Current Aspects in the Conception and Performance of Dispatching Manoeuvres in the National Electric Power Transmission System

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Abstract - **In this paper, the authors have structured a complete algorithm for calculating the self-excitement of the generating groups in the NPS power plants, a phenomenon that can occur in the operative manoeuvres performed in 220 kV, 400 kV and 750 kV electrical networks. This shows how with simple parameter calculations can be evaluated parameter approximate values for long lines switching regimes, the safety measures to be taken when manoeuvres are appropriately performed and their sequence in order to avoid dangerous overvoltages that would lead to non-admissible stresses of the energetic equipments. In order to increase the degree of generality of these calculations, the relative size method was used, for which a computational program developed in the Mathcad programming environment was designed. This calculation algorithm was customized for a double-circuit overhead electric line LEA 220 kV case study. Also are presented the practical algorithms for calculating the voltage jump that occurs when connecting and disconnecting the long electric transmission lines from the power system. The overvoltages caused by the switching of these lines are also evaluated. These values must be taken into account by the managerial and operational staff to properly perform and coordinate manoeuvres. For the considered double-circuit overhead power line 220 kV LEA, the calculation algorithms for both no load and under load switching were customized, and two scenarios were studied, namely when the line is not compensated and when the line is compensated by a compensation coil.**

Cuvinte cheie: *autoexcitarea grupurilor generatoare din centralele electrice;linii electrice lungi de transport; comutație în gol şi în sarcină; salt de tensiune; compensarea puterii reactive produse cu bobină de compensare.*

Keywords: *the self-excitement of the generating groups in the power plants; long electric transmission lines; no load and under load switching; voltage jump; produced reactive power compensation by a compensation coil.*

I. INTRODUCTION

The paper aims to present mainly certain practical aspects corresponding to specific activities that are carried out within the services of the planning, programming and functional analysis and operational command through dispatcher, such as the manoeuvres in the electric transport networks.

By conception of manoeuvres is meant the development of a succession of distinct groups of operations, distinct operations and manoeuvre operations in such a way as to ensure their correct unfolding.

A power system can be found, functionally in one of the states (regimes) explained in Fig. 1. The operating parameters of the system are monitored by the operating personnel in stations and at CTSI (Territorial Surveillance and Computerization Centres) as well as by the personnel from the dispatcher centres using command-control systems and EMS-SCADA ("Supervisory Control and Data Acquisition") respectively.

Among the main causes of system failure which may lead to instability in the operation of power systems is the overloading of the electricity transmission lines. These may be caused either by persistent short circuits in other installations (electrical lines or busbar systems in the area), or by the leaving the service of some power units (energy groups) or the triggering of network elements (transformers, autotransformers, electricity transmission lines) which lead to significant changes in power movements on the remaining lines in operation [1].

Since the 220 kV, 400 kV, 750 kV networks are characterized by a higher degree of complexity with the possibility of occurrence of dangerous overvoltages for the equipment, a series of general technical rules have been developed regarding to conceive and perform manoeuvres in their operation. To avoid dangerous overvoltages, driving and operating personnel must master the phenomena, drive the operating regime correctly, and perform appropriate manoeuvres [2], [3].

For this purpose, as an application of the long lines study, the phenomena occurring during manoeuvres are briefly presented, the way how to calculate the values of the parameters for the switching regimes, the safety measures to be taken during manoeuvres and their sequence in order not to endanger the energy equipment [4], [5], [6].

II. THE SELF-EXCITING OF THE GENERATING GROUPS THAT FEED OVERHEAD LONG LINES

The 750 kV, 400 kV and 220 kV lines have high capacitive susceptance because of the constructive gauges but especially of their large lengths and produce a considerable capacitive reactive power which in many cases has to be compensated to prevent the emergence of dangerous overvoltages. For this reason, in operation it is referred to *long lines* [4].

Lines longer than 150 km operating at the 220 kV voltage are included in this category because the breaking current of the circuit breakers with the weakest performance can be exceeded (VVN with I_{cap} = 60 A).

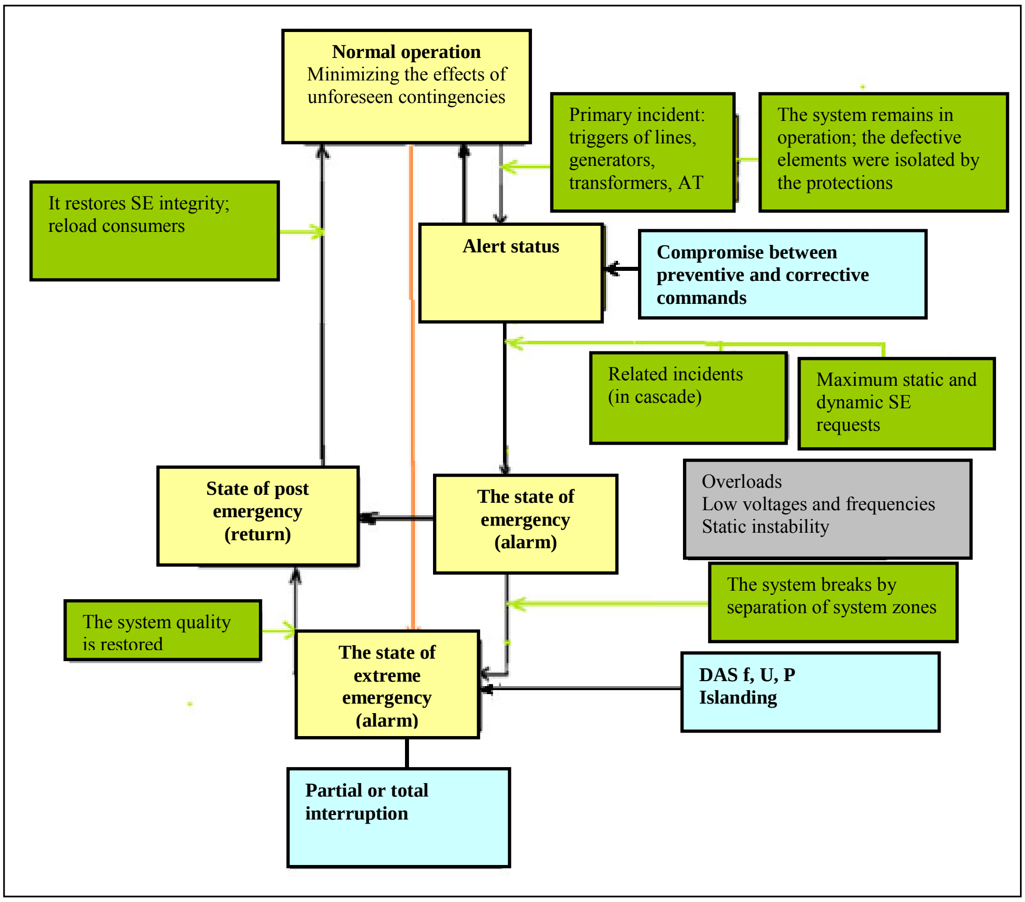

Fig. 1. Explaining the state of operation of a power system.

When supplying a long line in the block diagram with a generator [2] or in the case of triggering of a line being fed from a low short-circuit power station, the reactive power surplus that can not be quickly evacuated by self-regulation can lead to de-excitement of the generators and their transition into capacitive self-excitement regime.

This phenomenon may result in overvoltages of (2.5 – 3.5)·U_f with the breakdown of generator windings and destruction of line equipment.

Going through self-regulating of the generating groups under the inductive to capacitive regime does not implicitly mean their passing into a self-excited regime. But given that not all the groups can operate in a capacitive regime (some even have protection for this purpose) and on the other hand that the capacitive regime is necessary to be strictly controlled for the security of the groups and correlated with the conditions of stability, it is considered that the uncontrolled, automatic passing from inductive in the capacitive regime of the generators is dangerous. In this respect, the calculation algorithm and the measures to be taken to prevent such operating regimes are presented.

A. Calculation algorithm for generators self-excitement. Case study LEA 220 kV double circuit.

The self-excitement of the generators does not occur when energizing a no load long line if the capacitive reactance of the line (or the equivalent reactance resulting from the capacitive reactance of the line and the compensation coil reactance taken in parallel if the line is compensated) is greater than or equal with the sum of the circuit inductive reactance's according to the relation (1):

$$1.1\Sigma X_{ind} \le \Sigma X_c \| X_b \qquad (1)$$

The following parameters are known for the equipments from the block schema presented in Fig. 2:

- *hydrogenerators from hydroelectric power plants (CHE)*: $P_{n\ generator}$ = 50 MW; cosφ = 0.85; $x_d''\%$ = 20% - over-transient reactance for the generators from hydroelectric power plants (apparent pole synchronous machines).
- *the high voltage transformer station*: $u_{scT}\%$ = 11 % ; $S_{n\ trafo}$ = 2x25 MVA.
- *the high voltage autotransformer*: $u_{sc\ AT}\%$ = 10 % ; $S_{n\ AT}$ = 200 MVA.
- *the overhead electric line - LEA 220 kV (double circuit)*: $U_{n\ LEA}$ = 220 kV; l = 175 km – the long line length (> 150 km).

According to the scheme from Fig. 2 it can be written:

$$X_{ind} = X_{d\ gen} + X_{trafo} + X_{AT} + \frac{1}{2} X_L = 0.682 \qquad (2)$$

$$X_c \| X_b = -\frac{X_b X_c}{X_b - X_c} \qquad (3)$$

In formula (1), the value of 1.1 represents the safety coefficient allowed, given the approximate character of the formula and data used.

The calculation is performed using *the relative unit method* [1] (for the 220 kV voltages). The basic sizes are considered: $S_b = 100$ MVA; $U_b = 220$ kV.

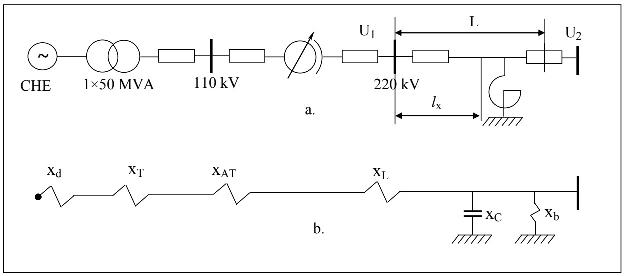

Fig. 2. The power scheme of a block line with a generator: a. Single phase diagram of the line disconnected from one end. b. Equivalent computation scheme in reactances.

$$X_d^{''*} = \frac{x''_d\,\%}{100}\frac{S_b}{S_{n\,generator}} = \frac{x''_d\,\%}{100}\frac{S_b}{\frac{P_{n\,generator}}{\cos\varphi}} = 0.34 \qquad (4)$$

$$X_T^* = \frac{u_{scT}\,\%}{100}\frac{S_b}{S_{n\,trafo}} = 0.22 \qquad (5)$$

$$X_{AT}^* = \frac{u_{sc\,AT}\,\%}{100}\frac{S_b}{S_{n\,AT}} = 0.05 \qquad (6)$$

$$X_L^* = X_L(\Omega)\frac{S_b}{U_n^2} = X_0 l\frac{S_b}{U_n^2} = 0.145 \qquad (7)$$

$$X_{LEA} = X_0 l\,[\Omega] = 70\,\Omega \qquad (8)$$

$X_0 \approx 0.4$ Ω/km - the specific inductive reactance of LEA.

$$X_c^* = X_c(\Omega)\frac{S_b}{U_n^2} = 4.373 \qquad (9)$$

$$X_c(\Omega) = \frac{1}{B_{LEA}} = 2116\,\Omega \qquad (10)$$

The specific capacitive susceptance of LEA 220 kV

$$B_0 = \omega C_{s0} 10^{-6}\ [\text{S/km}] \qquad (11)$$

where: $B_{0\ \text{LEA 220 kV}} = 2.7 \cdot 10^{-6}$ S/km.

Thus, the specific service capacity of the line can be determined:

$$C_{s0} = \frac{B_{0\,LEA\,220\,kV}}{\omega}10^6 = 0.008594\,\mu\text{F/km} \qquad (12)$$

The total capacitive susceptance of LEA 220 kV

$$B_{LEA} = B_{0\,LEA\,220\,kV}\,l = 4.725{*}10^{-4}\ \text{S} \qquad (13)$$

To estimate the capacitive power produced by the no load connected lines, the calculation formula was applied (14):

$$Q_1 = B_0 U^2 l = 22.869\ \text{MVAr} \qquad (14)$$

where: B_0 - the capacitive susceptance (S/km); U - the operate voltage (kV); *l* - the line length (km).

If *the line is not compensated*, it is found that inequality (1) (inequality (15)) is fulfilled:

$$1.1\Sigma X_{ind} = 0.751 < \Sigma X_c = 4.373 \qquad (15)$$

To verify that this condition is met when *the line is compensated* by a compensation coil, the inductive reactance of a compensation coil has been calculated beforehand, for which the following parameters are known: $U_{n\,b} = 220$ kV; $Q_{n\,b} = 10$ MVAr.

$$X_b = \frac{U^2}{3Q_{Bf}} = 1613\,\Omega \qquad (16)$$

$$X_b^* = X_b(\Omega)\frac{S_b}{U_n^2} = 3.333 \qquad (17)$$

Then the equivalent reactance resulting from the capacitive reactance of the line and the compensation coil reactance taken in parallel was calculated with the relation (3):

$$X_c \| X_b = -\frac{X_b X_c}{X_b - X_c} = 14.023 \qquad (18)$$

It is found that inequality (1) is achieved with a higher reserve if *the line is compensated* (inequality (19)):

$$1.1\Sigma X_{ind} = 0.751 < \Sigma X_c = 14.023 \qquad (19)$$

B. Determination of the passage of the generators from the stations of the power plants, from inductive in capacitive regime

Passing of generators from the power stations of the power plants from inductive in capacitive regime to switches with long no load lines or to triggering them in load while considering the same slope of the regulating characteristics of the generators and the equivalent system in the respective station, can be determined as follows:

1) Is the reactive power surplus (+ Q = 22,869 MVAr, calculated with relation (14)) resulting in the respective station after switching or triggering, according to the criteria shown for no load line switches or load triggering;

2) Determine the contribution of the group (s) to the total short-circuit power of the station, with the relation (20):

$$S_{sc} = \frac{S_b}{X^*} = 163.934\,\text{MVA} \qquad (20)$$

where X* is calculated for the over-transient inductance of the respective generator (s) and the inductance of the transformers and autotransformers by which it connects to the reference bar, with the relations (4), (5), (6).

$$X^* = X_{d\,gen} + X_{trafo} + X_{AT} = 0.61 \qquad (21)$$

3) Determine the ratio:

$$\frac{\Sigma S_{sc}}{\Sigma S^{sc}_{total\,station}} = K = 0.055 \qquad (22)$$

where it was considered the minimum short-circuit power for the stations supplied from one-two lines of 400 kV without a direct contribution from the power plants, $\Sigma S^{sc}_{total\,station} = 3000\,\text{MVA}$.

4) It is considered, as stated, that the surplus (+Q = 22.869 MVAr) of reactive power is proportionally taken over by the system and groups. In this way, the groups are back for adjustment K (+Q) = 1.257 MVAr;

If inequality (23) is fulfilled:

$$K(+Q) \geq Q_{ind} \qquad (23)$$

where Q_{ind} - is the sum of the inductive reactive powers produced by the generators, then the respective groups enter in the capacitive regime.

In this case study:

$$Q_{ind} = P_{n\,generator} tg\varphi = P_{n\,generator} tg \arccos 0.85 = \\ = 30.987\,\text{MVAr} \qquad (24)$$

It is noted that because 1.257 MVAr = K(+Q) < Q_{ind} = 30.987 MVAr, *the respective groups do not enter in the capacitive regime.*

III. THE VOLTAGE JUMP COMPUTATION TO THE CONNECTING AND DISCONNECTING OF THE LONG ELECTRICITY TRANSMISSION LINES

A. The connecting and disconnecting of the no load long electricity transmission lines

When connecting no load long electricity transmission lines, a voltage jump in the power station occurs, which, depending on the line-generated capacitive power, its compensation degree, and the short-circuit voltage of the station, may cause a dangerous voltage level to be set for the primary equipment or consumer installations.

At the disconnected end of the no load long electricity transmission line, the voltage value is even greater by endangering the line equipment (the capacitive transformers, the phases of the circuit breaker, and even the arresters).

When disconnecting the no load long electricity transmission lines, there is no longer the danger of exceeding the maximum allowable voltage, the voltage variation leading in this case to lowering the voltage level in the supply station. The big danger is in this case the restriking of the electric arc in the extinguishing chamber, if the circuit breaker can not safely break the capacitive current of the line. Overvoltages of the order (2,5-3,5) U_l may occur [7].

- Calculation of the voltage jump in case of switching no load long electricity transmission lines

Are considered as **initial data** the sizes calculated for the considered *overhead power line LEA 220 kV (double circuit)*: Q_l = 22.869 MVAr (14); S_{sc} = 163.934 MVA (20) and U_{real} = 235 kV resulting value using calculation models and simulations made with the **NEPLAN V 5.5.5** [10] software for analysis of the possibility of simultaneous withdrawal from service of the 220 kV LEA double circuit Cetate - Iron Gates circuits 1+2 for replacement of the protection conductor by optic fibre OPGW (Optical fibre composite overhead ground wire).

In order to avoid damage to equipment and production of faults to the power system when switching to no load long lines, should be determined in advance (in case when *the line is not compensated*):

$$\Delta U = \frac{Q_l}{S} U_{real} \left[kV\right] \qquad (25)$$

The voltage in the supply station will be:

$$U_1 = U_{real} + \Delta U \left[kV\right] \qquad (26)$$

The voltage to the disconnected end of the line can be determined with the relation:

$$U_2 = U_1 \cdot \left(1{,}02 \ldots 1{,}10\right)\left[kV\right] \qquad (27)$$

This depends on the length of the line and the voltage after switching, at the supply end and as seen in Fig. 2 is 2 to 10 % higher for lines with lengths between 150 km and 400 km.

The voltage jump at switching depends on the position (placement) in the line and the power of the compensation coils (for 750 kV and 400 kV). Generally, it can be admitted that in order to determine the voltage jump at the supply end, from the power produced by the line Q_l will lower the power of the compensation coil Q_b, resulting in the power $Q = Q_l - Q_{n\,b}$ which conditions the voltage jump.

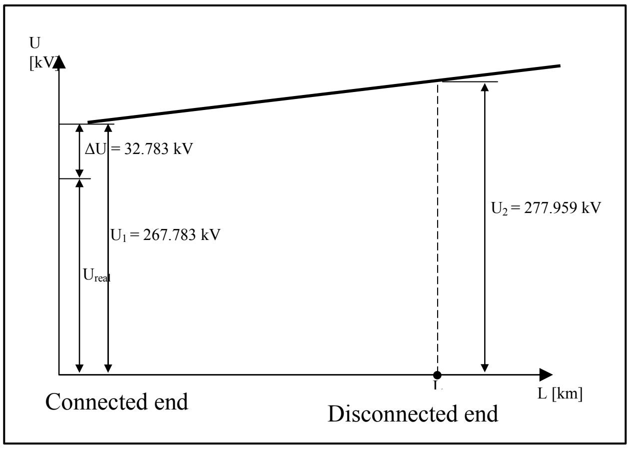

Fig. 3. Voltage variation along the uncompensated line disconnected at one end

In the most general case, at the point *x* of the line from the supply end (Fig. 3), in the absence of compensation coils, the voltage can be estimated using the relation:

$$U_x = U_1 + \frac{l_x}{L}\left(U_2 - U_1\right) \qquad (28)$$

where:

U_1 is the voltage that results after the line connecting at the supply end, determined with the relation (26).

U_2 is the voltage that results at the no load end of the line, after connecting determined according to the relation (27) by length customizing $l_x = L$.

For the calculation of the voltage at any point in the line, in the case of compensation coils mounted in the line, the calculation can not be performed even approximately, only if the line capacity is considered uniformly distributed.

The same *calculation algorithm* was followed for the case when *the line is compensated* by a compensation coil, and the results were synthesized in TABLE 1.

TABLE I.
THE CALCULATION OF THE VOLTAGE JUMP AT THE SWITCHING OF THE STUDIED NO LOAD LONG LINE

	Without compensation	Compensation by compensation coil
Voltage jump, ΔU [kV]	32.783	18.448
The voltage at the connected end, U_1 [kV]	267.783	253.448
The multiplying factor from the calculation expression of the voltage at the disconnected end, k_m	1.038	1.096
The voltage at the disconnected end, U_2 [kV]	277.959 < 278	277.779 < 278

It is noted that in order to calculate the voltage at the disconnected end of line U_2, the multiplying factor was chosen of the imposed interval k_m □ [1.02...1.10] according to the relation (27), so that the value $U_{\text{max adm short duration}}$

= 278 kV [7] is not exceeded for 220 kV lines. Thus it is found that if *the line is compensated* by a compensating coil, k_m can be chosen almost equal to the upper edge of the range, while if *the line is not compensated* k_m is very close to the lower edge of this range of variation.

In Fig. 4 were represented the variation curves in the most general case, of the line voltage in any point of the line, in the *x* point of the line relative to the feed end.

It is noted that for the calculation of the voltage at any point of the line, in the case of the use of compensation coils mounted in line, the calculation was made considering the capacity of the line uniformly distributed.

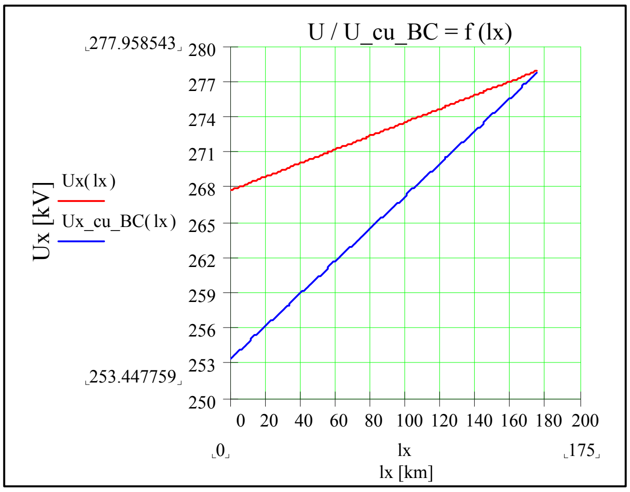

Fig. 4. Variation of the line voltage (at any point of the line) according to the line length, measured relative to the feed end (connected) in the two analysed cases: the uncompensated line (red); the line compensated by a compensation coil (blue).

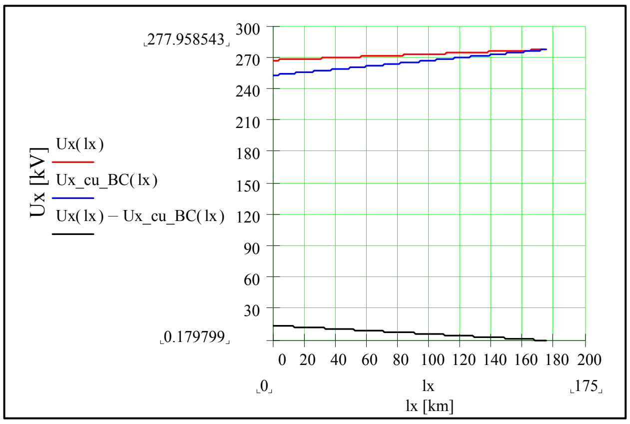

Fig. 5. Variation of the line voltage (at any point of the line) according to the line length, measured relative to the feed end (connected) in the two analysed cases: the uncompensated line (red); the line compensated by a compensation coil (blue) and of the difference of the voltages (black).

Also it is noted from Fig. 4 and Fig. 5 that the values of the growth slopes of the voltage of the two lines (straights) calculated with the relation:

$$m_d = \frac{U_2 - U_1}{L} \tag{29}$$

meet the following inequality:

$$\begin{gathered} m_d = \frac{U_2 \text{-} U_1}{L} = 0.058\,\frac{\text{kV}}{\text{km}} < \\ m_{d\_cu\_BC} = \frac{U_{2\_cu\_BC} \text{-} U_{1\_cu\_BC}}{L} = 0.139\,\frac{\text{kV}}{\text{km}} \end{gathered} \tag{30}$$

so the voltage of the line compensated by a compensation coil increases with a slope higher than for the uncompensated line.

B. The disconnecting of the under load long electricity transmission lines

The disconnecting of a long electricity transmission line in the load at one end may lead to the voltage jump at the supply end and the disconnected end, much higher jumps than when connecting or disconnecting no load of the line. The voltage variation also depends on the short-circuit power of the station to which the line remains connected [11], [12].

- Calculation of the voltage jump in case of switching long electricity transmission lines in load

It is known that as the active power transported on the line is higher, the reactive power losses in the line are higher, so that to the natural power of the line (P_n) the reactive power (Q_l) produced by the line is consumed by it to cover the losses.

At values of active power over the natural power of the line, the line becomes a reactive power „consumer".

The reactive power balance of *the uncompensated studied long line in load,* is calculated by using the formula:

$$\pm Q = Q_l \left(1 - \frac{P^2}{P_n^2}\right) = 19.21\,\text{MVAr} \tag{31}$$

where:

P = 50 MW is the real power transported on the line, and P_n is the natural power of the lines and has the following indicative value:

- for 220 kV lines, P_n = 125 MW.

If in the line is rigidly connected a compensation coil will do so:

a) If the compensation coil would be installed at the end of the line, the balance of reactive power would become:

$$\pm Q = Q_l \left(1 - \frac{P^2}{P_n^2}\right) - Q_b = 9.21\,\text{MVAr} \tag{32}$$

where: Q_b - the reactive power of the compensation coil.

b) If the compensation coil is installed at a point on the line, the expression (11) can be used, but it introduces some (acceptable) errors.

In this case, for the errors to be as low as possible, it will proceed to the sectioning of the line at the point of the coil connection, the expression of point **a)** being applied for both line portions. The reactive power Q_b of the coil is distributed in proportion to the length of the line.

$$Q_b = \frac{k}{100} Q_{nb}\ [\text{MVAr}] \tag{33}$$

$$l_{LEA} = \frac{k}{100} \cdot L\,[\text{km}] \tag{34}$$

where the coefficient: k □ [0...100].

From Fig. 6 it is noted really that the reactive power Q_b of the coil is distributed in proportion to the length of the line and it is easy to determine the reactive power of the compensation coil corresponding to each of the two sections of the line when dividing the line into the coil connection point.

For *example*, if the connection point of the compensation coil is located at 30 % of the length of the line from the connected end ($l_{LEA\ 1}$ = **52.5 km**), the reactive power of the coil is Q_{b1} = **3 MVAr** and for the second section having the length $l_{LEA\,2}$ = 175 km – 52.5 km = **122.5 km**, the reactive power of the coil is Q_{b2} = **7 MVAr**.

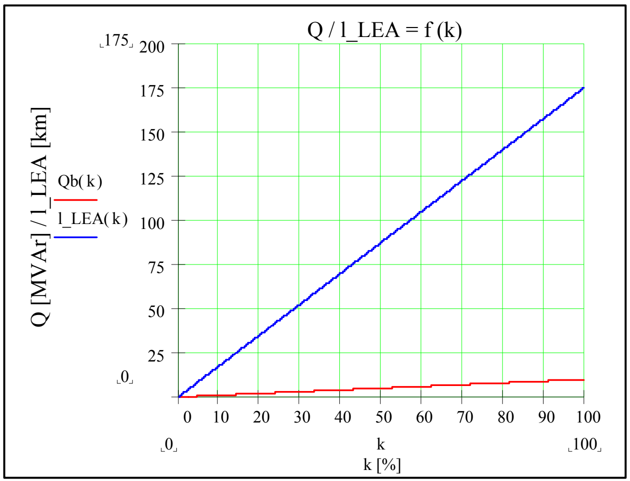

Fig. 6. Variation of the reactive power of compensation coil Q_b (red) and of the length (blue) of the studied line, depending on its percentage length.

In this case the reactive power balance of *the compensated studied long line in the load* according to the calculation relation (32) is applied for both portions of the line.

Appreciating qualitatively the phenomenon of triggering the long line in the load, a voltage jump occurs in the end station depending on the regime line.

In order to appreciate *the voltage jump* from the moment when the under load line is triggered at one end, the following approximate formula can be used:

$$\Delta U_+ = \frac{Q_1 + Q}{S} \cdot U_{real}\ [\mathrm{kV}] \qquad \Delta U_- = \frac{Q_1 - Q}{S} \cdot U_{real}\ [\mathrm{kV}] \tag{35}$$

where: Q is the reactive power entering in the station from the line (+Q) or going out of line to the station (-Q) before triggering the circuit breaker at the opposite end and Q_1 is the capacitive reactive power produced by the no load line.

If at the line is rigidly connected a compensation coil instead of the term Q_1 is the difference Q_1-Q_b; U_{real} is the real voltage at the connected end of the line.

Further U_1 and U_2 are determined as:

$U_1 = U_{real} + \Delta U$ - at the connected end of the line and

$U_2 = U_1(1{,}02 \ldots 1{,}1)$ - at the disconnected end of the line.

Thus in TABLE II it was made an synthesis of the results obtained following application of the computational algorithm previously presented, for the two operation cases of the analyzed line namely *without / with compensation with compensation coil*.

TABLE II.
THE CALCULATION OF THE VOLTAGE JUMP TO SWITCHING OF THE STUDIED LONG LINE IN THE LOAD

		Without compensation	Compensation with compensation coil
The reactive power entering in the station from the line +Q / or going out of line to the station –Q, ±Q [MVAr]		19.21	9.21
Voltage jump, ΔU [kV]	The reactive power entering in the station from the line +Q	60.32	31.65
	The reactive power going out of line to the station –Q	5.245	5.245
The voltage at the connected end, U_1 [kV]	The reactive power entering in the station from the line +Q	295.32	266.65
	The reactive power going out of line to the station –Q	240.245	240.245
The multiplying factor from the computation expression of the voltage at the disconnected end, k_m	The reactive power entering in the station from the line +Q	1.02 (value at the lower limit of the allowed range)	1.04
	The reactive power going out of line to the station –Q	1.15	1.15
The voltage at the disconnected end, U_2 [kV]	The reactive power entering in the station from the line +Q	301 > 278 *Observation*: The voltage at the disconnected end U_2 exceeds $U_{\text{max adm short duration}}$ = 278 kV.	277.3 ≤ 278
	The reactive power going out of line to the station –Q	276 < 278	276.28 < 278

IV. CONCLUSIONS

Some conclusions can be drawn on how to act in avoiding the entry into capacitive regime of generating groups from the power plants of the national power system [5]:

- Generally, with no special calculations, it is not allowed connecting no load, in the block diagram with a generator, of a line whose capacitive reactive power produced no load and uncompensated is greater than 0.6 of the apparent power of the group, according to the relation (25).

$$Q_1 > 0.6 * S_{n\,generator} \tag{36}$$

In this case study, it is found that the inequality (36) is not verified,

$$22.869\ \mathrm{MVAr} = Q_1 < 0.6 * S_{n\,generator} = 35.294\ \mathrm{MVA}$$ in principle, it is allowed to connect no load, in the block diagram with a generator, of this overhead electric line.

- When connecting no load long lines that produce high capacitive power, simultaneously with lowering the voltage level in the power station, the inductive regime charging of generating groups that flow on the station bars, will be maintained as much as possible.
- It is not allowed to connect no load long lines from the stations in which exist generators operating in capacitive regime.

It is noted that if *the line is uncompensated* the voltage at the disconnected end U_2 exceeds $U_{\text{max adm short duration}}$ = 278 kV, when *the reactive power entering in the station from the line* +Q.

If *the line is compensated by compensation coil,* the voltage jump, ΔU [kV] is lower then if *the line is uncompensated* (31.65 kV < 60.32 kV) when *the reactive power entering in the station from the line* +Q and the voltage jump, ΔU = 5.245 kV is the same when *the reactive power going out of line to the station* –Q.

Also it is noted that if *the line is compensated by compensation coil,* the voltage at the connected end, U_1 [kV] and respectively at the disconnected end, U_2 [kV], are lower then if *the line is uncompensated* and the voltage at the disconnected end, U_2 [kV], does not exceed $U_{\text{max adm short duration}}$ = 278 kV.

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