

OVERVOLTAGES DUE TO CAPACITORS BANK SWITCHING IN A 60kV SYSTEM

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Abstract - This paper deals with the evaluation of electrical transients in power systems, in particular for the switching surges. These overvoltages arise from the modifications of the electric pattern of the network and can be expressed by transitory regimes sufficiently complex. They can cause sufficiently high overvoltages in transmission and distribution lines.

The switching surges that are studied result from the switching of a capacitors bank in a 60 kV substation of the Portuguese electrical system, located in North of the country near the city of Vila Real. This study concerns the instantaneous values of the voltages during the first cycles after the switching of the capacitors bank, in particular the effects to the production units. This is done for different topologies of the network. The simulation tool used was the EMTP/ATP (Electromagnetic Transient Program / Alternative Transient Program).

Keywords: Overvoltages, transients, switching surges, EMTP/ATP.

I. INTRODUCTION

The area of electromagnetic transients involves an wide gamma of phenomena's, originated by sudden variations of voltage or current in electrical systems. These sudden voltage and current variations are originated by atmospheric discharges, system faults or equipments operations. The transient study can lead to the specification of equipment protection devices of an electrical system and allows the determination of the causes that originated a disturbance in the system.

The switching surges studied results from the switching of a capacitors bank in a 60 kV substation of the Portuguese electrical system, located in North of the country near the city of Vila Real. The system is constituted by two substations, Valdigem (220 kV/60 kV) and Telheira (60 kV/30 kV), a switching

station (Soutelo) and three units of production, two of them hydroelectric (Covas do Barroso and Alvadia) and one of wind type (Pena Suar).

The simulations, tacked into account the operation of different switches and topologies, with different initial conditions of the system. The study was carried out with the important contribution of EDP Distribution - Electricity of Portugal. These simulations were obtained to reproduce the real operation conditions in which we can find the system at the moment to perform the different types of actions.

The study analyzes the instantaneous values of the voltages during the first cycles after the capacitor banks switch, in particular for the units of production. The simulation tool program EMTP/ATP was used (Electromagnetic Transient Program/Alternative Transient Program).

II- DESCRIPTION OF THE SYSTEM

The diagram of tablets and the unifilar scheme of the network of 60 kV that will be studied are presented in figure 1 and 2 respectively. De seguida são apresentadas as principais características nominais dos diferentes elementos que constituem o sistema.

2.1- Transformers

The power transformers taken in account to define the topology of the system are the following ones:

Transformer T1

Function: Connection of the generator of the producer Pena Suar to the 60 kV network
Type: Three-phase Transformer
Voltages: 63 kV / 15 kV
Connection: Yd11
Rated Power: 11 MVA

Transformer T2

Function: Connection of the generator of the producer Alvardia to the 60 kV network
 Type: Three-phase Transformer
 Voltages: 60 kV / 6 kV
 Connection: Ynd11
 Rated Power: 10 MVA

Transformer T3

Function: Connection of the generator of the producer Covas do Barroso to the 60 kV network
 Type: Three-phase Transformer
 Voltages: 60 kV / 6,6 kV
 Connection: Ynd
 Rated Power: 8 MVA

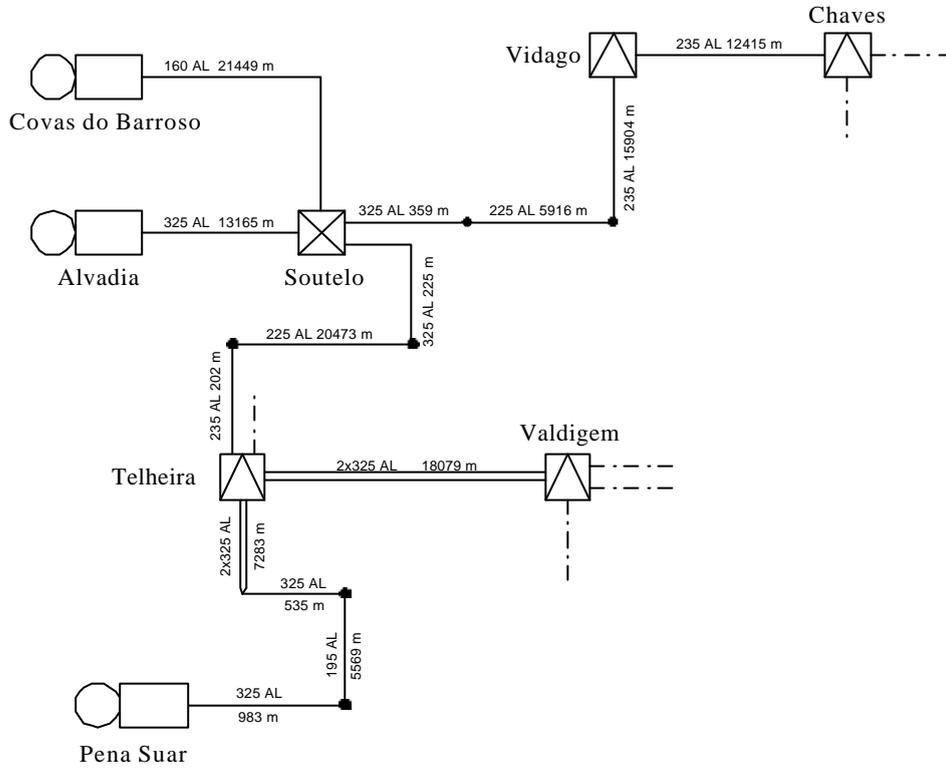


Fig. 1. Network diagram

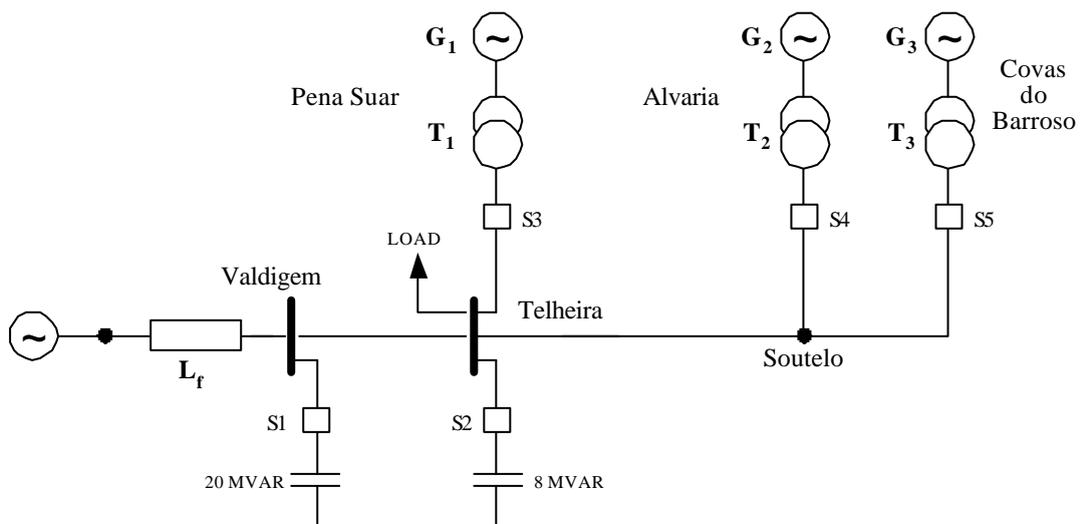


Fig. 2. Unifilar scheme of the studied system

2.2- Overhead lines

The overhead lines that had been considered in the study are the ones that compose the system of 60 kV and that connect the substation of Telheira and Valdigem to the producers of Pena Suar, Alvaldia and Covas do Barroso. Then, the diverse considered branches data is presented in table 1.

Table 1 – Characteristics of the lines

Line	Length (Km)	Section (mm ²)	Earth cable section(mm ²)
Valdigem - Telheira	18,079	2*325AL	81,6
Telheira - Soutelo	0,202	235AL	50,0
	20,473	225AL	50,0
	0,225	325AL	127,5
Telheira - Pena Suar	7,283	2*325AL	81,6
	0,535	325AL	81,6
	5,569	195AL	81,6
	0,843	325AL	127,5
Soutelo - Alvaldia	13,165	325AL	81,6
Soutelo - C. Barroso	21,449	160AL	127,5

2.3- Generators

In the studied system exist three synchronous generators with the following rated features:

Generator G1

Type: Synchronous Generator with variable speed
 Quantity: 20
 Location: Aeolian Park of Pena Suar
 Voltage: 400 V
 Rated speed: 18-38 m/s
 Power: 500 kW each

Generator G2

Type: Synchronous
 Quantity: 2
 Location: Hydroelectric producer of Alvaldia
 Voltage: 6 kV
 Frequency: 50 Hz
 Power: 5 MVA each

Generator G3

Type: Synchronous
 Quantity: 2
 Location: Hydroelectric producer of Covas do Barroso

Voltage: 6,6 kV
 Frequency: 50 Hz
 Power: 4 MVA each

2.4- Network equivalent

The influences that the remaining network exerts on the 60 kV system was had in account by a network equivalent, connected to the Valdigem substation, which is an important node of the 220 kV power grid. We assumed that the Scc is very high compared with the values obtained in the 60 kV power network. In these conditions the influence of the network equivalent is minimum.

2.5- Load

To represent the typical exploration conditions of the system it was considered one load connected to the Telheira substation with the following features:

Rated Power: 40 MW
 Power factor: 0.8 (i)

2.6- Capacitor banks

The capacitors banks, whose maneuvers are object of the present work, are placed in the substations of Valdigem and Telheira and have the following features:

Capacitor bank of Telheira

Power: 2x8 MVAR
 Voltage: 60 kV
 Connection: Star

Capacitor bank of Valdigem

Power: 20 MVAR
 Voltage: 60 kV
 Connection: Star

III- SYSTEM MODELING

The EMTP/ATP program was used as a simulation tool, because it provides good results with great accuracy. For a well performed system modeling it was necessary to get a great amount of data, that had been supplied by the company who explores the electric network (EDP).

3.1- Transmission lines

All the transmission lines that compose the system of 60 kV had been modeled by distributed parameters,

taking in account its variation with the frequency, to calculate with high accuracy the produced transients. For such, JMARTI model was used.

3.2-Transformers

The transformers are the components that most influence the features of the resultant overvoltages. Its modeling was made with great accuracy, considering the data of the tests with no-load and short circuit.

It was possible to get all the approach parameters of the equivalent circuit as well as the magnetization characteristic (current versus flux) using an auxiliary program WTRAFOS.

3.3- Generators

The generators of the three producers had been approximated by ideal voltage sources in series with a equivalent impedance.

3.4- Network equivalent

The network equivalent that connected the substation of the Valdigem, was represented by an ideal voltage source in series with a PI line model whose parameters had been obtained by approximation.

3.5- Load

The load wired to the Telheira substation was connected in star and represented by impedances of corresponding value to its consumption.

3.6- Capacitor banks

The capacitor banks had been represented by pure capacities connected in star, with neutral wired directly to the earth.

IV- STUDIES AND RESULTS

The studies carry out had the goal to get the values of overvoltages get in the three producers during the transitory period, due to the beginning of operation of the capacitor bank of Telheira and Valdigem. The real conditions of operation were simulated for different topologies of the system.

The beginning of operation of the capacitor bank is made in accordance with the following sequence: first we switch one of the capacitor bank of 8Mvar located in Telheira substation and, if it is necessary to continue to correct the reactive energy of the network, starts operation the 20 Mvar capacitor bank of Valdigem substation.

In all the simulations, the beginning of operation of the capacitor bank of Telheira was made in the instant $t=20$ ms while the capacitor bank of Valdigem starts only after to have occurred the voltages regeneration for $t=80$ ms.

For the analysis of the simulation results, we can conclude that in all the cases, the maximum overvoltages that appear in the producers, occurs in the transitory period after the beginning of operation of the bank of the Valdigem. However the transitory harmonic component relative to the beginning of operation of the Telheira bank is in all cases much higher. In table 2 are presented the maximum values of the overvoltages obtained in the three producers, for different network topologies. It is important to note that the most adverse situations occur when only one of the producers is in operation.

Fig. 3 shows the voltages evolution in the three phases, in Pena Suar win farm for the most adverse situation (case 3). In fig. 4 are presented the voltages in Alvadia, when the three producers are in operation (case 7).

Table 2 – Studied cases and results

	Switch Situation			Maximum Overvoltage (p.u.)		
	S3	S4	S5	ALVADIA	COVAS	PENA SUAR
1	Open	Closed	Open	2,0	-----	-----
2	Open	Open	Closed	-----	1,78	
3	Closed	Open	Open	-----	-----	2,12
4	Open	Closed	Closed	1,67	1,58	-----
5	Closed	Open	Closed	-----	1,62	1,89
6	Closed	Closed	Open	1,73	-----	1,95
7	Closed	Closed	Closed	1,59	1,53	1,91

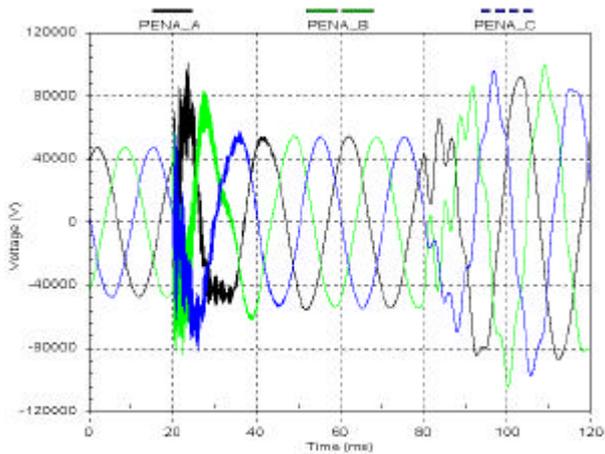


Fig. 3 – Voltages in Pena Suar (case 3)

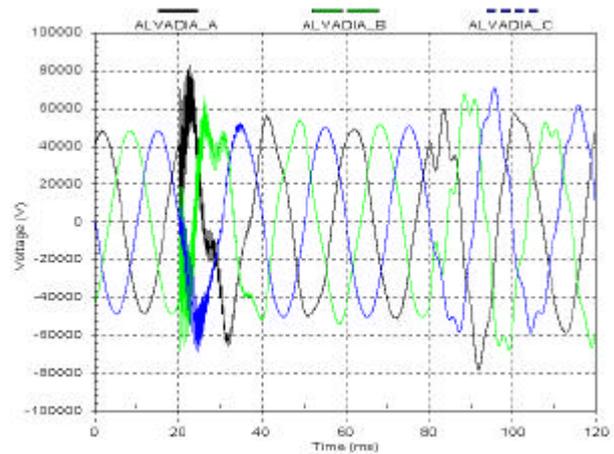


Fig. 4 – Voltages in Alvadia (case 7)

V- CONCLUSIONS

With the studies carry out it was possible to find the overvoltages that affect the producers connected to the 60 kV network, in different exploration situations. Analyzing the obtained results, it can be concluded that the most adverse situations for the producers occur when only one of them is in service, originating overvoltages about 2 p.u. The most affected producers are those located next to the substations where the correction of the reactive energy takes place (Pena Suar and Alvadia).

It is possible with these results to proceed with the selection of the protections, to design the logic connection of the capacitor bank and the producers, in order to minimize the impact of the switching in the consumers and equipment.

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