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A contribution to the control of voltage and power of the interconnection between two decentralized electrical grids with an optimal localization of the SVC devices in real-time

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ABSTRACT

Several problems related to the power grid in the region of Adrar, in southern Algeria, where it is not connected to the Algerian national network. This region contains many energy resources for power stations, wind and photovoltaic farms. The industrial development in this region requires a connection with the national network to rationalize renewable energy sources and allow sufficient capacity of power for the two grids. The work involved in studying the possibility of interconnection between the grid of Adrar region and the Algerian national network. Modeling, control and real-time analysis of various scenarios have been achieved. An SVC with an optimal location has controlled the improvement of the voltage of the interconnected grid.

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1. INTRODUCTION

The increase of the demand for electrical energy has required higher demands on the energy producer [1]. Nowadays, industrialized countries deal with a serious challenge with the strong demand for electrical energy for their industrial development and each one of them has its own strategy to satisfy their need in electrical energy [2], [3].

Nevertheless, the renewable energy integration, the energy storage, the demand response [4], [5] and the use of electric energy in all areas and every aspect of our lives are more difficult to maintain the stability between production and power consumption [6]-[8].

Algeria is one of the first African industrial centers, because of its economic policy, which is based on the realization of a large number of industrial sites in various fields (hydrocarbon, steel, agro-food, energy, etc.) [9]-[12]. However, the Algerian authorities have moved towards the green energy operation policy located in southern Algeria (the Adrar hub).

The work carried out concerns the interconnection of the Adrar region with the entire Algerian national grid. Real-time modeling, control and analysis were performed for different scenarios, and an optimal study of the SVC's location was performed.

The study carried out makes it possible to achieve this policy by setting up renewable energy sources (wind farms, photovoltaic parks, etc. [13], [14]) and the transfer of the energy produced by the interconnection between two electrical grids.

A FACTS device in shunt mode including the static compensator of reactive energy (SVC) controls the stability as well as the quality of the energy transported by the electrical grid. The SVC can increase the transmissible power in the power lines. The purpose is to provide or absorb reactive power in a way that allow us to modify the natural characteristics of the lines in order to make it more compatible with the load and to control the voltage at the nodes in a reasonable steady state. The optimal SVC's location in an electrical grid minimizes construction costs and increases stability margins [15]-[17].

1.1. Static Var Compensator (SVC)

The SVC's devices are shunt-connected static power generators / absorbers whose outputs are varied to control the voltage and power factor of electrical systems [18]. The main purpose of using SVC is usually the quick control of the voltage at the weak points of the grid. The grouping of both TSC and TCR devices; has the following component: capacitor banks C, inductors L, a controlled thyristor reactor and harmonic filters, constituting the compensator under the name SVC (static compensator reactive energy). In its simple form, the SVC is connected to a coupling transformer directly connected to the AC bus as shown in Figure 1 [19].

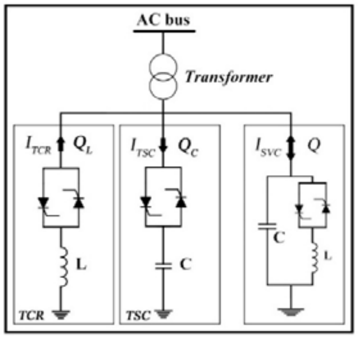


Figure 1. Schematic single-phase representation of an SVC

1.2. SVC Characteristics

The SVC can operate in two different modes: the voltage regulation mode (where the voltage is regulated within the limits [Vmax; Vmin]) and the VAR control mode (where the susceptance of the SVC is kept constant) [20], [21]. The variation of the thyristor firing angle α makes it possible to control the current in the reactance ensuring a fast and continuous control. Figure 2 shows the steady-state control characteristics in which three zones are distinct:

a. For V<V_min no TCR, Maximum capacitive susceptance, with all TSCs in service.
b. For V_min<V<V_max Control area where the reactive energy is a combination of TCRs and TSCs.
c. For V>V_max no TSC, Maximum inductive susceptance, with all TCRs in service.

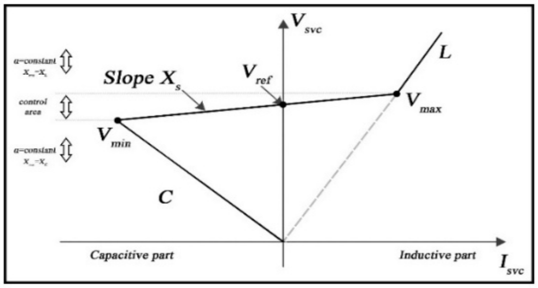


Figure 2. SVC steady-state control characteristics

SVC installations might be located in the Centre of the transmission interconnections or at the ends of the line to compensate for both the irregular load and optimize the active losses as well as the voltage and power factors of the source in the power grid [21].

2. MATERIALS AND CALCULATIONS

Algeria's industrial development in the last decade has contributed in the increase of the electricity consumption. This increase cannot be satisfied economically and reliably without the development of local electric power generation parks. Thanks to its geographical position, the region of Adrar (south) contains important renewable energy sources, mainly the sun and the wind. To ensure interconnection with the national grid, a study was realized concerning on the choice of interconnection site, data collection and real-time simulation.

2.1. Site selection

The optimal proposal, after several variants of interconnection between the two zones, is presented in Figure 1. It represents the Algerian geographical map with a presentation of the lines and substations and interconnection of the decentralized electrical grid of the southern region. 'Adrar and the northern grid of western Algeria. The interconnection zone is presented by a circle on the geographical map as shown in Figure 3.

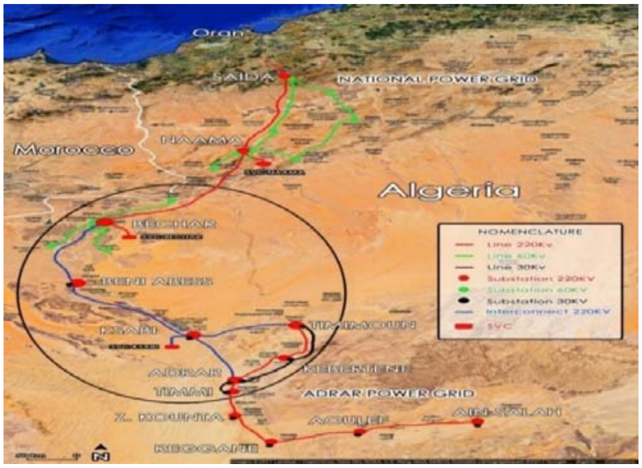


Figure 3. Interconnection grid between North and isolated adrar grid

2.2. Data collection

The basic data are those of the national electricity and Gas Company (SONELGAZ-Algeria) dating from the year 2017 for both the southern and northern Algerian grids [22].

2.3. Simulation tools

For the simulation and validation of the results of the interconnection between the two grids, the HYPERSIM simulator of the R6.1.0.o619 version was used where the data collection phase of the electrical systems for every grid component was implemented.

3. RESULTS

3.1. System description

The studied system is made of three electrical grids; the national interconnected grid (sub section of the Algerian West electricity grid), the Adrar grid (South), and the interconnection grid. The electricity grid studied consists of various components listed in Table 1.

Table 1. Data from electrical system studies

Generator	Central TG/CC	Renewable Energy Sources	
		Photovoltaic	Wind Turbine
Buses	08	09	02
	Load buses		Generator buses
	29		09
Transformers		21	
Lines		38	
Self		09	
SVC		03	

3.2. Voltage control and transit limits

Table 2 illustrates the lower and upper limits of the voltage for the three levels. Table 3. illustrates the transit limits for lines and transformers in a normal grid situation. The interconnection grid as shown in Figure 4.

Table 2. Interval of the voltages of the nodes 220/60/30 KV

	levels	Lower	Upper
Tension nominal (kV)	220 KV	0.91	1.09
	60 KV	0.91	1.09
	30 KV	0.91	1.09

Table 3. The Transit Limits for Lines and Transformers in A Normal Grid Situation

	Transits En Situation Normale
Line	80%
Transformer	80%

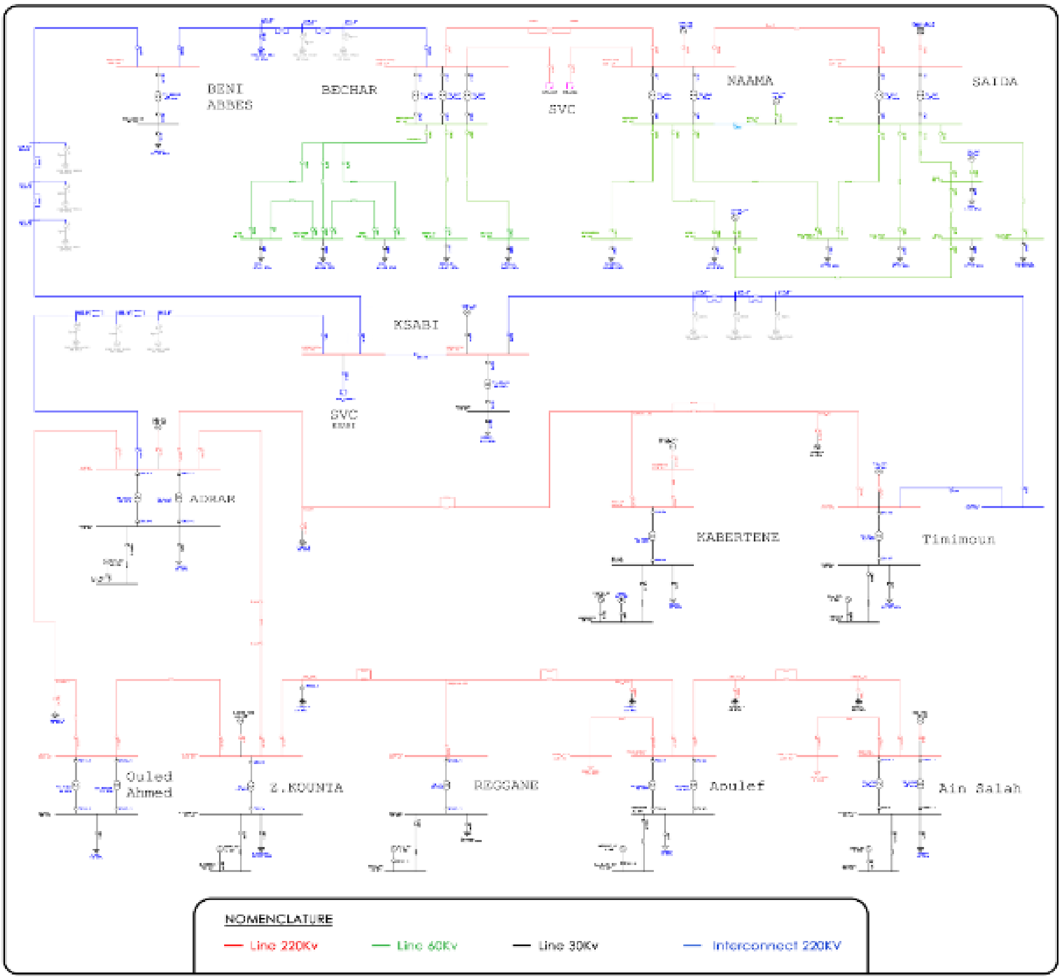


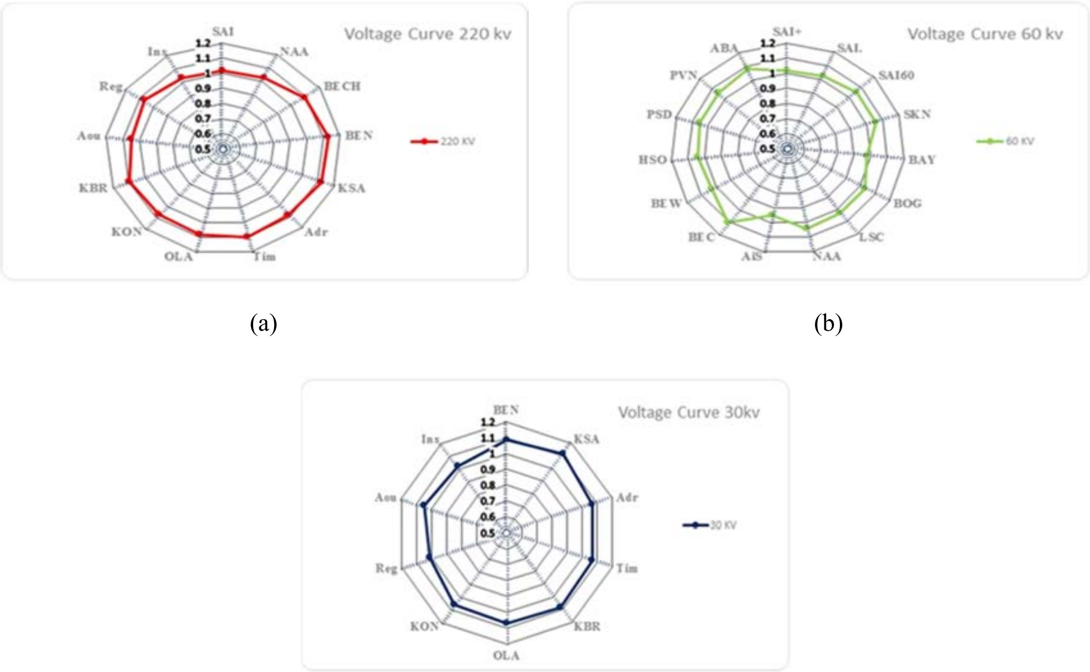
Figure 4. The representation of model study

3.3. Calculs result

In order to study the lattice behavior on the voltage side, calculations were performed with and without compensation as well as with the integration of the SVC.

3.3.1. Case 01: Calcul without Compensation

The results of the 220/60/30 KV voltages obtained without reactive compensation are shown in Figure 5.



(a) (b)

(c)

Figure 5. Results obtained for voltages of grids 220/60/30 KV (case 01)

We find that six nodes have exceeded the upper bound of the imposed voltage including four 220kv nodes: BEN, KSA, TIM and KBR, a 60kv node: BEC and another 30kv node: KSA Table 4.

Table 4. Exceeded limits of voltages 220/60/30 KV (case 01)

Tension KV	Bus	Vi (pu)	ΔVi
220 KV	BEN	1.131	0.024
	KSA	1.127	0.016
	TIM	1.102	0.041
	KBR	1.095	0.037
60 KV	BEC	1.106	0.012
30 KV	KSA	1.114	0.005

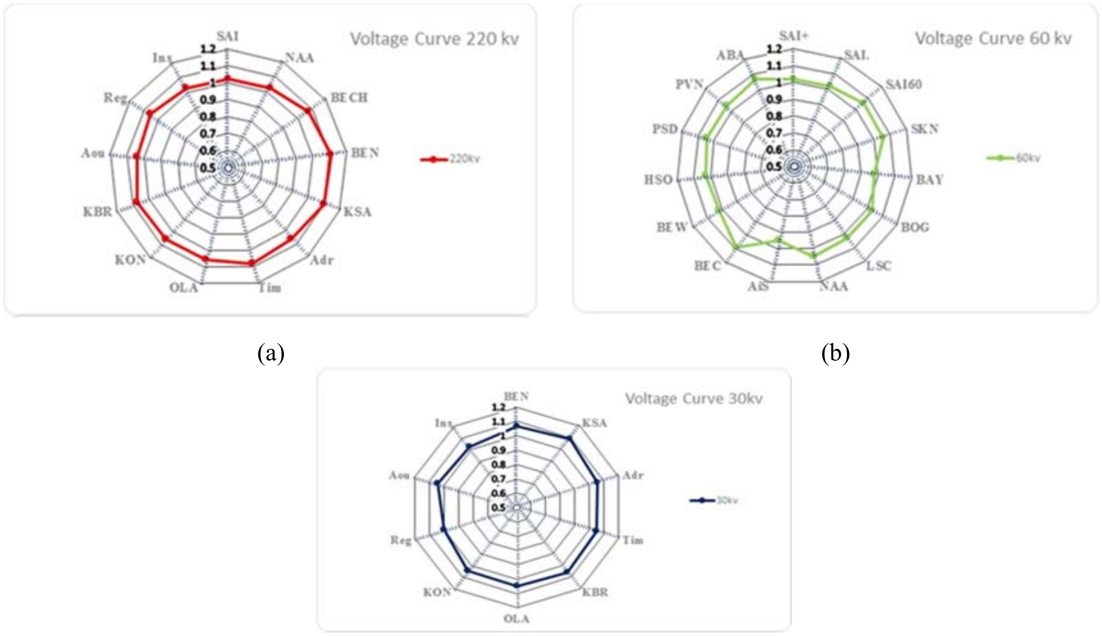
3.3.2. Case 02: Calcul of Compensation Using Selfs

In the second part, we used the self-reactive compensation to reduce the tensions of the nodes, which violate the limits. Figure 6 shows the obtained results:

We have notice that four nodes have exceeded the upper limit of the imposed voltage including two nodes of 220kv: BEN, KSA, a node of 60kv: BEC and another one of 30kv: KSA Table 5.

Table 5. Exceeded limits of voltages 220/60/30 KV (case 01)

Tension KV	Bus	Vi (pu)	ΔVi
220 KV	BEN	1.107	0.001
	KSA	1.104	0.003
60 KV	BEC	1.093	0.017
30 KV	KSA	1.091	0.014



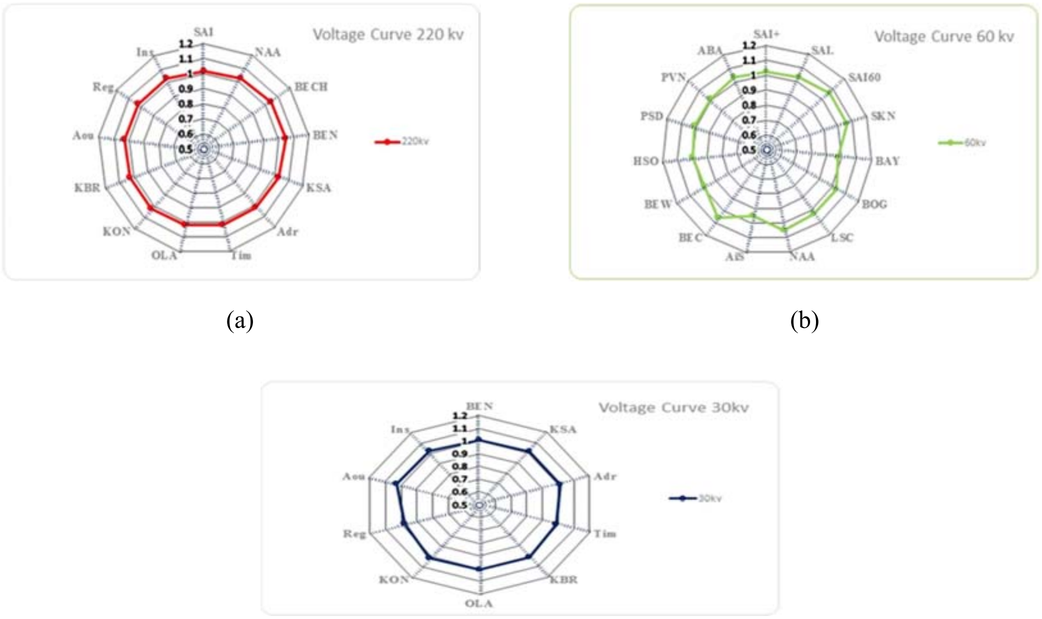
(a) (b)

(c)

Figure 6. Results obtained for voltages of grids 220/60/30 KV (case 02)

3.3.3. Case 02: Calcul of Compensation Using Selfs

After a series of calculations, the result was case number 03; the use of an SVC is the solution for the optimal reactive compensation between the load peaks and the load dips of our system. Figure 7 shows the results obtained using the SVC device at the KSB node. Table 6 shows the maximum and minimum values of each voltage level.



(a) (b)

(c)

Figure 7. The results obtained for the 220/60/30 KV grid voltages (case 03)

Table 6. Exceeded limits of 220/60/30 KV voltages (case 03)

	Max		Min	
	Bus	Vi (pu)	Bus	Vi (pu)
220 KV	BEN	1.046	TIM	1.015
60 KV	SAI60	1.063	AIS	0.953
30 KV	AOU	1.029	REG	0.975

4. DISCUSSIONS

From the results obtained in case number “02”, we have noticed that a slight decrease of the tension compared to the first case, but with always a violation of the tension in four nodes exceeding the upper limit. The use of a 60 Mvar SVC at the KSB node allowed the elimination of the three levels voltage violations (220, 60 and 30 KV). These obtained results made it possible to ensure tensions as well as transits within the admissible limits between [0.90; 1.09] and 80% respectively.

4.1. Active Losses of the System

Table 7 presents the results of the active losses during the different cases with the rate of reduction of the active losses.

Table 7. Evolution comparison of the total active losses for the three cases

	Apparent Losses			Reduction	Reduction%
	MW	Mvar	MVA		
Case 01	10.319	-537.242	537.341	-	-
Case 02	9.751	-525.288	525.379	11.962	2.226
Case 03	9.402	-483.023	483.114	54.227	10.092

The results obtained show that after each case of compensation of the reactive energy, the active losses of the system are reduced. The loss reduction rate using the SVC device at KSB is estimated at 10% compared to the first case, increasing the power transfer capacity.

5. OPTIMISATION DES RÉSULTATS (OPF)

In order to minimize active and reactive power losses, we performed a loss optimization calculation basing on the SVC location between the two BNA and KSB nodes Table 8.

Table 8. Comparison between optimization active and reactive losses

	Apparent Losses			Reduction	Reduction%
	MW	Mvar	MVA		
SANS SVC	4.809	58.701	58.898	-	-
SVC au poste BNA	3.688	51.183	51.316	7.582	12.873
SVC au poste KSB	3.573	49.179	49.309	9.589	16.281

From the results we had, we notice that the use of the 60 Mvar SVC at the KSB node is the most desirable case comparing to the BNA node. This location has minimized active and reactive losses by 16% with a voltage profile of 1.04 at the BNA node and 1.02 at the KSB node.

6. CONCLUSION

Reactive energy compensation played a vital role in the stability of voltage and electrical transit through the connection between the two south and north Algerian network poles. The use of SVC devices has not only allowed and made it possible to set nodes voltage and reduce active losses, but also to increase power transmission from the north to the south grid and vice versa.

The use of this interconnection makes it possible to transfer the electrical energy generated in the region of Adrar (southern Algeria) through wind farms and photovoltaic plants, which constitutes a huge technical, economic and ecological efficiency by contributing to a sustainable and sustainable development.

The choice of the location of the point of interconnection between the two networks is crucial for maintaining the voltage within the permissible limits. The optimal location of SVC minimized active and reactive losses by 16% with a normal voltage profile.

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