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Numerical Method and Simulation of the Global Compensation of the Reactive Power in the Industrial Network Piloted By the Limite Substation.

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Abstract: *In this article, we will proceed with the digital method of reactive power compensation in the industrial network, driven by the Limete substation; whose feeders supplying the industrial nodes have a power factor that is not close to 1.*

Seek to make a global compensation of all the feeders by a power factor whose tangent is 0.4; is an ideal solution in the stable operation of the industrial power grid. This will allow operators to control and maintain voltage amplitudes within allowable limits. This is ensured by good compensation. In fact, voltage fluctuations are directly linked to variations in reactive power; it is necessary to expose, in this case, the expression of the voltage drop as a function of the reactive power.

Keywords: *Numerical method, Simulation, Global compensation, Reactive power, Industrial network, Substation.*

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I. INTRODUCTION

Any electrical, industrial or domestic network is based on compliance with the criteria and regulations in force established and designed by specialists in this field. Electrical energy is mainly distributed to users in the form of alternating current by high, medium and low voltage networks.

Reactive energy compensation equipment (capacitors and batteries) saves electricity bills and optimizes electrical equipment. Tangent Phi (tan φ) is an indicator of reactive energy consumption. It is equal to the ratio of reactive power to active power consumed.

The cosine Phi (cos φ) is a measure of the electrical efficiency of an installation. It is the quotient of the active power consumed by the installation over the apparent power supplied to the installation. A good efficiency corresponds to a cos φ close to 1.

Reactive energy is consumed by receivers, such as transformers, motors, fluorescent tube ballasts, etc. To compensate for this, it is necessary to supply reactive energy instead of the distribution network by installing compensation equipment.

II. PRINCIPLE OF COMPENSATION AND ELECTRICAL EQUATIONS

II.1. Principle of compensation

II.1.1 Consume reactive energy

Many receivers consume reactive energy to create electromagnetic fields (motors, transformers, fluorescent tube ballasts, etc.). Compensating for reactive energy means supplying this energy instead of the distribution network by installing capacitor banks, QC power reactive energy sources, synchronous or asynchronous rotating machines, but currently (except exception), their employment was abandoned mainly because of their expensive upkeep.

II.1.2Compensation and its use in networks

Currently, the operation of electrical power transmission networks has become increasingly complex due to the increase in their size, the presence of very long interconnection lines and technical and economic constraints. These factors force operators to operate them near their safety and stability limits.

Indeed, the management of a network does not only consist in ensuring that the power transits are lower than the transport capacity, it is also necessary to monitor several parameters including the voltage level which must remain within an authorized range at all points. of the network and in all situations.

II.1.3 Compensation power mode

When an electrical network supplies an industrial area, the power factor by imposition must have a tangent phi of 0.4 and cosine phi close to 1. Finally trim a good quality of electrical energy that will be supplied in the industrial area.

II.2.Parameter equation

II.2.1Power triangle

The reactive power, Qc to be compensated for electrical equipment can be deduced from the active power and the power factor of the installation.

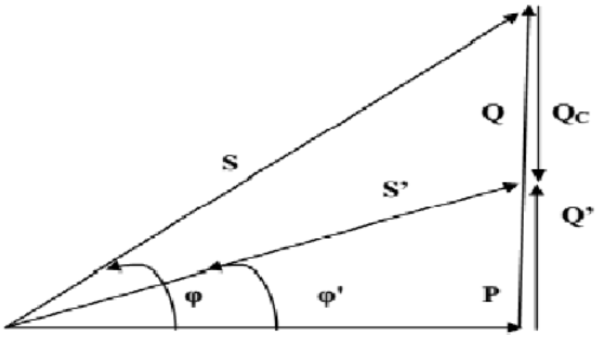


Figure II.1 : Power triangle

Before compensation
Active power P (en KW).
Reactive power Q (KVAR).
Apparent power S (en KVA).
Power factor Cosφ.

II.2.2 Power factor equation

After compensation with a compensation reactive power Qc (in Kvar)
Active power P (in KW).
Reactive power Q' (KVAR) Apparent power S' (in KVA).
Power factor Cosφ'.

$$\cos\varphi = \frac{P}{S} \quad (2.1)$$

$$\tan\varphi = \frac{Q}{P} \quad (2.2)$$

$$\tan\varphi' = \frac{Q'}{P} (2.3)$$

II.2.3 Reactive power equation to install

$$Q = Q' + Qc \quad (2.4)$$

$$Qc = Q - Q' (2.5)$$

The reactive power supplied by all the capacitors is given by the following expression:

$$Q_C = 3.\mathrm{Ceq}.\omega.U^2 \quad (2.6)$$

$$\mathrm{Ceq} = \frac{m}{n.c} \quad (2.7)$$

U: phase-to-phase voltage (V).
ω: network voltage pulsation (rd/s).
C: capacitance of the capacitor (F).
n: number of capacitors connected in series.
m: number of capacitors connected in parallel.

II.2.4Star mounting equation

The reactive power supplied by all the capacitors is as follows:

$$Q_C = C.\omega.V^2 \quad (2.8)$$

$$Q_C = 3.Ceq.\omega.U^2 \quad (2.9)$$

$$Ceq = \frac{Q_{C-\Delta}}{3.\omega.U^2} \quad (2.10)$$

$$3Ceq = \frac{Q_{C-\Delta}}{\omega.U^2} \quad (2.11)$$

$$C_{eq-\lambda} = 3.Ceq.\omega.V^2 = 3.Ceq.\omega\left(\frac{U}{\sqrt{3}}\right)^2 \quad (2.12)$$

$$C_{eq-\lambda} = \frac{3}{3}.Ceq.\omega.U^2 \quad (2.13)$$

$$C_{eq-\lambda} = \frac{Q_{C-\lambda}}{\omega.U^2} \quad (2.14)$$

$$C_{eq-\lambda} = 3.C_{eq-\Delta} \quad (2.15)$$

II.2.5Reactive power voltage relationship

In order to establish a simplified expression between the voltage drops in lines and the reactive powers transmitted, we consider as an example a line of the network represented as a model in π. The impedance of the line is given by the following relation:

$$Z = R + jX \quad (2.16)$$

$$S_{pq} = P_{pq} + jQ_{pq} = U_p.I_{pq} \,(2.17)$$

$$I_{pq} = U_p - \frac{U_q}{R} + jX \,(2.18)$$

Where:
S_{pq}: complex apparent power transmitted between the origin p and the end q of the line.
I^*_{pq}: complex conjugate of the current transiting the line pq.
U_p, U_q : complex voltages at the origin p and at the end q of the line.

From relations (2.17) and (2.18), we obtain:

$$P_{pq} + jQ_{pq} = \left[\frac{U^*{}_p - U^*{}_q}{R - jX}\right] x\, U_p \quad (2.19)$$

The expansion of relation (2.19) gives us:

$$P_{pq} = \frac{U^2{}_p.R}{R^2 + X^2} - \frac{U_p.U_q}{R^2 + X^2}\left(R.cos\theta_{pq} - X.sin\theta_{pq}\right) \quad (2.20)$$

$$Q_{pq} = \frac{U^2{}_p.X}{R^2 + X^2} - \frac{U_p.U_q}{R^2 + X^2}\left(R.sin\theta_{pq} - X.cos\theta_{pq}\right) \quad (2.21)$$

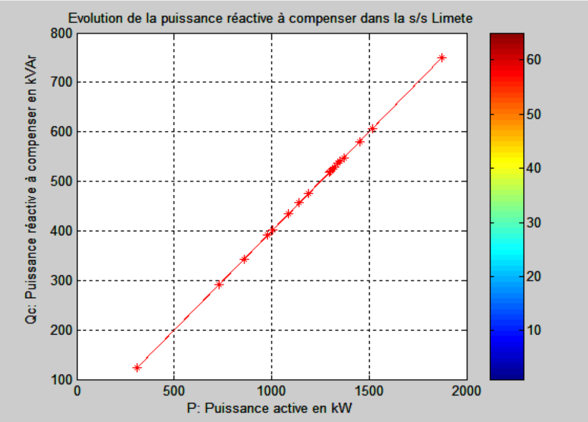
The two expressions become:

$$P_{pq} \cong \frac{U_p.U_q}{X}\theta_{pq} \quad (2.22)$$

$$Q_{pq} \cong -\frac{U_p}{X}\left(U_p - U_q\right) \quad (2.23)$$

III.SIMULATION OF RESULTS AND INTERPRETATION

III.1 Simulation



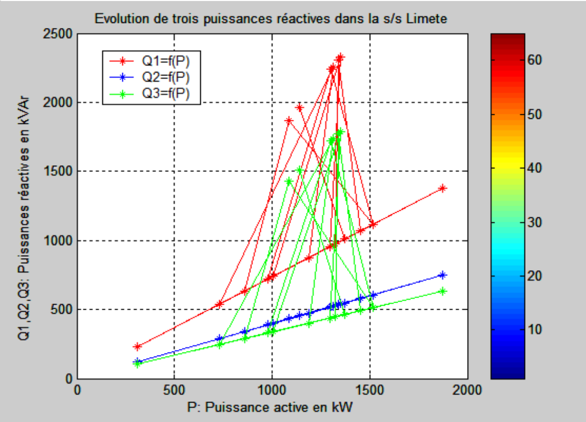
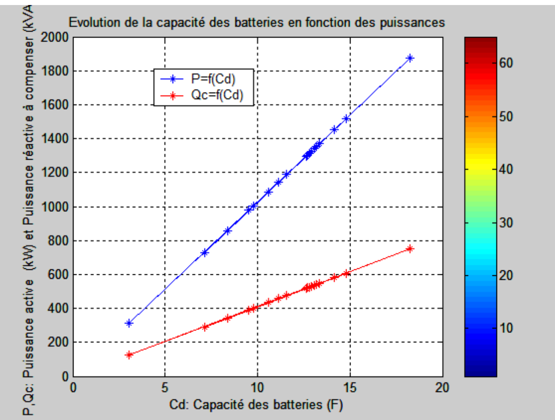


Figure III.1: Reactive power to be compensated Figure III.2: Reactive power to be eliminated



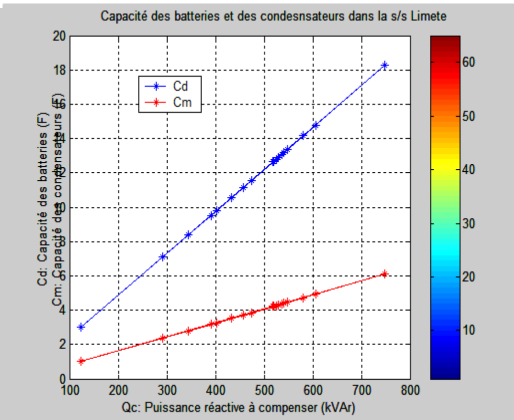
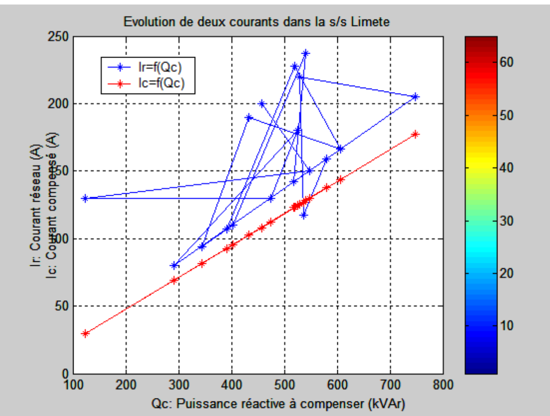


Figure III.3: Capacitance of battery compensations Figure III.4: Capacitance of compensation capacitors



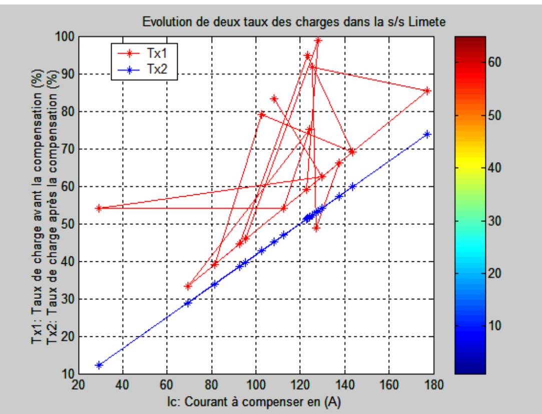


Figure III.5: Compensation current Figure III.6: New compensation load rate

III.2Interpretation of results

We have just examined in the first simulation the behavior of the reactive power of the network which varies according to their following;456.72, 548.064, 124.2276, 474.9888, 525.228, 292.3008, 749.0208, 529.7952, 536.646, 580.9476, 518.8336, 541.2132, 401.9136, 343.4532, 433.884, 606.524, 520.6608, 390.952 en kVAr. The second simulation shows the reactive power actually to be eliminated, whose values are 1507.176, 462.426, 104.8174, 400.7712, 1732.772, 246.6282, 631.9862, 447.0138, 1770.931, 490.1744, 437.7664, 1786.003, 339.1144, 289.7888, 1431.817, 511.754, 1718.18, 329.866en kVAr. The third simulation concerns the capacity of the batteries, whose values are 11.13041, 13.35649, 3.02747, 11.57563, 12.79997, 7.12346, 18.25388, 12.91128, 13.07823, 14.15788, 12.64414,13.18954, 9.79476, 8.37006, 10.57389, 14.78118, 12.68867, 9.52763 infarad. The fourth simulation demonstrates the capacitance of compensation capacitors whose values are 3.71013747, 4.45216496, 1.00915544, 3.85854297, 4.26665809, 2.37448798, 6.08462545, 4.30375946, 4.35941153, 4.71929291, 4.21471356, 4.3965129, 3.26492097, 2.79002143, 3.52463059, 4.92706126, 4.22955671, 3.17587507infarad. The fifth simulation concerns the behavior of the compensation current which has the value of108.108, 129.73, 29.4053, 112.432, 124.324, 69.1892, 177.297, 125.405, 127.027, 137.513, 122.811,128.108, 95.1351, 81.2972, 102.703, 143.568, 123.243, 92.5405 en A. In order, the sixth simulation gives the evolution of the charge rate after compensation, which has the value of 45.045, 54.05417, 12.25221, 46.84667, 51.80167, 28.8288333, 73.87375, 52.2520833, 52.9279167, 57.2970833, 51.17125, 53.3783333, 39.63963, 33.87383, 42.79292, 59.82, 51.35125, 38.55854in %.

CONCLUSION

We have seen that this article consisted of the numerical method and simulation of the global compensation of the reactive power of the industrial network controlled by the Limete substation. This mode of global compensation, which is found to be better in terms of long-term investment, eliminates the reactive energy which circulates upstream of the batteries. The decrease in the reactive current passing through allows us to have low cable sections and also a low voltage drop. To calculate the compensated reactive power Qc, the steps mentioned above must be taken into account for the mode to be chosen.

Thus, by considering a simplified model of an electrical network feeder, and by introducing certain simplifications, it was possible to establish by the mathematical relations of the proportionality between the voltage phase shifts and the active powers transited in the network and the voltage drops and the reactive powers transited in the network. Note that with a power factor by a tangent of 0.4 applied to all the feeders to be compensated. We have obtained a significant reduction in the load rate of 45% at the level of the allowable current of the feeders. On the other hand, at the level of the transformer current, the charge rate drops by 15%.

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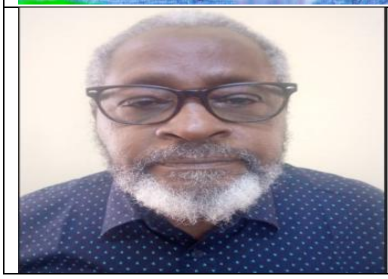	**Pof.Dr.Ir Pasi Bengi Masata**, PhD en Sciences Appliquées. Teacher-Researcher at ISTA-Kinshasa.