Dispatching and scheduling at load peak with the optimal location of the compensation under constraints in real-time

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ABSTRACT

The development of the electricity grid and the use of intelligent control in real-time has today become one of the most important pillars that control the quality and continuity of the electricity supply for industrial consumers and even ordinary consumers. The increase in the load led to an increase in the demand for electrical energy, so this increase was accompanied by multiple problems such as a decrease in the voltage, an increase in the reactive energy in the lines of transport, a decrease in active transited energy, also an increase in active losses and other problems related to electrical synchronization and ultimately overall instability of the electrical network. Through this study, we offer some solutions related to electrical control, using specially developed algorithms to determine the optimal reactive energy compensation locations, taking into account the technical limitations in transformer stations related to high lines 220 kV electric transmission voltage. Thanks to the good results obtained, we were able to apply the algorithms to the real network by taking the southwest region of Algeria as a study sample in order to improve the electrical quality of this region. The modelling, analysis, control and confirmation techniques were studied using an advanced numerical simulation.

Nomenclature

- TCR: Thyristor Controlled Reactor.
- TSC: Thyristor Swiched Capacitor.
- SVC: Static Var Compensator.
- Vi or Ui : Tension au nœud i [V]
- ΔVi or ΔUi : Voltage droop at bus i [V]
- Rs: Resistance of windings.
- Ls: inductance of windings.
- Xs: Reactance of windings.
- n1 et n2 : Number of primary and secondary windings.
- p.u. : Per Unit
- P : Active power [W]
- Q : Reactive power [Var]
- S : Apparent power [VA]

I. Introduction

The Algerian progress society in different sectors; industrial, agriculture, domestic, health, need more energy consumption and an optimal management to avoid the electricity power losses. However, the industrial and demographic development re-quires the grid manager to investigate, monitoring and planning optimal structuring production service, transmission, repartition and distribution of electricity [1], constantly respecting the economic and ecological aspect. The growing demand for energy and the development of distributed generation systems have led to great progress in the field of voltage control quality and active and reactive power. Nevertheless, the regulation of power quality and the appearance of new compensation devices have enabled better control of electrical energy. As the network grows, it becomes more complex, difficult to control and its margin of stability decreases [1,2]. For this reason, the structure of the southern grid forces the operator to find the optimal solution to the problems related to compensation in order to maintain the stability of the power system. Interest in the installation of electronic power devices in substations has increased considerably in recent years. In fact, static converters make it possible to meet the quality requirements imposed by the electric power supplier and to ensure the smooth operation of substations [3]. Reactive power control and voltage stability aspects are effective for power system reliability. Voltage instability usually occurs because of a reactive power deficit. Therefore, reactive power and voltage control is one of the major challenges for power system dispatching [4]. The good quality of the power and the continuity of service play the essential part in the optimal management of the electrical network, then, the compensation of the reactive power transited is the means that ensures the stability of the voltage and increasing the active power flow. The reactive power compensation, capacitive TSC (Thyristor switched capacitor) or inductive TCR (Thyristor-Controlled Reactor) re-quirement installed for transport grids on an electrical interconnection or compensa-tion substation, according to the desired objectives. The capacitive compensation for the distribution grid frequently installed upstream of consumers to optimize the power factor [5,6,7]. Omar Ouledali et [8], presents the Direct Torque Control (DTC) strategy for the Permanent Magnets Synchronous Machine (PMSM) with tuning the PI controller by using genetic algorithms to ensure optimal performance it allows reducing the ripples of the torque and flux. The simulations result of this technique is justified the minimization the ripples of switching in the inverter and reduces the harmonious of the torque and the stator current. The transit of reactive power in enormous capacities through transmission and repartition lines affects the disturbance of the electricity grid, in particular the overall stability of the electricity system [9]. So this difficulty increases the total active and reac-tive losses, and consequently the voltage drops in the substations which obliges the electricity distribution companies to increase the regulation range of the autotrans-formers and use a many primary sources to produce electricity, that is to say an in-crease in the costs of managing electrical energy. Mohammed Bouzidi et al [10], present the design of an intelligent approach based on adaptive fuzzy logic applied to the speed controller for a three-phase asynchronous motor. The results show, for the fuzzy controller of RLF5 excellentesperformances, with a very good track beyond reference speed. Abd Essalam BADOUD et al [11], Developed a new methodology for automatic supervision and fault detection of PV Systems, based mainly on optimal placement of sensors. The experimental results are quite satisfactory, showing the effectiveness of the bond graph model proposed in improving the power quality and the reliability of the power supply. 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 [9,12].The analysis and planning of power system operations not only contributed to the control of power systems but also to the development of these systems, including lines, transformers and reactive compensation means [12-14].

I.1. Reactive energy compensation:

Reactive power has always been difficult to achieve the balance between minimum amounts of reactive power flow Q and a sufficient amount of reactive power flow to maintain an appropriate system voltage profile (maximizing the active power flow capacity P). Voltage control on a power network is strongly related to reactive power transits [6]. The first measure to be taken to maintain the voltage at a correct level is to minimize these transits, by forcing the customers connected to the network to limit their reactive power consumption (the loads are indeed mostly inductive) [7]. This reactive power compensation is generally done by means of capacity banks connected on the incoming busbar of the substation. It can also be carried out, at least partially, by an alternator. The power factor (PF) is equal to the ratio of the active power PMW to the apparent power SMVA [9]. The power factor or almost the Cos (φ) and the tg (φ) are related by the following relation:

$$\cos\phi = \frac{1}{\sqrt{1+(\tan\phi)^2}} \qquad (1)$$

Where; $\cos\phi = \frac{P}{s}$, $tg\phi = \frac{Q}{S}$

On an installation of reactive power Q, and apparent power S, C bank of capacitors of power Qc is installed.

- The reactive power changes from Q to Q'.
- The apparent power goes from S à S'.
- The apparent power after compensation S' is therefore reduced.

The compensation capacitance through the capacitors is calculated by:

$$Qc = 3U^2.C.w \qquad (2)$$

Where $Q' = Q - Qc$

I.2. Voltage drop in a PS under load

When the currents are very high, the voltage drops in the ohmic resistances of the primary and secondary transformer windings and in the leakage, inductances must be taken into account [15,17]. The magnetizing current and the iron losses remain linked to the flux. In practice, the voltage drop in the primary resistors and reactors is small compared to the voltage. Using the Kapp equation, we will have:

$$\frac{n_2}{n_1}.U_1 = U_2 + (R_s + jwl_s)I_2 \qquad (3)$$

With:

U_1 et U_2: Primary and secondary voltages,

R_s et l_s: Resistance of windings and leakage inductance to the secondary side.

n_1 et n_2 : Number of primary and secondary windings.

Actually..., R_s I_2 et l_s I_2 are low in front of U_2 and one can often use a simplified relation, one can construct the Fresnel vectors associated with the voltages, the voltage drop equation.

The voltage drop is a difference between the RMS values of the no-load and on-load secondary voltage for the same primary voltage. U_1.

$$\Delta U_2 = abs(U_2 - U_{20}) \qquad (4)$$

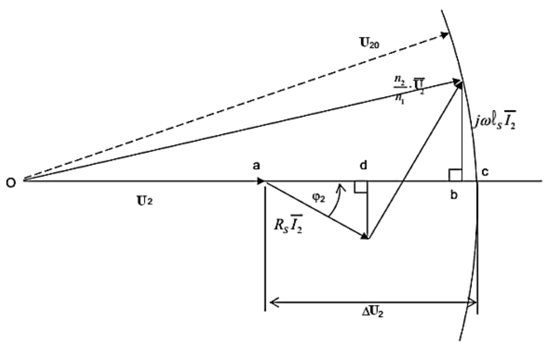

Figure.2 Fresnel representation of the voltage vectors.

Using figure.2 the projection on the ab axis, the development of equation (E.2) gives:

$$\Delta U_2 = (R_s \cos(\varphi_2) + X_s \sin(\varphi_2)) I_2 \qquad (5)$$

The voltage drop is proportional to the current delivered and the nature of the load.

II. Research Method

II.1. System Description:

The system studied is composed as shown in Table 1 below:

Table 1. Description of the electrical system.

Generator	***Central TG/CC***	
	02	
buses	***Load buses***	***Generator buses***
	17	***02***
Transformers	***10***	
Lines	***22***	

II.2. Voltage control and transit limites:

Table 2 below shows the voltage and transit limits;

Table 2. Limits of node and transit voltages in normal situation

Tension		
	The Lower Limit	**The upper limit**
220 kV	0.92 p.u.	1.1 p.u.
60 kV	0.92 p.u.	1.1 p.u.
Transits		
Line	80 %	
Transform	80 %	

Figure 3 shows the implementation of the study model in the RT simulator.

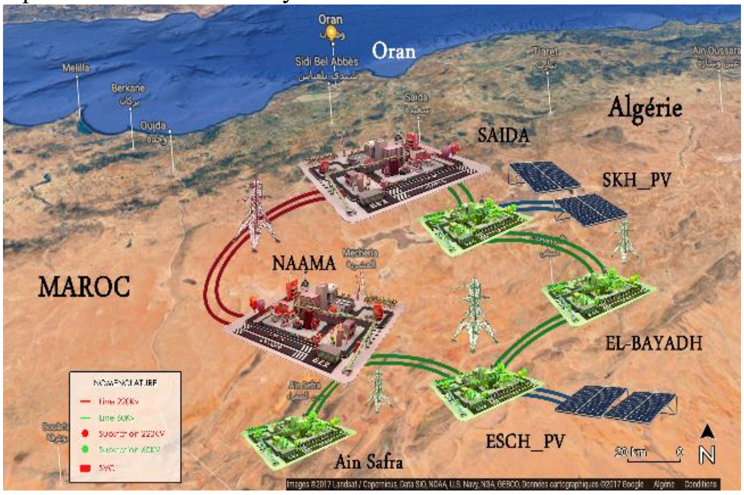

Figure 3. The study model under the RT simulator.

III.Simulation results

We used Gauss-Seidel method with the acceleration factor of 1.45 and an accuracy of 10^{-6}.

III.1. Calcul sans compensation

The results obtained for 220/60 kV voltages without compensation are shown in Figure 4.

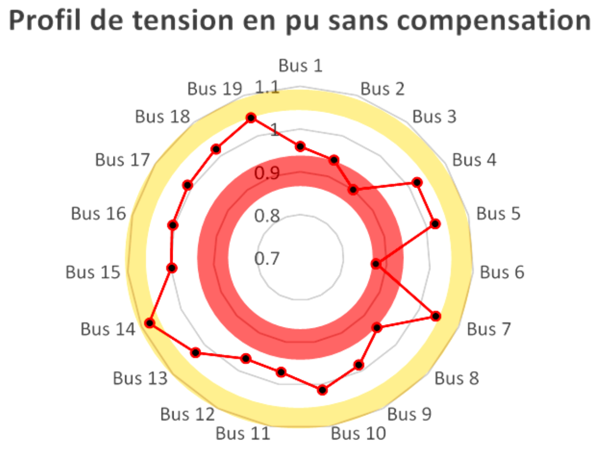

Figure 4. Variation of load voltages according to marginal and critical nodes without compensation

Table 3. Marginal and critical nodes with voltage drops.

Bus	Nominal kV	P.u.	Situation
Bus 1	60	0.9585	Marginale
Bus 2	60	0.94	Critique
Bus 3	60	0.9	Critique
Bus 6	60	0.8768	Critique
Bus 7	60	1.0419	Marginale
Bus 8	60	0.9421	Marginale
Bus 11	60	0.9713	Marginale
Bus 12	60	0.9681	Marginale
Bus 13	60	1.028	Marginale
Bus 14	60	1.0813	Critique
Bus 19	220	1.045	Marginale

III.2. Calculation with compensation

Figure 5 shows the evolution of the voltage according to the inrush powers.

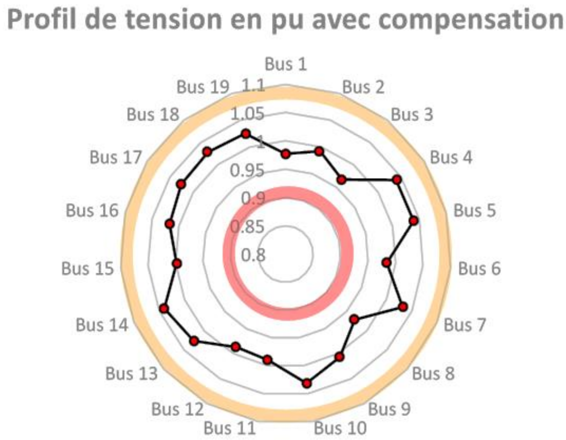

Figure 5. Voltage variation under load according to marginal and critical nodes with compensation

Table 4. Voltages after compensation

Bus	**Nominal kV**	**P.u.**	**Situation**
Bus 1	60	0.9771	Normale
Bus 2	60	0.9923	Normale
Bus 3	60	0.9668	Normal
Bus 6	60	0.9843	Normal
Bus 7	60	1.0321	Normal
Bus 8	60	0.9705	Normal
Bus 11	60	0.9901	Normal
Bus 12	60	0.9869	Normal
Bus 13	60	1.0267	Normal
Bus 14	60	1.0399	Normal
Bus 19	220	1.025	Normal

IV. Discussions

From Figure No. 6 and Table No. 6, it can be seen that there are voltage violations in the different 220/60 kV levels respectively. In this network, two types of voltage violations exist, either critical or marginal in normal situation N at the peak of a summer day in July 2018.

The network SAIDA- Bechar is a radial one, and the subsequent voltage drops in remote substations due to the large loads consumed, is completely logical. This problem appears clearly in the nodes mentioned in Table 7, and in particular in the following critical nodes: Bus 2, Bus 3, Bus 6, and Bus 14which are at the end of the line.

After several variants of optimal installation of the compensation means in the network nodes, the optimal stations located for compensation are as follows: Bus 2, Bus 9, and Bus 12.

The optimal solution proposed consists in installing a capacity of 8 Mvar on the two nodes: Bus 2 and 9 and another capacity of 10 Mvar on the node: Bus 12. The optimal reactive compensation in these nodes will reinforce the margin of stability for power transport in the South Algerian region.

IV.1. Active system losses

Figure 6 shows the results of active losses during peak hours with and without PV injection:

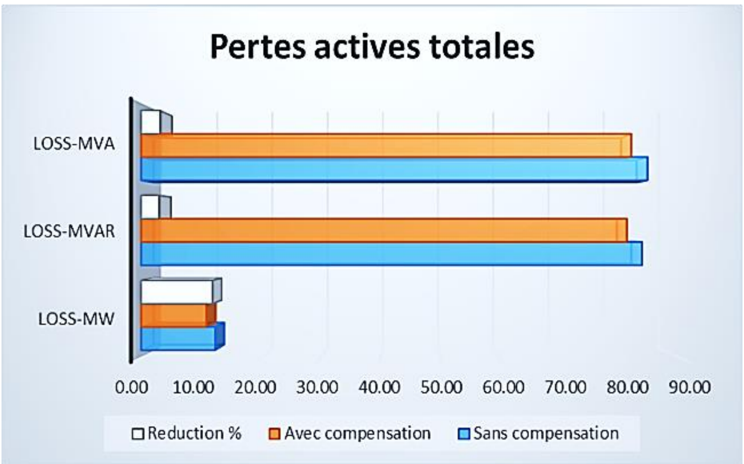

Figure 6. Total active losses

Table 7 shows the results of active losses in the different cases with the rate of reduction of active losses.

Table 7. Total Active Losses.

	Loss-MW	**Loss-Mvar**	**Loss-MVA**
Witout compensation	12.40	83.69	84.60
With compensation	10.92	81.15	81.88
Reduction %	11.91	3.04	3.22

The results obtained show that after compensation of the reactive energy, the active losses of the system are reduced. The rate of loss reduction using conventional means of compensation in substations with voltage violations is estimated at 11.91% compared to the first case, which increases the transit capacity of the powers.

V. Conclusion

We have developed a control algorithm designed for the problem of optimal control of the power transmitted in the electrical network; the results obtained are adequate with the reality which application on the correction of the voltages and reactive powers in the Algerian South-West grid. The optimal choice of location for the compensation point is of crucial importance in resolving voltage drops in remote 60 kV substations, keeping the voltage within acceptable limits and minimizing active losses in the system.

This planning of scenarios for the Algerian southwest electrical network is very useful, it will make it possible to predetermine the next state of the network for a given production plan thus for a fixed power demand, there are a priori an infinity of plans for production possible. For that, the optimal distribution of the power appeared to optimize the production on the various plants and to maximize the power transit while continuing to satisfy this demand in an economical and reliable way.

The advantage of using digital environments made it possible to improve the quality of the study and to save a lot of time; in particular, in the technical problems which it contains the algorithms and its problems of convergences.

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