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Enhancement of Voltage Profile in Delta Egypt and its Importance for Oil Refining Process

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Abstract

The electrical energy is transmitted from the generating stations to the consumers through the transmission network. A high performance network must have voltage stability and sustain with in permissible variation levels in magnitude ± 10% of the rated voltage at each bus [1].

The effectiveness of improving voltage profile yields high network efficiency and increase the capacity of transmission lines; also decrease power losses, voltage drop and unplanned shut down in big industrial and strategic loads like (Oil Refining Process).

The suggested solutions are applied on Delta Egypt network with voltage levels (66, 11, 6.6, 0.4) KV, the simulations were performed in the digital simulation and electrical network calculation (DIgSILENT Power Factory Software) to study the voltage profile.

The validation of results was performed by comparing the voltage profile of proposed four different scenarios:

1st: power system in normal operation (without using any voltage improving devices), 2nd: using Automatic Tap Changer (ATC) of transformers, 3rd: installing a Static VAR System(SVS) with (ATC), 4th: installing a (SVS) with (ATC) and Shunt Reactive Power compensation devices (parallel capacitor / inductor).

Keywords: ATC (Automatic Tap Changer), reactive power, SVS (Static VAR System), under voltage, voltage quality.

I. INTRODUCTION

Recently due to increasing power demand and growth in the use of inductive loads in all industries which consume more reactive power and tend to more power losses, power systems are operated to their maximum operation conditions. It will cause many problems and tended to poor power quality, the most common of these problems are under voltage, sag and unbalance (voltage instability). Voltage instability disturbance which caused malfunction or unplanned shut down in big industrial and strategic loads like (Oil Refining Process) [2], to overcome this problem Several methods are available to improve Voltage Profile, one of commonly used methods are:

Automatic Tap Changer (ATC) of transformers, Static VAR System (SVS), Shunt Reactive Power compensation devices (parallel - capacitor / inductor) and a combination of them.

This paper study the performance of electrical network and voltage profile by using each method to get the optimum solution and best voltage profile, all of these cases is performed simulated Using the Digital Simulation and Electrical Network calculation (DIgSILENT Power Factory Software).

II. VOLTAGE QUALITY IMPORTANCE FOR OIL REFINING PROCESS

A poor voltage quality leads to unscheduled electric power supply interruption to an oil refining process and can trigger a chain of catastrophic events. This is due to the multiple interlinked chains of electrical systems and the mixture of highly volatile materials on which the processes are based. Ensuring power system reliability is essential to avoid putting staff and neighboring areas at risk, and to minimize costly incidents and production stoppages.

Continuous of electric power source with high reliability and quality is necessary for oil refining industry, which considers one of the most strategy processes with operating of production 24 hours a day, 7 days a week. Unscheduled electric power supply failure due to a poor voltage quality creates unwanted costly troubles:

A. According to oil refining process

1) Time for restarting the plant:

Costs of shutdown and restarting the entire plant after an unscheduled electric power supply failure. Costs of These restarting can be high.

2) Downtime of Critical units:

Unplanned power failure or disturbances which affect equipment operation leads to production stoppage costing a lot of money. A consequence reaction leads to a sudden multiple shutdowns of plant units.

3) More repairs and maintenance:

Carrying out of these sudden interventions needs expensive emergency of unplanned maintenance and time of staff or more efforts to restart the plant units.

4) Equipment damage:

Unscheduled shutdown leads to unwanted operation like safety valves acts as safe fail status (full open /close), over pressure can damage equipment and increased insurance premiums.

5) Neighboring companies effect:

Companies which depend on oil refining process like distribution of oil products business need to be compensated for oil products in case of unplanned shutdown [3].

B. According to utility

Sustained over voltages or under voltages can cause the following impacts:

1) Less equipment efficiency operation or Improper and minimized life time, like rotating machines may run slow or fast.

2) Tripping and malfunction of sensitive loads, like a battery charger, PLC, DCS and UPS may revert to battery mode during low or high voltage which leads to discharge the batteries of UPS and cause power outage to critical loads.

3) Insulation damage or failure of electrical equipment due to over voltage.

4) Increase of no-load losses and magnetizing current in transformers at over voltage.

5) Low power factor, increasing of starting current and increasing torque of induction motors during voltage disturbance.

6) Low voltage causes reduction of induction motors torque, increasing power losses, utility costs, load current and temperature more than necessary transmitted current through the system [4].

From above discussion we can say that the voltage quality indicates the power quality which is defined as: Any power problem manifested in voltage, current, or frequency deviations that result in failure or malfunction of customer equipment [5].

III. MODELING OF ELECTRICAL NETWORK USING DIGSILENT POWER FACTORY SOFTWARE

DigSilent Power Factory is a high end power system analysis tool for applications in transmission, distribution, generation, industrial, and smart grid operations. It has set standards and trends in power system modeling, analysis and simulation [6].

A voltage levels at Delta Egypt in this study are 66KV for transmission network and

(11,6.6,0.4) KV for distribution network which supply electrical power required for oil refining company. All of them are established and simulated using DigSilent Power Factory software as shown in Fig. 1.

The validation of results was performed by comparing the voltage profiles of proposed four different scenarios:

Scenario 1: power System in normal operation, *scenario 2:* by using Automatic Tap Changer (ATC) of transformers, *scenarios 3:* installing a Static VAR System(SVS) with (ATC), *scenario 4:* installing a Static VAR System(SVS) with (ATC) and shunt reactive power compensation devices (parallel capacitive and inductive).

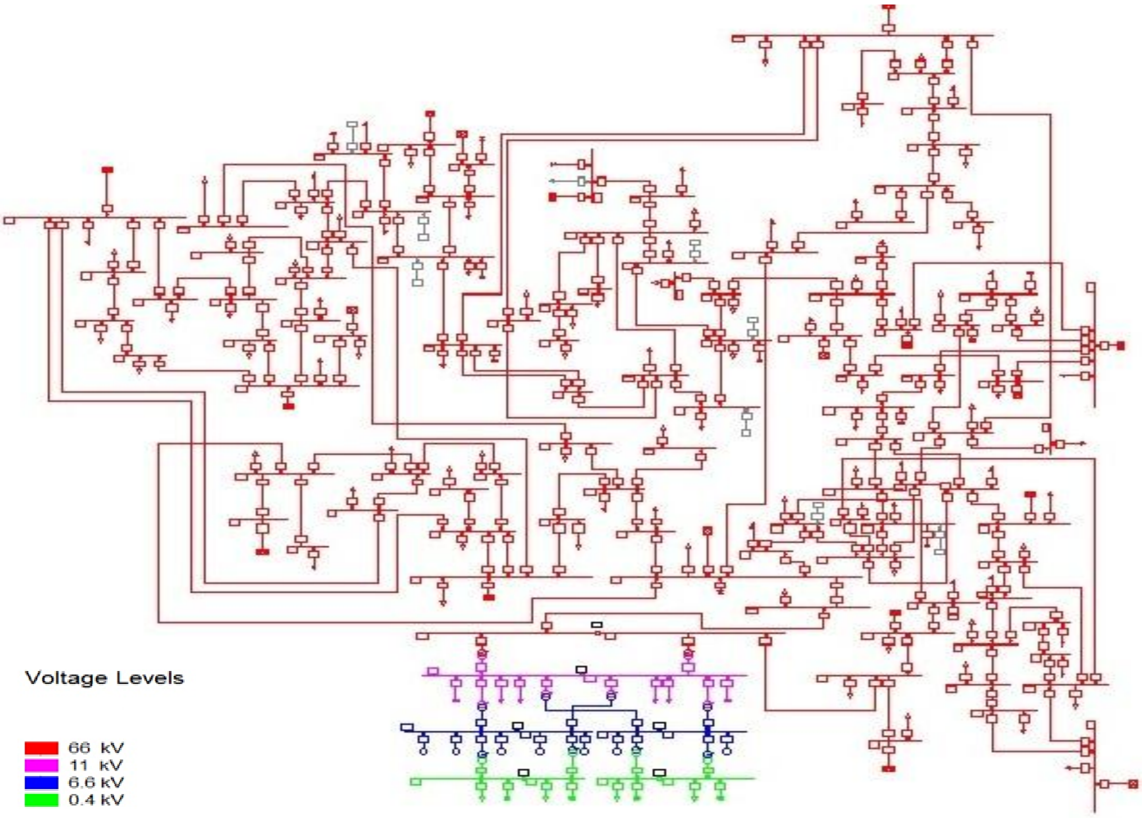

Fig. 1. A single line diagram of a 66KV network supplying oil refining company Constructed by DigSilent Power Factory software.

Four scenarios are performed to comparing the voltage profiles for each bus (only 23 buses are selected which indicate the voltage profile for all system).

A. scenario 1: power System in normal operation

Constructing and simulated the electrical network as shown in Fig. 1, Run the load flow calculation and find the Voltage magnitudes at each bus as shown in table I and Fig. 2.

TABLE I

Voltage magnitudes in P.U. at (system normal operation)

Bus Name	voltage Magnitude in P.U. (normal operation)
Abo Ghanema	0.9419348
Al Gamaliya	0.8007651
Al mandowa	0.9818294
Al mosalas	0.8360475
Al santa	0.9148444
Alborolos West	0.9559873
Albosyle	0.9628006
Alflandi	0.9725568
Almahala	0.9275878
Aolad Hamam	0.9130047
Balteem	0.7982459
Batra	0.8542577
Berkt Alsaba	0.9272687
Beyala	0.8404525
Damitta East	0.9058774
Fowa	0.9459228
Gamasa	0.9148678
Kafr Shokr	0.9553394
Sheben Alkom 2	0.9716483
Tafree el erad	0.8824861
CORC 11KV Alzayat East	0.9930507
CORC 6.6KV	0.9910274
CORC 0.4KV	0.9819487

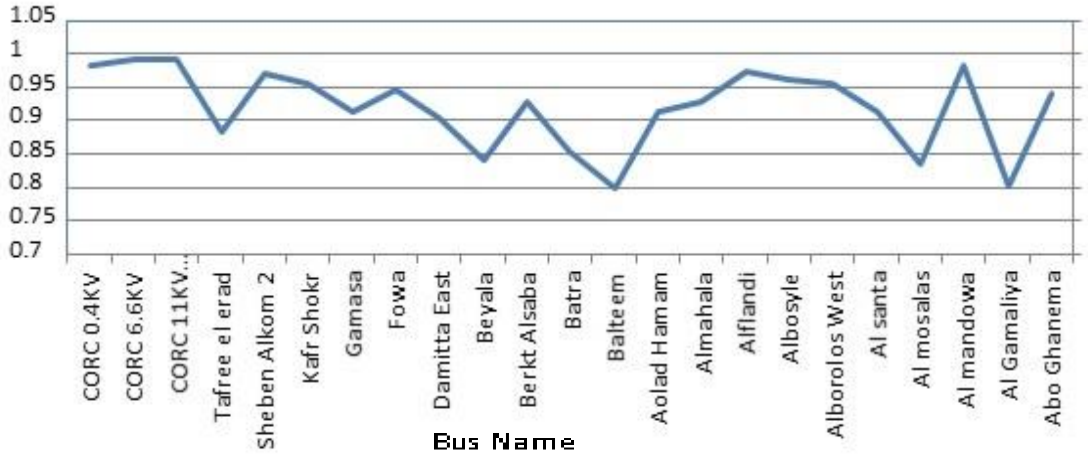

Fig. 2. Voltage magnitudes in P.U. at (normal operation)

According to the results after load flow calculations shown in table I and fig.2, the under voltage problem clearly notifies where The minimum voltage magnitude in the network is around 20% less than the nominal value at 66 KV at (Balteem), this value is not in acceptable range, and should be enhanced. To improve voltage magnitude, scenario 2 is suggested.

B. scenario 2: Using Automatic Tap Changer (ATC) of transformers

Tap-changers are devices that will vary the turns ratio of a transformer and hence regulate the voltages of that transformer [7].

$$\frac{Vp}{Vs} = \frac{Np}{Ns} \qquad (1)$$

where:

Vp = voltage on primary coil.

Vs = voltage on secondary coil.

Np = number of turns on the primary coil.

Ns = number of turns on the secondary coil [8].

Equation (1) indicates, the voltage amplitude can be easy controlled via change the coil number of turns.

Tap-changers that can perform at step down transformers installed at Oil Refining Company (CORC) with the specifications shown at table II.

TABLE II

Transformers Specifications

Quantity	Transformer ratio	Rated (MVA)	Vector group	impedance voltage %
2	66/11 KV	12.5	Dyn 11	5
2	11/6.6 KV	2.5	Dd 0	5.3
2	11/6.6 KV	4	Dyn 11	4.5
2	6.6/0.4 KV	2	Dyn 11	6.6
2	6.6/0.4 KV	2	Dyn 11	5.8

For all transformers have Automatic tap changer at HV side with parameters shown in table III.

TABLE III

Transformer Tap-Changing Parameters

Voltage set point	1.0 P.U
Lower voltage Bound	0.9 P.U
Upper Voltage Bound	1.1 P.U
Additional voltage per tap	1.0%
Min and Max position	-10 and 10
Controller time constant	0.5 sec

After performing automatic tap changers at step down transformers, again Run the load flow calculation and find the values of voltages at each bus and make a comparison with the power system in normal operation (scenario 1), as shown in table IV and Fig. 3.

TABLE IV

Voltage magnitudes in P.U. at (normal operation) and after using ATC

Bus Name	voltage Magnitude in P.U. (normal operation) (scenario 1)	voltage Magnitude in P.U. (Using ATC) (scenario 2)
Abo Ghanema	0.9419348	0.9419285
Al Gamaliya	0.8007651	0.8006359
Al mandowa	0.9818294	0.9818182
Al mosalas	0.8360475	0.8360274
Al santa	0.9148444	0.9148344
Alborolos West	0.9559873	0.9559797
Albosyle	0.9628006	0.9627973
Alflandi	0.9725568	0.972554
Almahala	0.9275878	0.9275876
Aolad Hamam	0.9130047	0.912958
Balteem	0.7982459	0.79823
Batra	0.8542577	0.8542488
Berkt Alsaba	0.9272687	0.9272662
Beyala	0.8404525	0.8404395
Damitta East	0.9058774	0.9058303
Fowa	0.9459228	0.9459164
Gamasa	0.9148678	0.9148636
Kafr Shokr	0.9553394	0.9553387
Sheben Alkom 2	0.9716483	0.971646
Tafree el erad	0.8824861	0.8823648
CORC 11KV Alzayat East	0.9930507	1.003138
CORC 6.6KV	0.9910274	1.001123
CORC 0.4KV	0.9819487	1.00235

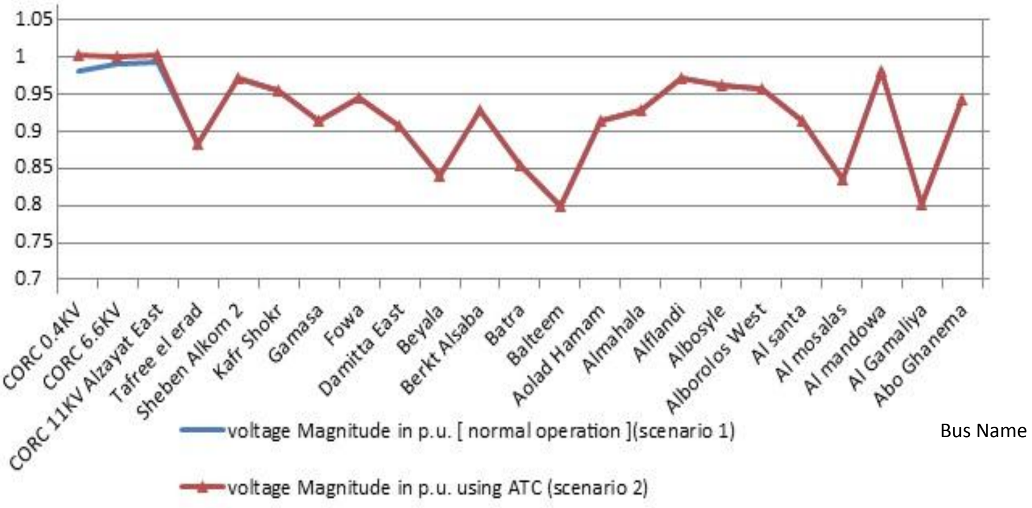

Fig. 3. Voltage magnitudes in P.U. at (normal operation) and after using ATC

According to the results shown in table IV and fig.3, After using ATC the voltage profile has been improved as shown at (CORC 11KV Alzayat East, CORC 6.6 KV and CORC 0.4 KV) Buses, but still the under voltage problem clearly notified which the minimum voltage magnitude in the network is still around 20% less than the nominal value at 66 KV at (Balteem) bus, and this is unacceptable voltage magnitude and should be enhanced, so scenario 3 shall be performed to eliminate this problem.

C. scenario 3: Using a (SVS) with (ATC)

The Static VAR compensator System (SVS) is a combination of a shunt capacitor bank and a thyristor controlled shunt reactance.

The capacitors in the capacitor bank can be switched on and off individually. The capacitors could be switched with thyristors (TSC) or could be permanently (mechanically) connected (MSC) Fig. 4 [9].

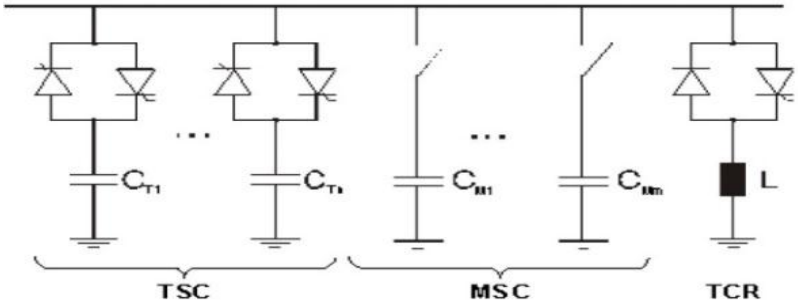

Fig. 4. Static VAR System Model

The optimum location for installing a SVS by selecting the minimum voltage amplitude buses, and apply a SVS at one of them, then run the load flow calculation and check the values of all voltage amplitudes at each bus on the network then select another one to install a SVS on it, and run the load flow calculation again and so on.

Finally: the optimum location for installing a SVS which achieved the best voltage profile of the network.

The installed SVS Basic Data considered: Thyristor Controlled Reactance (TCR) maximum limit is 200Mvar, Thyristor Switch Capacitance (TSC): maximum number of capacitors is (5) (50Mvar/Capacitor) and the amount of reactive power injected into the network is 212.9 Mvar.

Table V shows the final result after installed a SVS and compared voltage magnitudes at each bus with pervious scenarios.

TABLE V

Voltage magnitudes in P.U. at (normal operation) and after using ATC&SVS

Bus name	voltage Magnitude in P.U. [normal operation] (scenario 1)	voltage Magnitude in P.U. [using ATC] (scenario 2)	voltage Magnitude in P.U. [using (ATC & SVS)] (scenario 3)
Abo Ghanema	0.9419348	0.9419285	0.9732539
Al Gamaliya	0.8007651	0.8006359	0.8296768
Al mandowa	0.9818294	0.9818182	1.037865
Al mosalas	0.8360475	0.8360274	0.9372907
Al santa	0.9148444	0.9148344	1.005868
Alborolos West	0.9559873	0.9559797	0.9940954
Albosyle	0.9628006	0.9627973	0.9796433
Alflandi	0.9725568	0.972554	1.016776
Almahala	0.9275878	0.9275876	0.9624498
Aolad Hamam	0.9130047	0.912958	0.9275752
Balteem	0.7982459	0.79823	0.8754059
Batra	0.8542577	0.8542488	0.8811228
Berkt Alsaba	0.9272687	0.9272662	0.9702769
Beyala	0.8404525	0.8404395	0.900479
Damitta East	0.9058774	0.9058303	0.9205705
Fowa	0.9459228	0.9459164	0.9781362
Gamasa	0.9148678	0.9148636	0.9332567
Kafr Shokr	0.9553394	0.9553387	0.9830487
Sheben Alkom 2	0.9716483	0.971646	1.012042
Tafree el erad	0.8824861	0.8823648	0.9096456
CORC 11KV Alzayat East	0.9930507	1.003138	1.001748
CORC 6.6KV	0.9910274	1.001123	1.030972
CORC 0.4KV	0.9819487	1.00235	1.011848

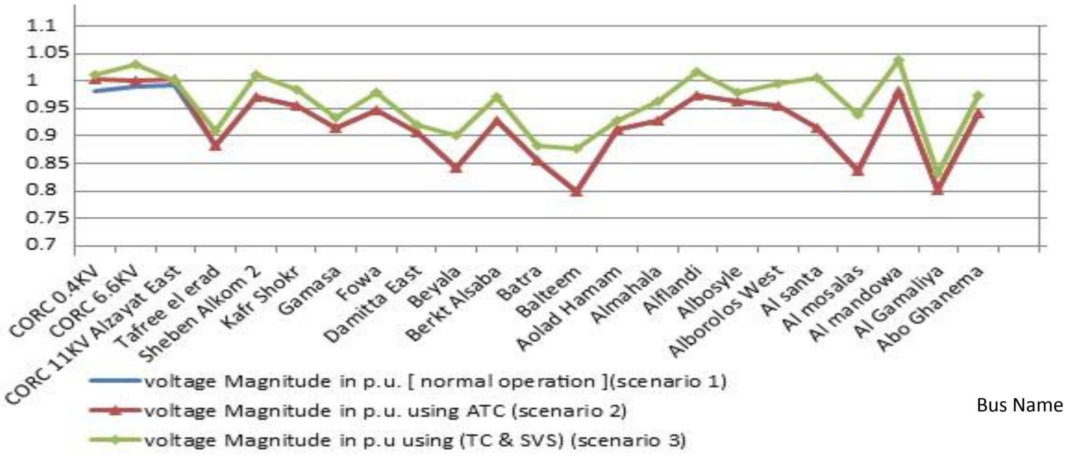

Fig. 5. Voltage magnitude in P.U. at (normal operation) and after using ATC&SVS

According to the results shown in table V and Fig. 5, After using ATC&SVS the voltage had a better profile than previous scenarios (1&2), but still the under voltage problem notified which the minimum voltage magnitude in the network is around 83% of a nominal value at (Al Gamaliya) bus, and this value is still unacceptable and should be improved. To enhance voltage magnitudes, scenario 4 is suggested.

D. scenario 4: using a (SVS) with (ATC) & shunt reactive power compensation devices (capacitor / inductor)

Voltage is propped up with reactive power support, alternatively, if there is inadequate reactive power, the system may have voltage collapse. Therefore, electrical network require compensation for this varying reactive power.

Load compensation is the management of the reactive power to improve the Voltage profile i.e. power quality and power factor.

In this scenario the reactive power flow is controlled by installing shunt compensation devices (capacitor/ inductor) at the load end bringing about power balance between generated and consumed reactive power. This is most effective in improving the power transfer capability of the system and its voltage stability. [10]

Scenario 4 procedure:

A. First step: Shunt capacitor compensation is installed at a bus which have a minimum voltage magnitude to inject a reactive power and enhance voltage profile, then Run the load flow calculation and check the values of all voltage magnitudes at each bus on the network, but over voltage problem was noted at buses which was in acceptable magnitude range before applying a Shunt capacitor.

B. Second step*:* The Shunt inductor compensation is installed to consume the reactive power and reduce over voltage problem at these buses, then Run the load flow calculation again and check the values of all voltage magnitudes at each bus on the network, but under voltage problem was noted again at buses which was in acceptable magnitude range before applying a shunt inductive device ,so the first step is repeated again and so on until an acceptable voltage magnitude range at all buses in the network are confirmed, the procedure flow chart shown in Fig. 6 .

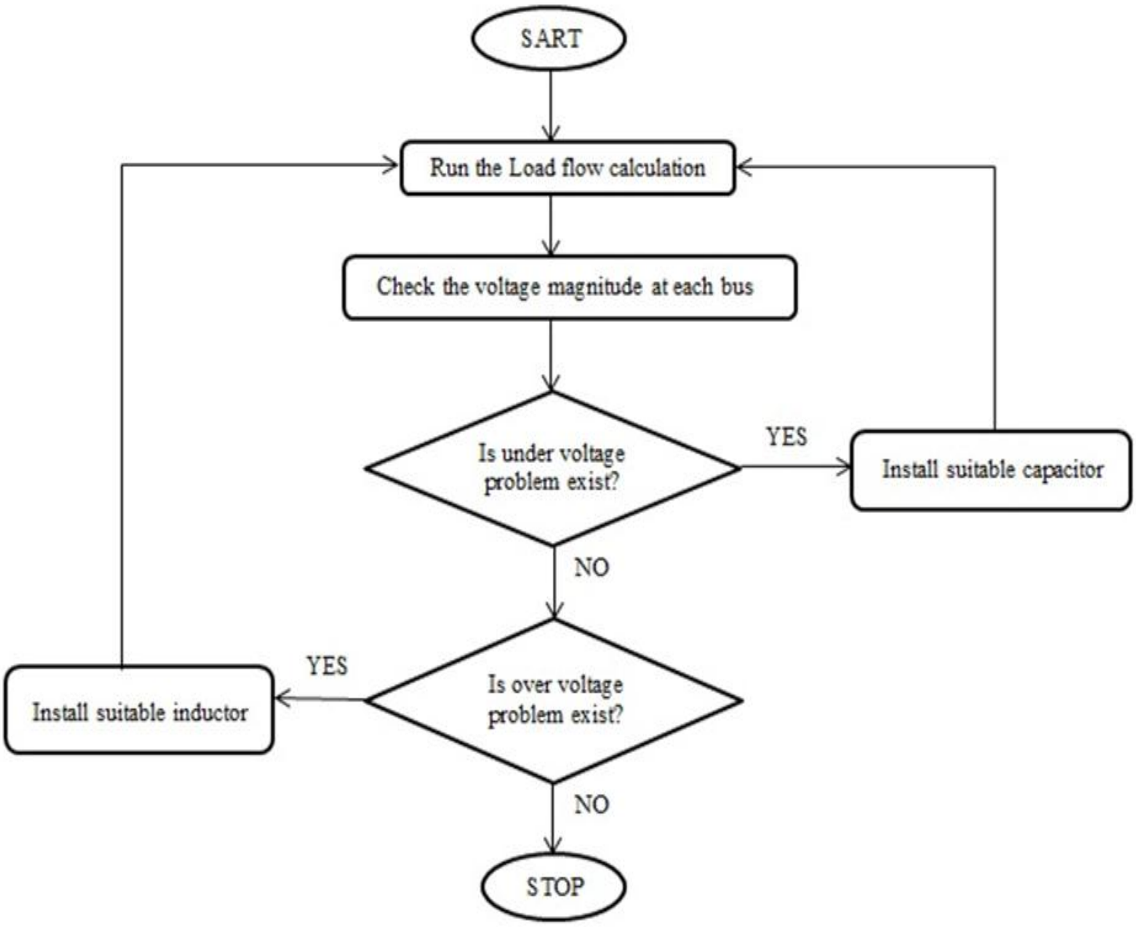

Fig. 6. Scenario 4 procedure flow chart

C. Finally: by using reactive power compensation devices (capacitors/inductors) can control the reactive power which influence at a voltage magnitude, table VI and Fig. 7 Indicates the comparison of voltage profiles for all previous scenarios.

TABLE VI

Voltage magnitudes in P.U. at (normal operation) and after using ATC&SVS& (L, C)

Bus Name	**voltage Magnitude in P.U [normal operation] (scenario 1)**	**Voltage Magnitude in P.U using [ATC] (scenario 2)**	**voltage Magnitude in P.U using [TC & SVS] (scenario 3)**	**voltage Magnitude in P.U using [TC & SVS&L, C] (scenario 4)**
Abo Ghanema	0.9419348	0.9419285	0.9732539	0.9775659
Al Gamaliya	0.8007651	0.8006359	0.8296768	0.9375144
Al mandowa	0.9818294	0.9818182	1.037865	1.046356
Al mosalas	0.8360475	0.8360274	0.9372907	0.9532892
Al santa	0.9148444	0.9148344	1.005868	0.9939926
Alborolos West	0.9559873	0.9559797	0.9940954	0.9997634
Albosyle	0.9628006	0.9627973	0.9796433	0.9820917
Alflandi	0.9725568	0.972554	1.016776	1.006726
Almahala	0.9275878	0.9275876	0.9624498	0.9517096
Aolad Hamam	0.9130047	0.912958	0.9275752	0.9901511
Balteem	0.7982459	0.79823	0.8754059	0.9038995
Batra	0.8542577	0.8542488	0.8811228	0.9040134
Berkt Alsaba	0.9272687	0.9272662	0.9702769	0.9817663
Beyala	0.8404525	0.8404395	0.900479	0.9133325
Damitta East	0.9058774	0.9058303	0.9205705	0.9836267
Fowa	0.9459228	0.9459164	0.9781362	0.9825044
Gamasa	0.9148678	0.9148636	0.9332567	0.9415177
Kafr Shokr	0.9553394	0.9553387	0.9830487	0.9933614
Sheben Alkom 2	0.9716483	0.971646	1.012042	1.005274
Tafree el erad	0.8824861	0.8823648	0.9096456	0.9930215
CORC 11KV Alzayat East	0.9930507	1.003138	1.001748	1.000929
CORC 6.6KV	0.9910274	1.001123	1.030972	1.023106
CORC 0.4KV	0.9819487	1.00235	1.011848	1.014193

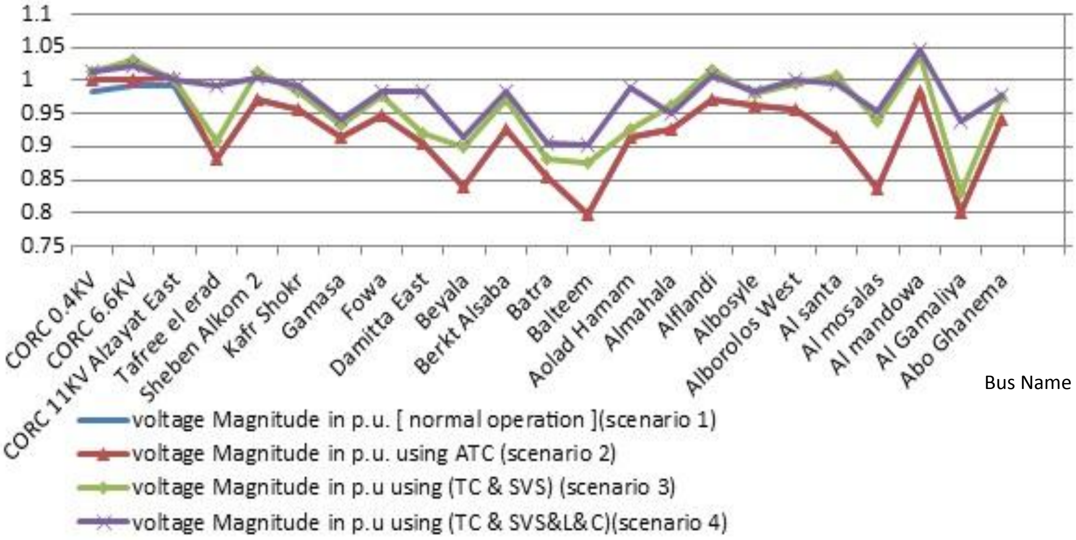

Fig. 7. Voltage Magnitudes in P.U. at (normal operation) and after using ATC&SVS& (L, C)

IV. CONCLUSION

This paper, presents and study the voltage profile in electrical network of Delta Egypt at voltage levels (66,11,6.6,0.4) KV, the transmission network construction and simulations of Delta Egypt were performed in the digital simulation and electrical network calculation (DIgSILENT Power Factory Software) to investigate the voltage profiles at each bus in the network.

The following scenarios were performed:

A. scenario 1: By applying and run the load flow calculation at normal operation (without using any voltage improving devices), under voltage problem was clearly notified at a 66KV voltage level, so the second scenario shall be performed.

B. scenario 2: By using Automatic Tap Changer (ATC) of transformers, this method had improving the voltage level magnitudes (11,6.6,0.4) KV, but still the 66KV voltage level suffer from under voltage problem, to reduce this problem, third scenario shall be suggested.

C. scenario 3: By installing a SVS with (ATC), this solution improved the voltage profile at each bus for all voltage levels as shown at above results, but some busses had unacceptable voltage magnitudes and need to be supported, so the final solution was applied.

D. scenario 4: By adding shunt reactive power compensation devices (capacitors / inductors), from previous results, this method supported and enhanced the voltage profile of all system and brings the magnitudes of all buses in permissible voltage limits and the system can be operated with more efficiently, stability and improve the capacity of the system.

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BIOGRAPHIES

Ibrahim Nassar received the B.Sc. (1999) &M.Sc. (2004) degrees in Electrical Engineering from Al-Azhar University. Since (2001), he has been at faculty of Engineering, Al-Azhar University. He received his PhD in Rostock University, Germany (2011). Currently he is a lecturer and research assistant at faculty of Engineering, Al-Azhar University, Egypt.

Mohammad Omara received the B.Sc. with Excellent Degree in Electrical power and Machines sector on July 15, 2007, From Al-Azhar University, Cairo, Egypt. His employment experience included the heating system company, Agency of (Whieshuput) burners in Egypt as electrical engineer after graduation. Since (2008) until now he has been working in Cairo Oil Refining Company (CORC),Egypt, as Electrical engineer, in Electrical Engineering General Management (EEGM).