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Implementation SVC and TCSC to Improvement the Efficacy of Diyala Electric Network (132 kV).

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ABSTRACT: *In modern power system, the quality and efficiency of the power system have become the rudiments control centers with no change or add new lines, through improving the performance of systems using the SVC and TCSC. In this paper, has been studying and analyzing the Diyala electricity network (132kV) and then improve the performance of the network using SVC and TCSC where improved set of goals within the network, which are: to reduce the real power losses and reactive power losses, reducing the power flow of transmission lines loaded with more than the allowable limit and improve voltages for buses network to maintain at acceptable values. The appropriate values and placement for SVC and TCSC are found using Newton Raphson method based on the above objectives. In this paper, using PowerWorld software and MATLAB based on power system analysis toolbox (PSAT) software to get the results. The simulation results demonstrate the effectiveness and robustness of the proposed SVC and TCSC on a set of goals as above to improvement of Diyala electric network (132kV).*

Keywords: *SVC, TCSC, Newton Raphson, PowerWorld, PSAT.*

I. INTRODUCTION

Modern power systems are prone to diffused failures. Operation and planning of large interconnected power system are becoming more and more complex when the power demand is increase, so power system will become less secure. Operating environment, conventional planning and operating methods can leave power system exposed to instabilities [1, 2]. The planning and daily operation of modern power systems call for numerous power flow studies. The main objective of a power flow study is to determine the steady state operation condition of the electrical power network. The steady state may be determined by finding out the flow of active and reactive power throughout the network and the voltage magnitude and phase angles at all nodes of the network [3, 4] The power electronics technology development gives good opportunities to design new power system equipment for power system stability. FACTS technology has become a very effective means to improve the performance of power system without the necessity of adding new transmission lines. These devices can regulate the active and reactive power and control the power flow by reducing the power flow in overloaded lines, the system security margin improved, voltage profile maintain at acceptable levels and reduce active and reactive line losses [2,5,6 and 7].The combination of TCSC and SVC were considered in the power system and the best location of these devices can be very effective to improved power system network and incorporating the SVC and TCSC will regulates the voltage and power flows even under network contingencies [8, 9]

This paper focuses on the rating and best location of SVC and TCSC models and their implementation in Diyala Electric Network (132 kV) based on Newton Raphson load flow algorithm, to control voltage of the buses, reducing the power flow in overloaded transmission lines and reducing the overall system losses.

II. PROBLEM FORMULATION

The objective function of this paper is to find the optimal sizing and location of TCSC and SVC devices. This paper investigation three objective function combination which maintain bus voltage at desired level, minimizes the power flow in overloaded lines and minimizes the real and reactive power loss. Better results can be obtained by investigate all the objective function.

1.1. Voltage Level [6]

Bus voltage magnitude should be maintained within the allowable range to ensure quality service. Voltage profile (Voltage level) is an important problem to power system. This objective function takes voltage levels into account. For voltage levels between 0.95 to 1.1 p.u.

1.2. Overloaded Lines [6, 10]

This objective is to minimize the power flow in overloaded transmission lines; this objective is calculated for every line of the system. The lines loading must be less than 100%. The active power and reactive power flow on lines can be applied as follows:

$$\mathbf{P_{Gi} - P_{Di} = V_i \sum_{k=1}^{N_B} V_j\left[G_k \cos(\delta_i - \delta_j) + B_k \sin(\delta_i - \delta_j)\right]} \quad \dots (1)$$

$$\mathbf{Q_{Gi} - Q_{Di} = V_i \sum_{k=1}^{N_B} V_j\left[G_k \sin(\delta_i - \delta_j) + B_k \cos(\delta_i - \delta_j)\right]} \quad \dots (2)$$

Where P_{Gi} is the real power generation at bus **i**; P_{Di} is the real power demand at bus **i**; Q_{Gi} is the reactive power generation at bus **i**; P_{Di} is the reactive power demand at bus **i**; N_B is the total number of buses in the system; V_i is the voltage magnitude at bus **i**; V_j is the voltage magnitude at bus **j**; G_k is the conductance of the kth line; B_k is the susceptance of the kth line; δ_i is the voltage angle at bus **i**; and δ_j is the voltage angle at bus **j**.

1.3. Active and Reactive Power Loss [11]

The objective is to minimize the total active and reactive power losses in the transmission lines can be expressed as follows:

$$\mathbf{P_L = \sum_{k=1}^{N_L} G_k\left(V_i^2 + V_j^2 - 2V_iV_j \cos(\delta_i - \delta_j)\right)} \quad \dots (3)$$

$$\mathbf{Q_L = \sum_{k=1}^{N_L} B_k\left(V_i^2 + V_j^2 - 2V_iV_j \sin(\delta_i - \delta_j)\right)} \quad \dots (4)$$

Where N_L is the total number of lines in the system; G_k is the conductance of the kth line; B_k is the susceptance of the kth line; V_i is the voltage magnitude at bus **i**; V_j is the voltage magnitude at bus **j**; δ_i is the voltage angle at bus **i**; and δ_j is the voltage angle at bus **j**.

III. MODELING OF FACTS CONTROLLER

In this paper, two different FACTS devices have been selected to place in suitable location and suitable size to improve the performance of Diyala Electric Network (132 kV). These are: SVC (Static VAR Compensator) shown in Fig. 1, TCSC (Thyristor Controlled Series Compensator) shown in Fig. 2. SVC can be used to control reactive power in network and TCSC can change line reactance.

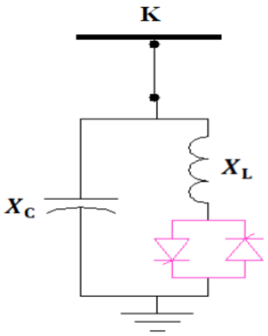

Figure (1): Model of SVC

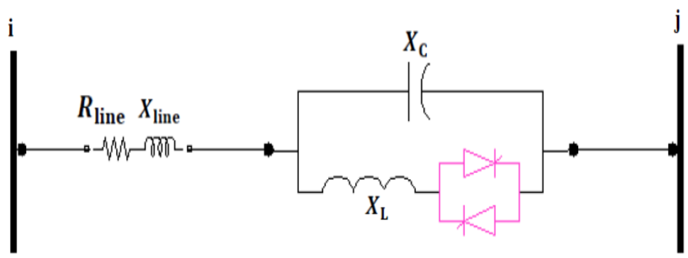

Figure (2): Model of TCSC

2.1. Static VAR Compensator (SVC) Model [12, 13]

Static VAR Compensator (SVC) is a shunt connected FACTS controller whose main objective is to regulate the voltage at a given bus by controlling its equivalent reactance. SVC firing angle model it consists of a fixed capacitor (FC) with a thyristor controlled reactor (TCR) and the thyristor switched capacitor (TSC) with TCR as shown in Fig. 1. The equivalent reactance X_{SVC}, which is function of a changing firing angle α (range of 90° to 180°), is made up of the parallel combination of a thyristor controlled reactor (TCR) equivalent admittance and a fixed capacitive reactance. SVC firing angle model is implemented in this paper as follows:

$$\mathbf{X_{TCR} = \frac{\pi X_L}{\sigma - \sin\sigma}} \quad \dots (5)$$

Where $\sigma = 2(\pi - \alpha)$; σ is the conduction angle and α is the firing angle.

$$X_{TCR} = \frac{\pi X_L}{2(\pi-\alpha)-\sin(2\alpha)} \quad \dots (6)$$

$$X_{SVC} = \frac{\pi X_C X_L}{X_C[2(\pi-\alpha)+\sin(2\alpha)]-\pi X_L} \quad \dots (7)$$

$$B_{SVC} = -\frac{1}{X_{SVC}} \quad \dots (8)$$

2.2. Thyristor Controlled Series Compensator (TCSC) Model [7, 14]

Thyristor Controlled Series Compensator (TCSC) is a series connected FACTS controller whose main objective is to regulate the power flow on a transmission line by controlling its equivalent transmission line reactance.

Fig.2 is a representation of TCSC model which consists of a series capacitor in parallel with a Thyristor Controlled Reactor (TCR). The equivalent reactance X_{TCSC} of the combination of fixed capacitor and thyristor controlled reactor is a function of the firing angle α (range of 90° to 180°). In this paper TCSC model can be represented by the following equation:

$$X_{TCSC} = X_C - \frac{X_C^2}{(X_C-X_L)}\frac{(\sigma+\sin(\sigma))}{\pi} + \frac{4X_C^2}{(X_C-X_L)}\frac{\cos^2(\sigma/2)}{(k^2-1)}\frac{(k\tan(k\sigma/2)-\tan(\sigma/2))}{\pi} \quad \dots (9)$$

Where $\sigma = 2(\pi-\alpha)$; $k = \sqrt{\frac{X_C}{X_L}}$; σ is the conduction angle and α is the firing angle.

IV. SIMULATION RESULTS

The implementation of SVC and TCSC are performed on Diyala (132kV) electrical network system. The system consists of 3 generators, 10 buses, 7 loads and 15 lines (3 double lines and 9 single lines). The configuration of Diyala electrical network (132kV) shown in figure (3) and the line data is given in table (1).

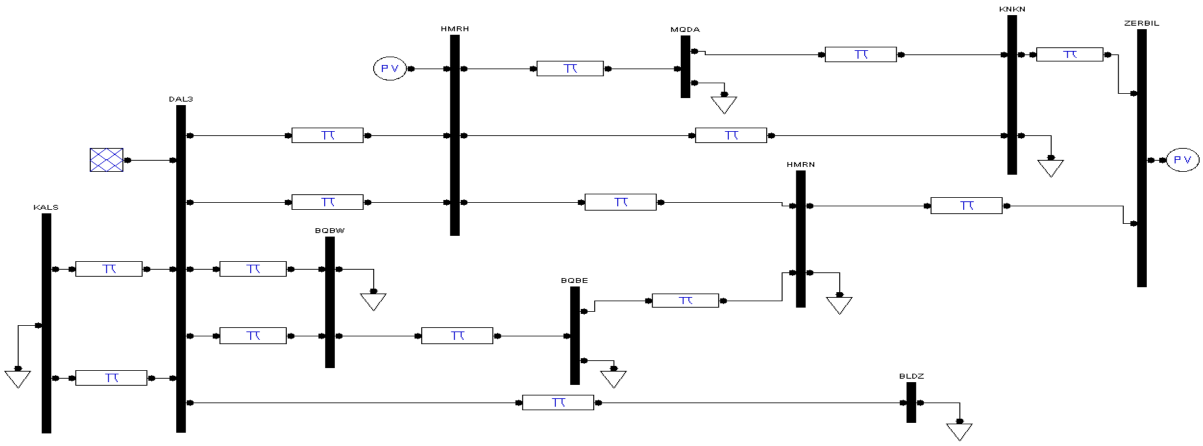

Figure (3): Diyala electrical network (132kV)

Table (1): Line data for Diyala electrical network (132kV)

Line	R (p.u)	X (p.u)	B (p.u)	Rating (MVA)
KALS - DAL3	0.0027	0.0156	0.0073	236
KALS - DAL3	0.0027	0.0156	0.0073	123
DAL3 - HMRH	0.0333	0.1332	0.031	123
DAL3 - HMRH	0.0333	0.1332	0.031	123
DAL3 - BQBW	0.0044	0.019	0.0041	123
DAL3 - BQBW	0.0044	0.019	0.0041	123
HMRH - MQDA	0.0222	0.0953	0.0191	123
HMRH - KNKN	0.0528	0.2263	0.0454	123
HMRH - HMRN	0.0205	0.0881	0.0177	123
BQBW - BQBE	0.0146	0.0366	0.0067	74
DAL3 - BLDZ	0.0372	0.1596	0.032	123
BQBE - HMRN	0.0879	0.1782	0.0313	74
MQDA - KNKN	0.0267	0.1143	0.0229	123
KNKN - ZERBIL	0.0356	0.1525	0.0306	123
HMRN - ZERBIL	0.0773	0.3312	0.0665	123

The simulation results are presented as follows:

The optimal size and placement of FACTS device based on maintain bus voltage at desired level, reducing the power flow in overloaded lines and reduce losses. These objectives investigated when SVC connected at buses BQBE and MQDA shown in figure (4), the parameter setting of SVC is given in table (2) and TCSC connected in series with lines (HMRH – HMRN) and (DAL3 – BLDZ) shown in figures (5&6) respectively, the parameter setting of TCSC is given in table (2).

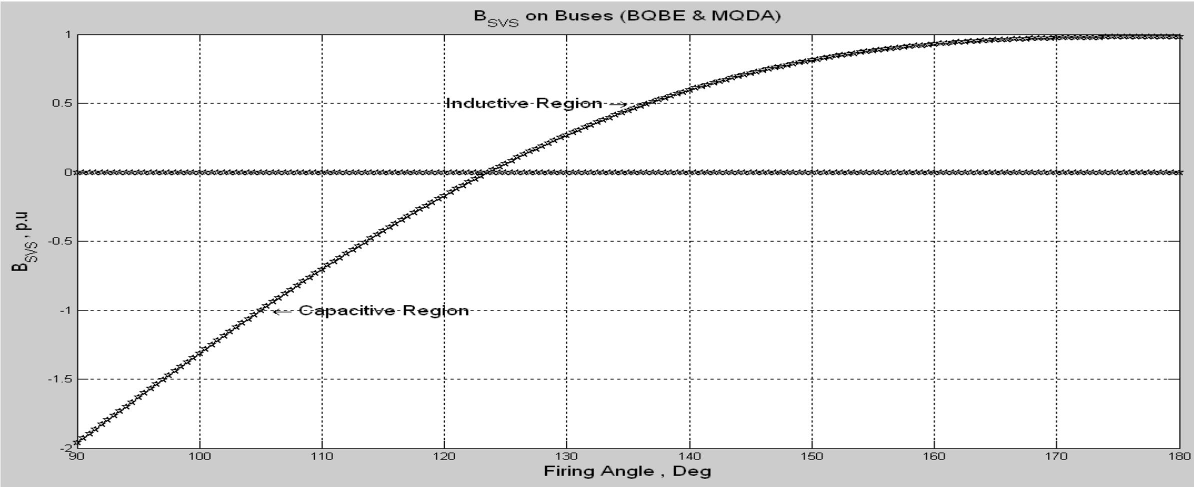

Figure (4): SVC on buses BQBE and MQDA

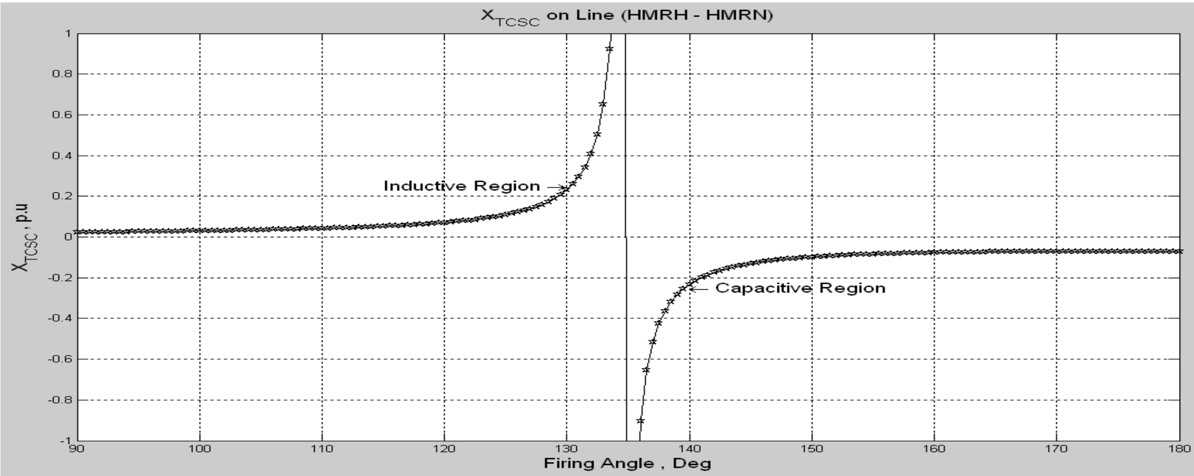

Figure (5): TCSC on line (HMRH – HMRN)

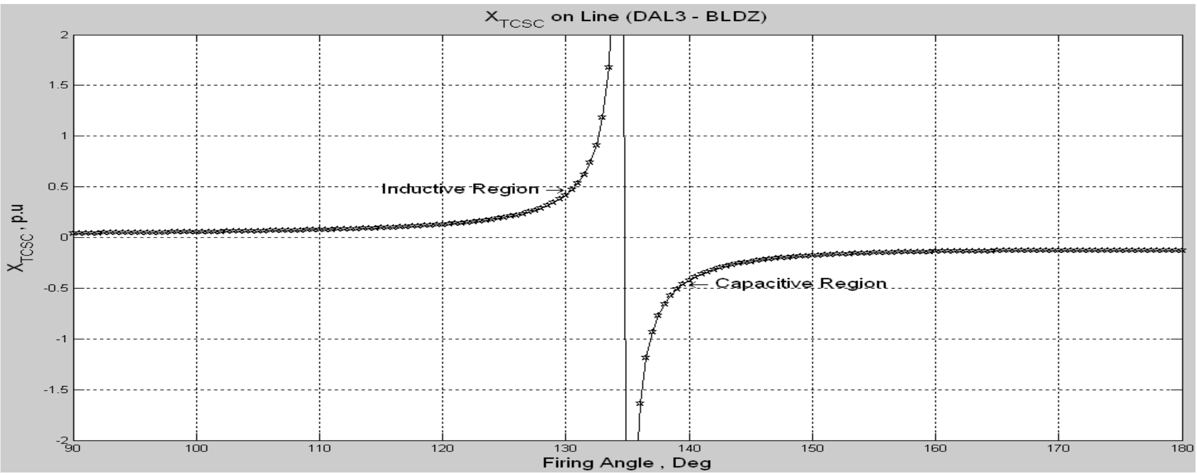

Figure (6): TCSC on line (DAL3 – BLDZ)

Table (2): Parameter setting of SVC and TCSC

	Bus BQBE	Firing Angle	Bus MQDA	Firing Angle
B_{SVC} (p.u)	- 0.736	109.5	- 0.568	112.4
	Line (DAL3 – BLDZ)	Firing Angle	Line (HMRH – HMRN)	Firing Angle
X_{TCSC} (p.u)	- 0.1273	169.8	- 0.0702	170.2

The results carried out using PowerWorld and MATLAB based on power system analysis toolbox (PSAT). In figures (7&8) without using SVC and TCSC shows the lines (BQBW – BQBE) and (KNKN – ZERBIL) are loaded over than maximum rating, active power losses (19 MW by PowerWorld, 18.122 MW by MATLAB) and reactive power losses (33 MVAR by PowerWorld, 28.915 MVAR by MATLAB). The bus voltages at buses (KNKN, MQDA, BQBE and BLDZ) are lower than of desired value.

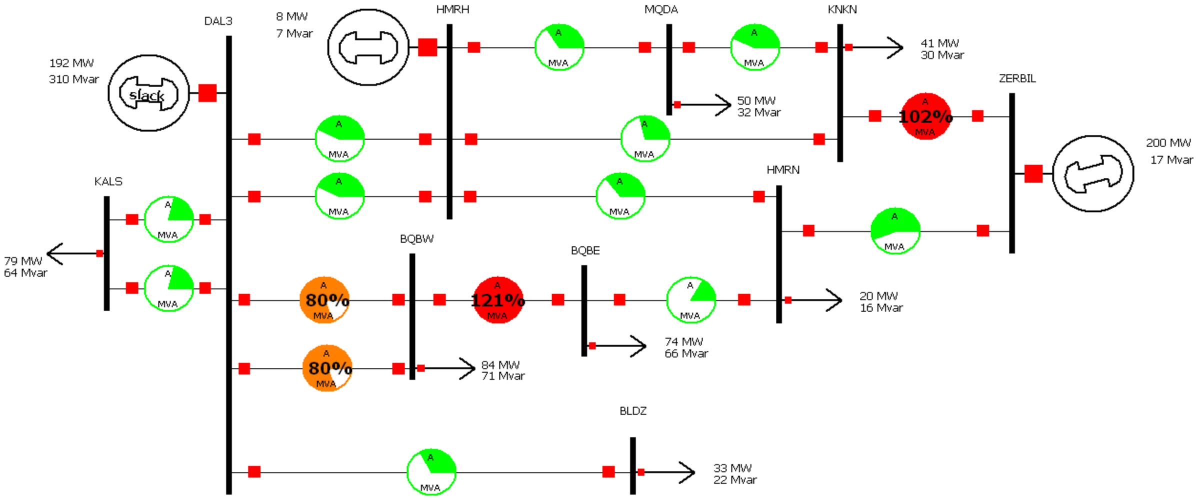

Figure (7): Diyala electrical network (132kV) using PowerWorld without (SVC&TCSC)

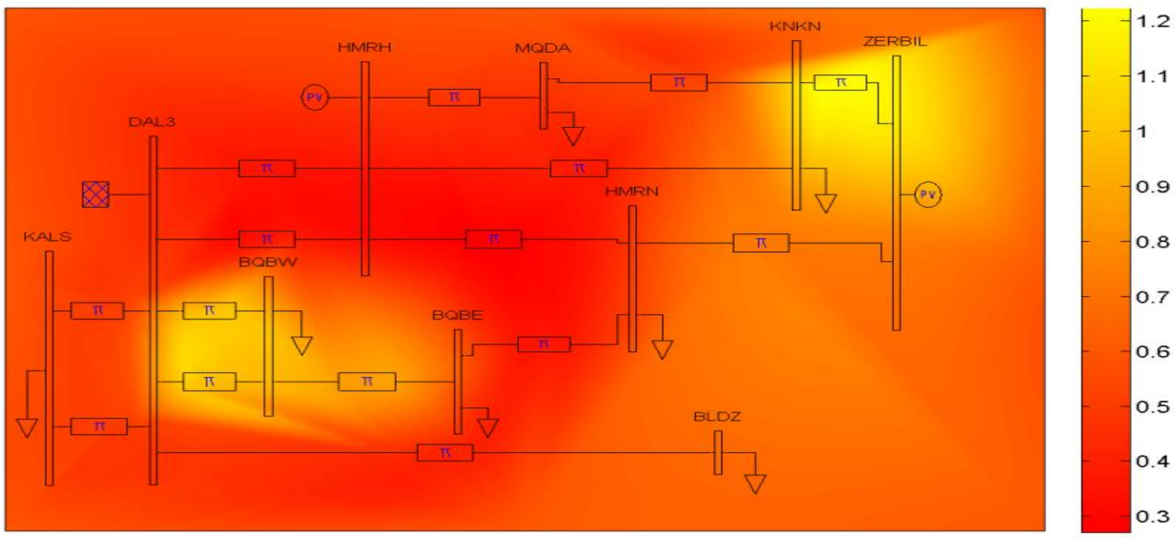

Figure (8): Diyala electrical network (132kV) using MATLAB without (SVC&TCSC)

In figures (9&10) with using SVC and TCSC shows the lines (BQBW – BQBE) and (KNKN – ZERBIL) are loaded lower than maximum rating, active power losses (17 MW by PowerWorld, 16.041 MW by MATLAB) and reactive power losses (24.5 MVAR by PowerWorld, 20.343 MVAR by MATLAB). The bus voltages at buses (KNKN, MQDA, BQBE and BLDZ) are within desired value.

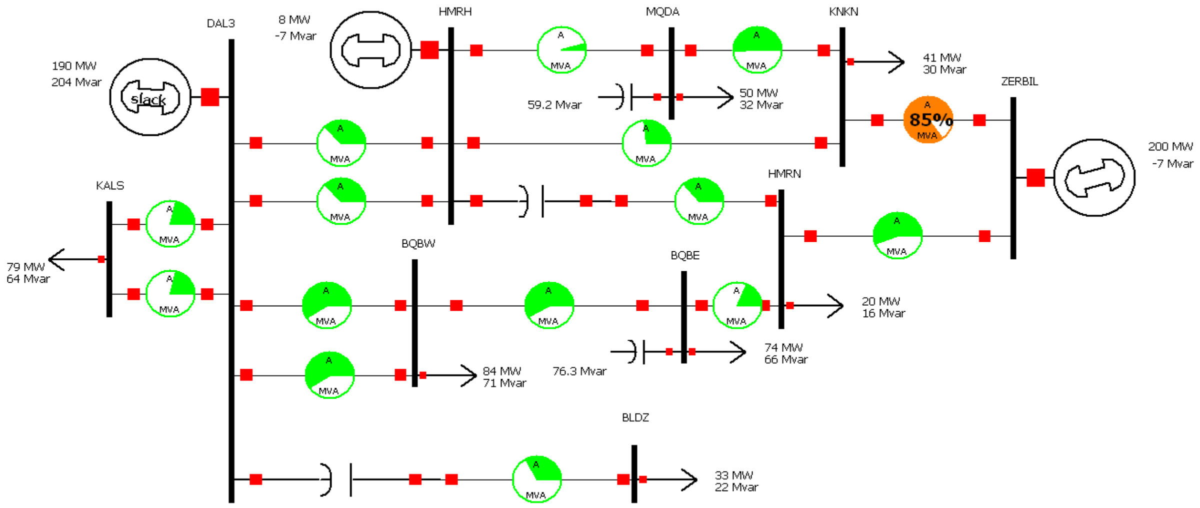

Figure (9): Diyala electrical network (132kV) using PowerWorld with (SVC&TCSC)

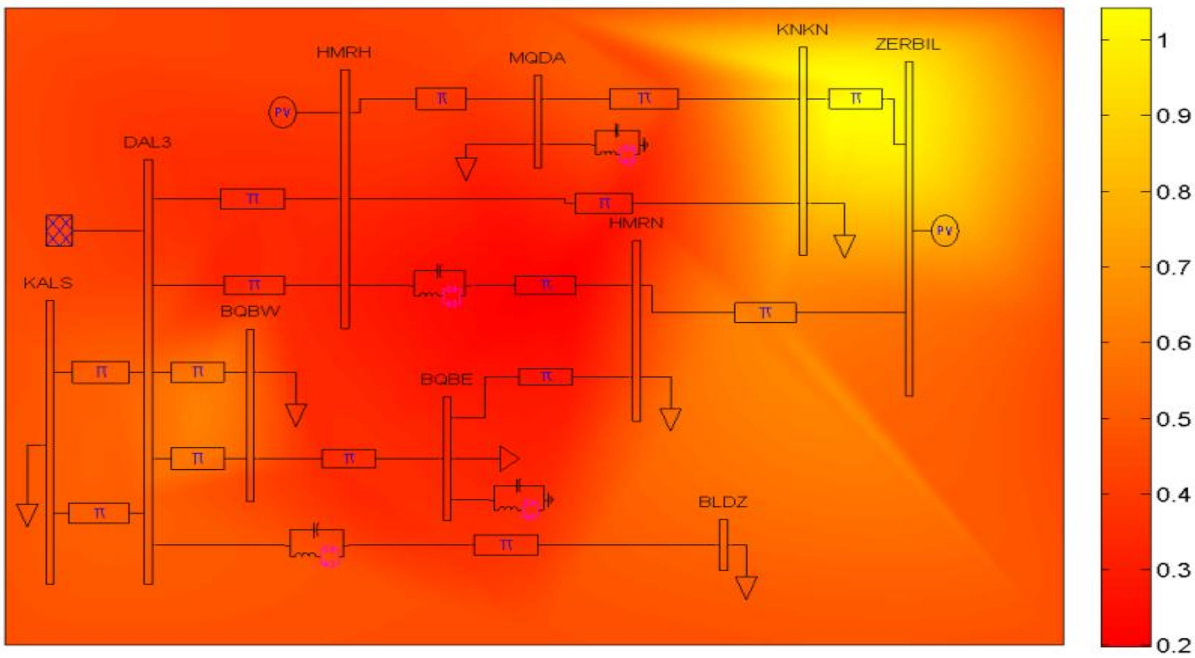

Figure (10): Diyala electrical network (132kV) using MATLAB with (SVC&TCSC)

The bus voltage before and after placing SVC and TCSC shows in table (3), while active and reactive power generation, active and reactive power losses before and after placing SVC and TCSC shows in table (4) and power flow in overloaded lines before and after placing SVC and TCSC shows in table (5).

Table (3): The bus voltage before and after placing SVC and TCSC

Voltage at Bus (p.u)	PowerWorld		MATLAB	
	Without SVC&TCSC	With SVC&TCSC	Without SVC&TCSC	With SVC&TCSC
KNKN	0.907	1.0	0.928	1.001
MQDA	0.916	1.021	0.924	1.022
BQBE	0.908	1.018	0.915	1.02
BLDZ	0.919	1.01	0.926	1.016

Table (4): Total active, reactive power generation and losses before and after placing SVC and TCSC

	PowerWorld		MATLAB	
	Without SVC&TCSC	With SVC&TCSC	Without SVC&TCSC	With SVC&TCSC
Total Active Power Generation (MW)	**400**	**398**	**398.122**	**396.041**
Total Reactive Power Generation (MVAR)	**334**	**325.5**	**329.915**	**321.343**
Total Active Power Losses (MW)	**19**	**17**	**17.122**	**15.041**
Total Reactive Power Losses (MVAR)	**33**	**24.5**	**28.915**	**20.343**

Table (5): Line flow before and after placing SVC and TCSC

	PowerWorld		MATLAB	
Line Flows Between Bus (MVA)	Without SVC&TCSC	With SVC&TCSC	Without SVC&TCSC	With SVC&TCSC
BQBW – BQBE	**89.54**	**44.4**	**88.131**	**43.707**
KNKN – ZERBIL	**125.46**	**104.55**	**124.985**	**104.431**
DAL3 – BQBW	**98.4**	**73.8**	**96.862**	**73.002**

V. CONCLUSIONS

This paper combination of SVC and TCSC has been considered to improvement the voltage profile (maintain at acceptable limits), reduction active and reactive losses of power system and reduction power flow in overloaded lines for Diyala electrical network (132kV). The optimal location and sizing of SVC and TCSC are calculated for objectives as above by Newton Raphson technique based on MATLAB m-file, the bus bars BQBE and MQDA represent optimal locations to placement SVC while; the lines (DAL3 – BLDZ) and (HMRH – HMRN) represent optimal locations to placement TCSC. In this paper, a power flow analysis was carried out using PowerWorld and MATLAB and the lines with over loaded were indentified also, the buses with low voltages were indentified. The effect of the application of SVC and TCSC for enhancing the performance of Diyala electric network (132kV) was demonstrated. PowerWorld and MATLAB (with and without SVC & TCSC) provided approximately the same effect on the voltage profile and same effect on over loaded lines. MATLAB gives a higher minimization in active and reactive power losses compared to PowerWorld. Finally, the results are very much promising.

VI. Acknowledgements

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