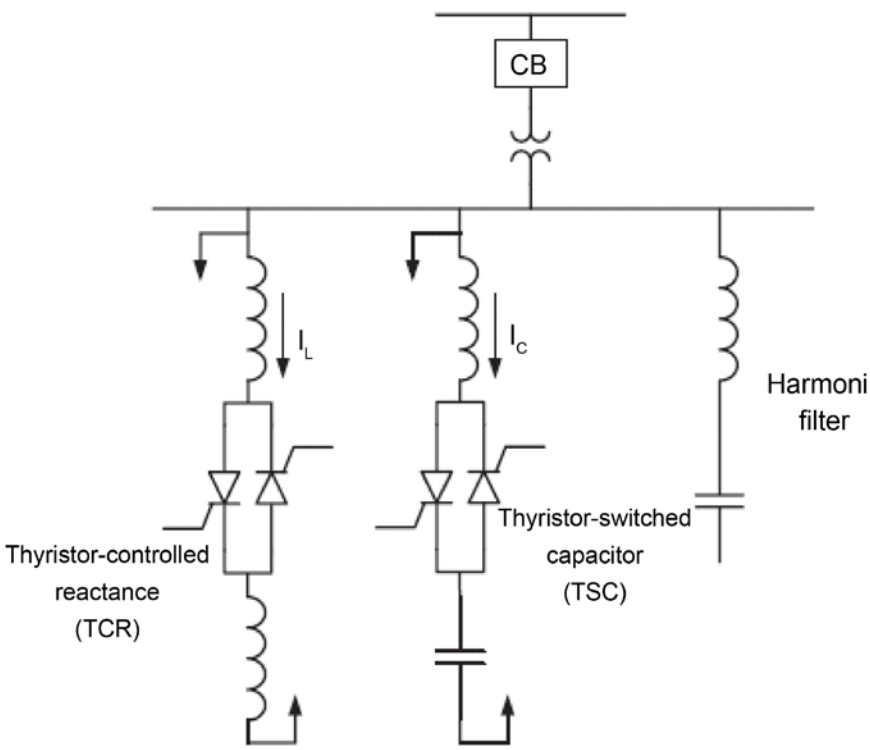

Figure 3. Static compensators (TSC) and (TSR).

It is the simplest type of device as it consists of integrating a group of disconnecting and connecting capacitors installed in parallel, or consisting of a group of coils also connected in parallel by a thyristor (STC) and a thyristor-controlled reactor (TCR) in one device called a static compensator for reactive power, (STC) in generating reactive power, while the (TCR) contributes to its withdrawal, and to achieve both purposes of reactive power, they are used together, provided that one of them is variable by changing the starting angle in the thyristor, and thus, the static compensators of the reactive power act as an ineffective resistance controlled to a certain extent.

This type of compensator is used to adjust the voltage of the system at certain points, and it is also used to dampen oscillations and thus improve the stability of the electrical system.

The reactance value is controlled by controlling the degree of conductivity of the silicon control rectifier (SCR).

Note the necessity of having a transformer between the reactive power compensators and between the network because we cannot install it directly on high voltage due to the limited efforts with which the silicon control rectifiers work so far [6].

3.1. Advantages of Using SVC

The value is automatically and easily changed according to the changing status of the loads.

No need for expensive cutters.

Reactive power can be generated through the thyristor switched capacitor, and the same device can also absorb reactive power by a Thyristor controlled reactor.

The value of the impedance becomes as if it were a variable.

Quickly and reliably control the line voltage in normal and emergency conditions.

Increases the effective power, reduces losses and prevents voltage surges in the case of light loads.

3.2. Disadvantages of Using SVC

High cost compared to other flexible AC transmission system devices.

Limited reactive power according to the sizes of capacitors and coils available on the site.

The inability to control the voltage in cases of low voltage because the reactive power of the capacitors is proportional to the square of the voltage [6].

3.3. Static Compensator (SVC) Functions

It is used as a power factor correction device to improve it and reduce line losses resulting from the effective power.

It is a component of the power system to improve its quality and is also used to curb harmonics.

As a microelectronic control system, where there is no need for mechanical transformation, *i.e.* a quick response.

4. Placing the Static Var Compensators (SVC) in the Network

4.1. (Case 1) Compensator (SVC) Has Been Placed in Shawek's Feeder

The network is modeled when the compensator (SVC) Shawek feeder, as in Figure 4, and then the losses in the line are determined. Table 4 shows the real power losses when the (SVC) injected in Shawek feeder. The simulation result presented in Figure 5, which showed a reduction in the total loss of this system.

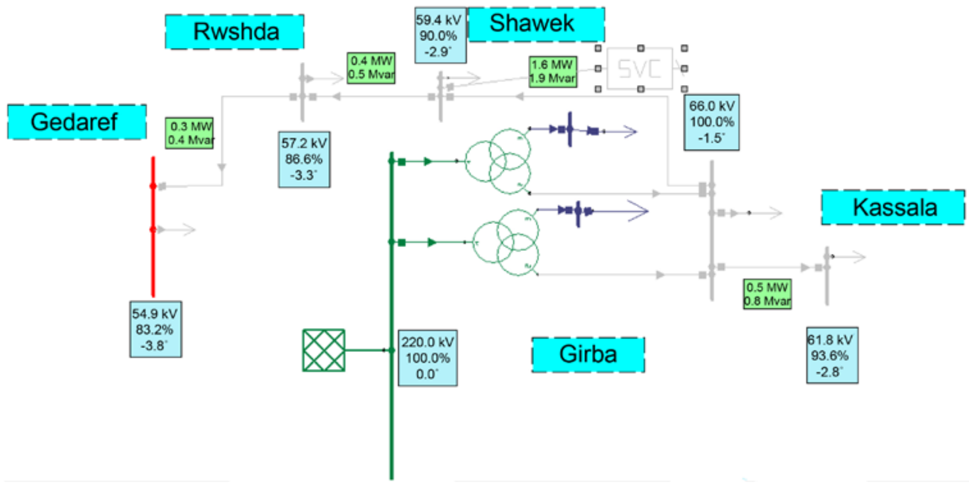

Figure 4. Network modeling after the compensator (SVC) Shawek feeder.

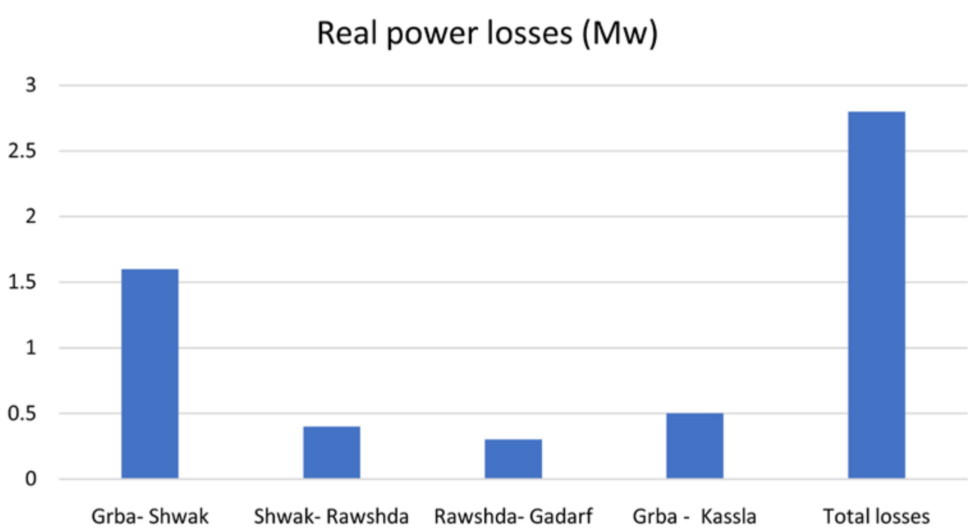

Figure 5. System losses when placing (SVC) in Shawek's feeder.

4.2. (Case 2) after Compensator (SVC) Has Been Placed in Rwshda's Feeder

The network is modeled when the compensator (SVC) in Rwshda feeder, as in Figure 6, Table 5 shows the real power losses when the (SVC) injected in Rwshda feeder. The simulation result presented in Figure 7, which showed a reduction in the total loss of the system.

Table 4. Loss in the system when placing (SVC) in Shawek's feeder.

Line Name	Real power losses (MW)
El-Girba - Shawek	1.6
Shawek - Rwshda	0.4
Rwshda - Gedaref	0.3
El-Girba - Kassala	0.5
Total losses	2.8

Table 5. Loss in the system when placing (SVC) in Rwshda's feeder.

Line Name	Real power losses (MW)
El-Girba - Shawek	1.2
Shawek - Rwshda	0.3
Rwshda - Gedaref	0.3
El-Girba - Kassala	0.5
Total losses	2.3

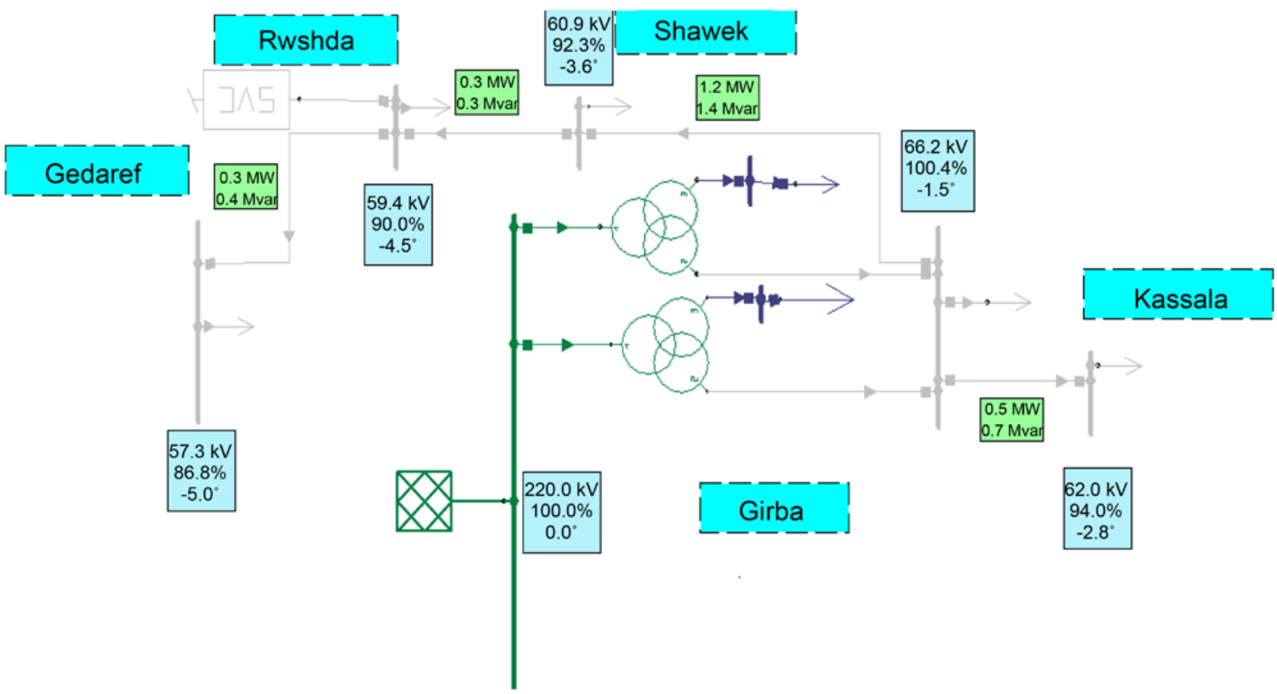

Figure 6. Network modeling after the compensator (SVC) Rwshda feeder.

4.3. (Case 3): Compensator (SVC) Has Been Placed in Gedaref's Feeder

The network is modeled when the compensator (SVC) Gedaref feeder, as in Figure 8, Table 6 shows the real power losses when the (SVC) placed in Gedaref feeder. The simulation result presented in Figure 9, which showed a reduction in the total loss of the system.

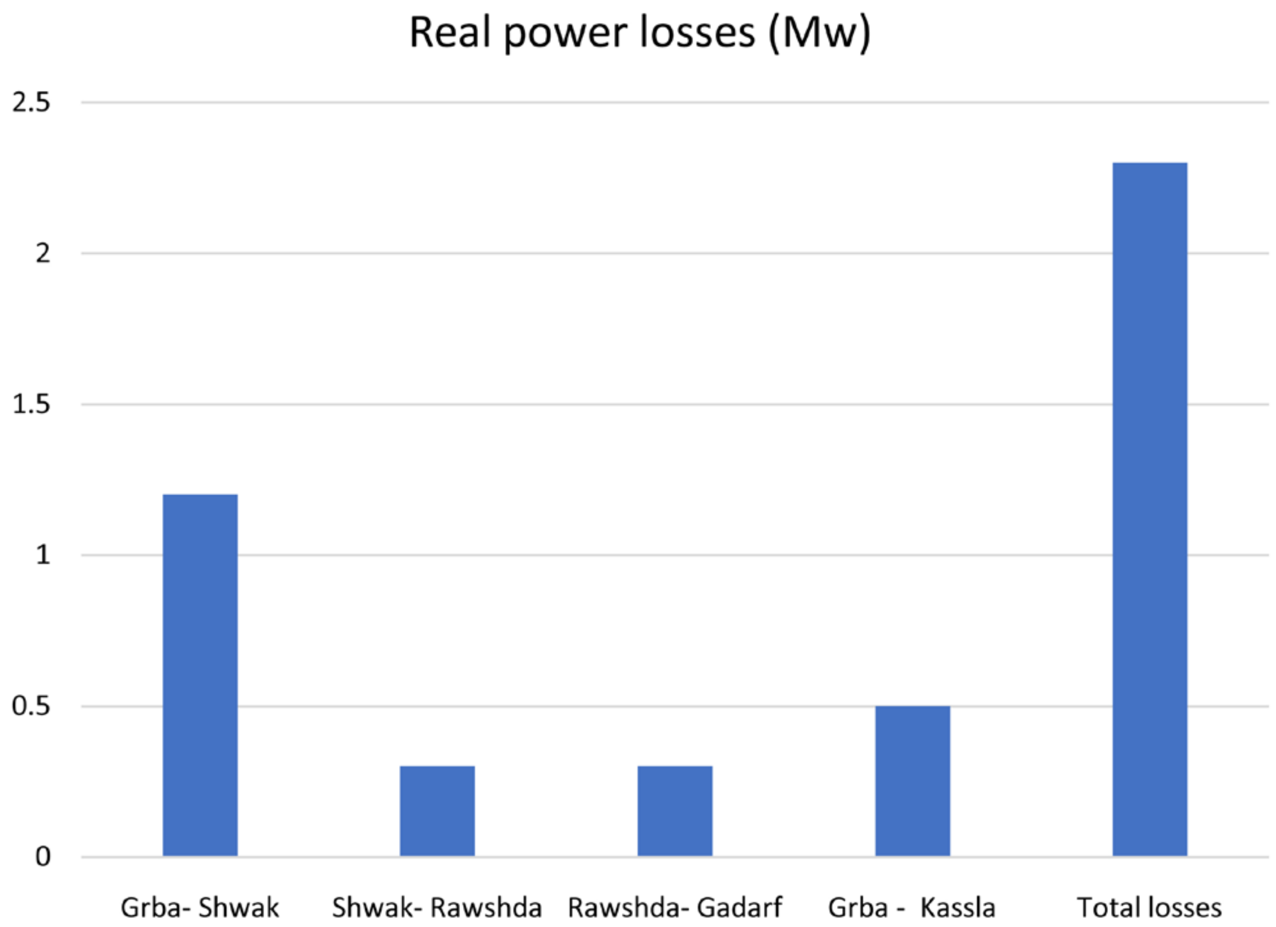

Figure 7. System losses when placing (SVC) in Rwshda's feeder.

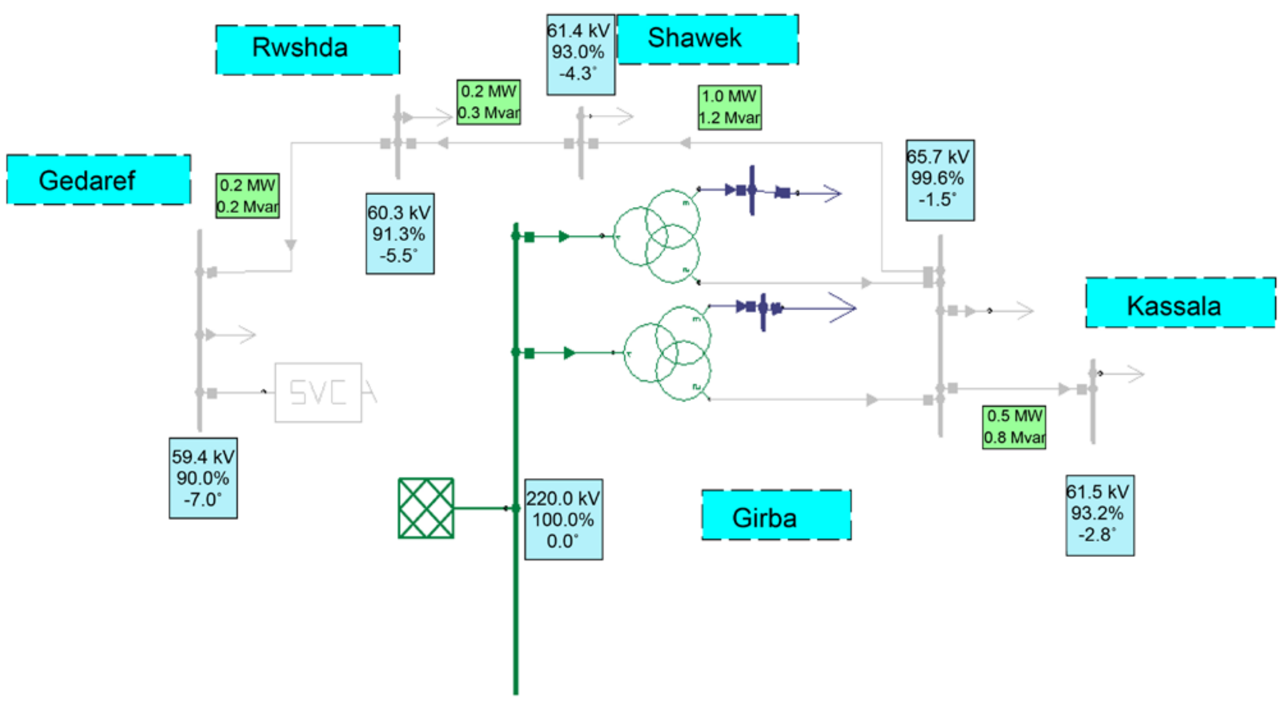

Figure 8. Network modeling after the compensator (SVC) Gedaref feeder.

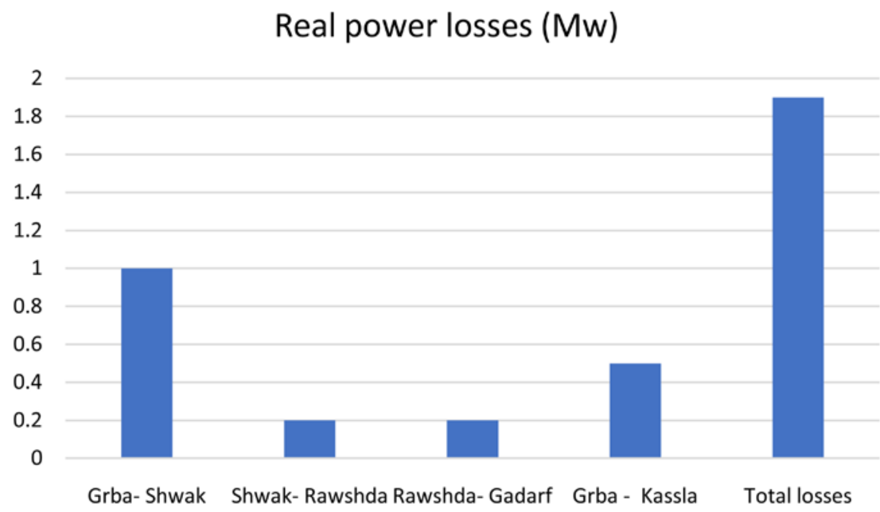

Figure 9. System losses when placing (SVC) in Gedaref's feeder.

Table 6. Loss in the system when placing (SVC) in Gedaref's feeder.

Line Name	Real power losses (Mw)
El-Girba - Shawek	1
Shawek - Rwshda	0.2
Rwshda - Gedaref	0.2
El-Girba - Kassala	0.5
Total losses	1.9

From Table 5 was found that the losses were reduced by 0.4 MW, that value not satisfied so that the SVC compensator must placed in another place.

4.4. (Case 4) Compensator (SVC) Have Been Placed in Rwshda's Feeder and Gedaref's Feeder

The network is modeled when the compensator (SVC) Rwshda's feeder and Gedaref feeder, as in Figure 10. Table 7 shows the real power losses when the (SVC) placed in Rwshda's feeder and Gedaref feeder. The simulation result presented in Figure 11, which showed a reduction in the total loss of the system.

From Table 7, we can observe that the losses in all feeder reduced and then the total losses also decrease.

5. Result

The Loss reduction percentage is calculated as follows: total loss before placing the (SVC) minus the loss after placing the compensator in the feeder divided by the total loss before placing the compensator. In all previous cases, it was found that the losses are reduced in varying percentages such as: in Shawek's feeder reduces wastage by 3.45%, reduces wastage by 20.68% when set in Rwshda's feeder, and reduces wastage by 34.48% at Gedaref's feeder, reduces wastage by

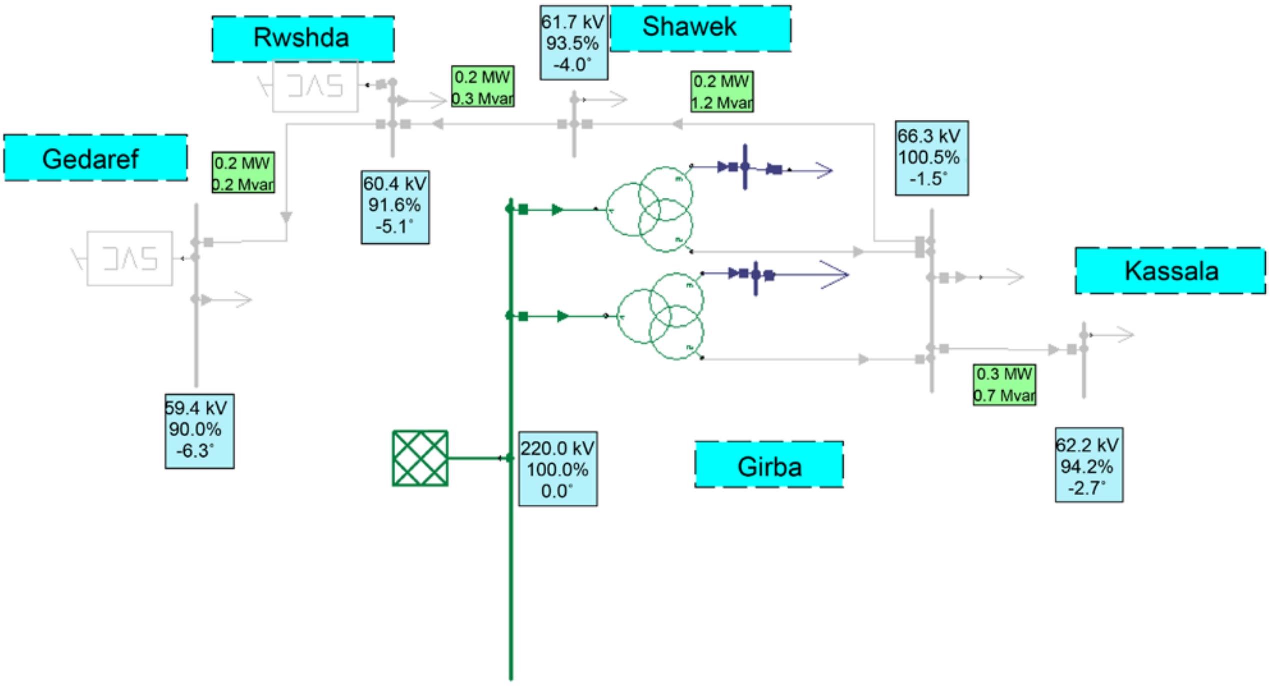

Figure 10. Network modeling after the compensator (SVC) Rwshda's feeder and Gedaref's feeder.

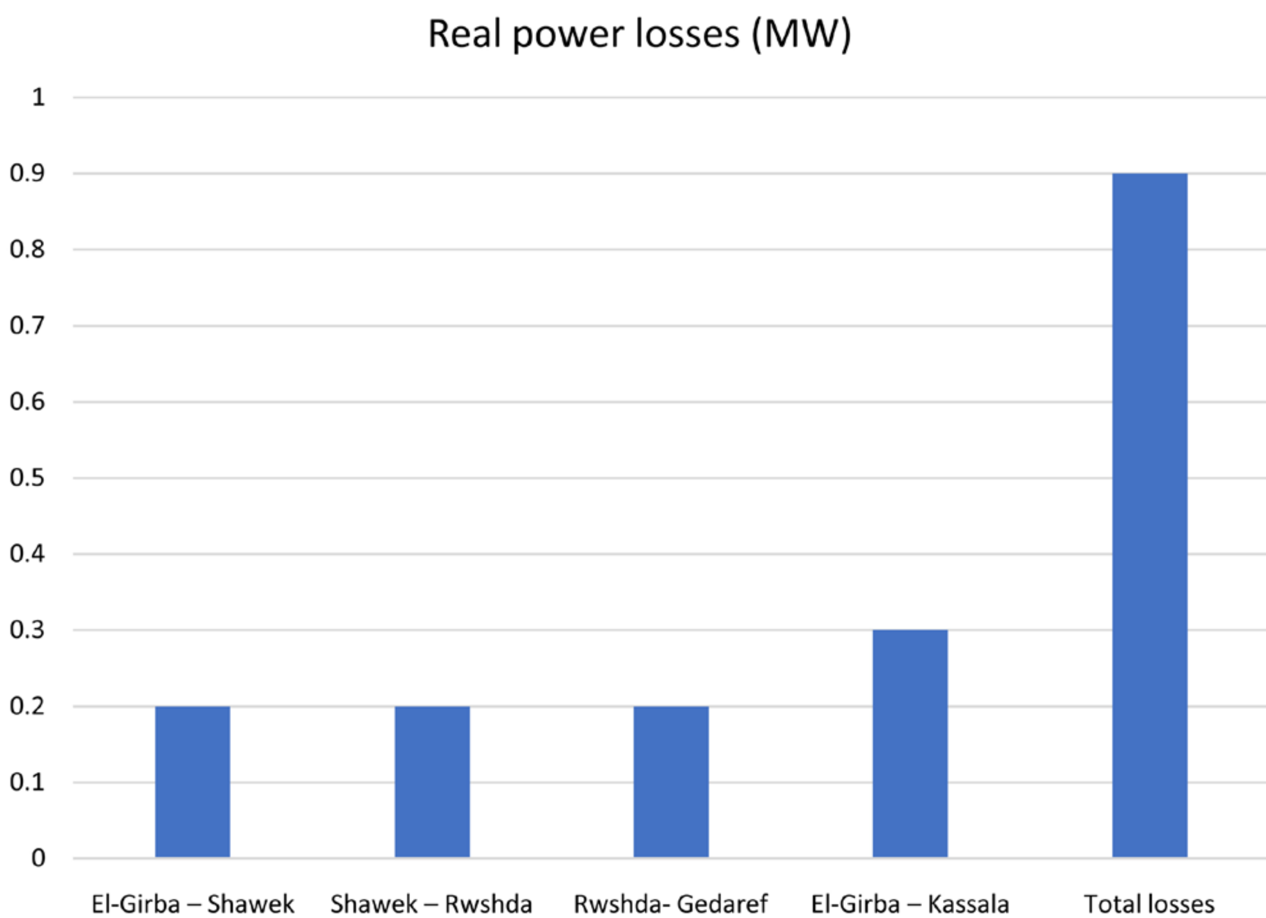

Figure 11. System losses when placing (SVC) in Rwshda's feeder and Gedaref's feeder.

68.96% when placed at Rwshda's feeder and Gedaref's feeder, as shown in Table 8. Figure 12 shows comparison of the losses reduction ratios at each location of the compensator. From the result, the best area to place (SVC) is in Rwshda's feeder and Gedaref's feeder.

6. Conclusion

The electric power system is exposed to energy loss during the delivery of electricity along the transmission and distribution system, and this energy is transformed into a form that is not used effectively during the processes of energy production, transportation and consumption in the system. It is generally the difference between input and output power. One of the problems of losses is the increase in distribution losses, which leads to an increase in the operating cost and a high cost of electricity, as well as the breakdown of the insulation of transmission lines. The program (NEPLAN) was used to analyze and reduce losses by placing the compensator (SVC) in each the feeder of the Shawek, the feeder

Table 7. Loss in the system when placing (SVC) in Rwshda's feeder and Gedaref's feeder.

Line Name	Real power losses (MW)
El-Girba - Shawek	0.2
Shawek - Rwshda	0.2
Rwshda - Gedaref	0.2
El-Girba - Kassala	0.3
Total losses	0.9

Table 8. The percentage of loss reduction.

Line bus	Percentage reduces real losses
Shawek	3.45%
Rwshda	20.68%
Gedaref	34.48%
Rwshda and Gedaref	68.96%

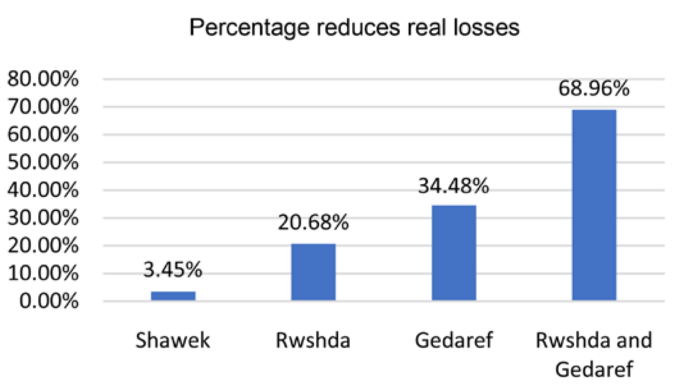

Figure 12. Percentage of loss reduction.

of the Rwshda and the feeder of Gedaref in the Sudanese transmission lines network sector (66 KV).

Conflicts of Interest

The authors declare no conflicts of interest.

References

[1] Mongkul, D.S. (2002) Non-Technical Losses in the Electrical Power System. College of Engineering and Technology, Ohio University, Athens, OH.

[2] Date of Entry 17/7/2022. http://www.electrobrahim.com/

[3] Date of Entry 17/72022. https://ieeexplore.ieee.org/abstract/document/6564582

[4] Sadat, A.-H. (1990) Power Systems Analysis. Mcgraw-Hill Company, New York.

[5] Zhou, E.Z. (1993) Application of Static Var Compensators to Increase Power System Damping. *IEEE Transaction on Power Systems*, **8**, 655-660.

[6] Singh, N. and Bhandakkar, A. (2016) Review on Power Compensation in Transmission Line Using FACTS Technology. *International Journal of Novel Research in Electrical and Mechanical Engineering*, **3**, 15.