

THE USE OF DSTATCOM EQUIPMENT IN THE MEDIUM VOLTAGE NETWORKS OF THE USERS

FUNCȚIONAREA DSTATCOM ÎN REȚELE ELECTRICE DE MEDIE TENSIUNE ALE UTILIZATORILOR

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Abstract: *The presence of a DSTATCOM equipment at a user's terminals with significant variations in absorbed reactive power ensures real-time compensation of reactive power and the limitation of voltage fluctuations (flicker effect) in the power substation. The sizing of the equipment and then validation by simulation and measurement of performance as well as their compliance with the limits set by the regulations ensure the necessary level of power quality of the other users connected to the common coupling point. In the paper are analyzed the implications of the operation of a DSTATCOM equipment, especially the influence on the level of voltage fluctuations at the power bus bars, for a medium voltage network in which a disruptive receiver is connected.*

Keywords: DSTATCOM, flicker, short circuit power, electromagnetic disturbance, medium voltage network.

Rezumat: *Prezența unui echipament DSTATCOM la bornele unui utilizator cu variații importante ale puterii reactive absorbite asigură compensarea în timp real a puterii reactive și limitarea fluctuațiilor de tensiune (efect de flicker) la barele de alimentare. Dimensionarea echipamentului și apoi validarea prin simulare și prin măsurări a performanțelor precum și încadrarea acestora în limitele stabilite de normative asigură nivelul necesar de calitate a energiei electrice a celorlalți utilizatori conectați în punctul comun de cuplare. În cadrul lucrării sunt analizate implicațiile funcționării unui echipament DSTATCOM, în special influența asupra nivelului fluctuațiilor de tensiune la barele de alimentare, pentru o rețea de medie tensiune în care este conectat un receptor perturbator.*

Cuvinte cheie: DSTATCOM, flicker, putere de scurtcircuit, utilizator perturbator, rețea de medie tensiune.

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1. Introduction

The connection to the medium voltage network of receivers characterized by rapid variations of reactive power (electric arc furnaces, electric arc welding installations, rolling mills, etc.) causes voltage fluctuations in the substation (flicker effect) disturbing for users connected to the bus bars with the disruptive user.

The real-time compensation of reactive power variations with the DSTATCOM equipment connected to the bus bars of the user allows to fit the power quality indicators within the limits accepted by international norms and limit the active power losses due to the limitation of the reactive power flow.

The sizing of the DSTATCOM equipment must consider the actual structure of the power system in the user's connection area as well as the short-circuit power (node hardness) at the connection point.

The increasing of the share of renewable energy sources, connected to the electric grid through power converters, in the system generation structure causes the short-circuit power in a node of the system to become weather-dependent and thus influence the quality indicators of the electricity supplied to connected users in this node.

The validation of the performance of the DSTATCOM equipment in different operating conditions of the user and in different structures of the electrical power scheme is of particular interest for the users in the area but also for the distribution operator who must ensure the power quality to users.

Electric arc furnaces require, from a technological point of view, operation with a low power factor and cause significant fluctuations in active and reactive power during material processing.

2. DSTATCOM equipment structure

DSTATCOM equipment (*Distribution Static Synchronous Compensator*) are part of the family of DFACTS (*Distribution Flexible AC Transmission Systems*) type installations with multiple functions in distribution installations: controlling the flow of reactive power, limiting the level of voltage fluctuations, limiting the unbalance of electric currents, limiting the level of distortion of electric currents, the limitation of voltage gaps (Figure 1) [1].

The DSTATCOM equipment basically consists of a VSC converter (*Voltage Source Converter*), a capacitor C for energy storage and a coupling transformer T2 also acting as a coil for limiting harmonics. The control of the converter is done with a frequency of 2 kHz based on the PWM signals

transmitted from the control block BC which receives information from the instrument transformers of voltage TT and electric current TC.

In the analyzed diagram, DSTATCOM is connected to the 6 kV bus bars to which other users can be connected. The 15-ton electric arc furnace is powered by the T3 furnace transformer (6/0.36 kV) and the electric short-circuit currents are limited by coil B.

The reactive power generated by the DSTATCOM can be determined from the relationship:

$$Q_{DSTAT} = \frac{U_{PCC} \cdot (U_{PCC} - U_{DSTAT})}{X_{T2}}, \quad (1)$$

which highlights the possibility that, depending on the voltage amplitudes at the terminals of the coupling transformer, inductive or capacitive reactive power may be generated.

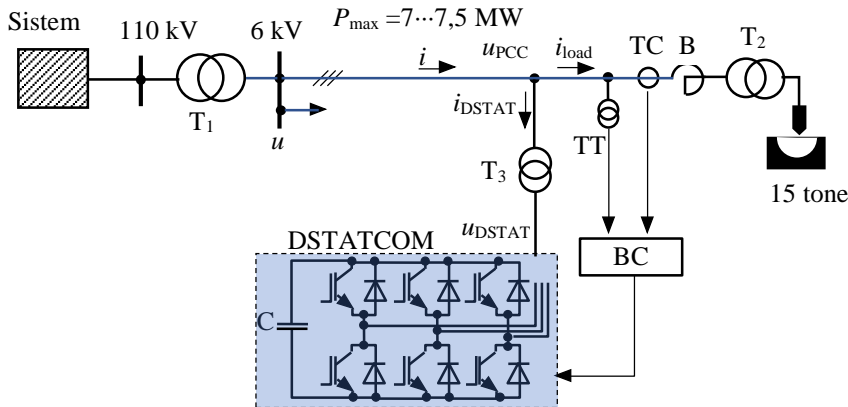


Figure 1. Simplified supply diagram of the analyzed end-user.

The DSTATCOM equipment has been sized so that during the burning of the electric arc furnace the voltage fluctuations (short-term P_{st} and long-term P_{lt} flicker indicators) fall within the standardized limits (Table 1) [2].

Figure 2 shows the variation in electrical quantities in the presence of DSTATCOM equipment.

From Figure 2, it is noted that the inductive reactive power compensation decreases the electrical current value and consequently reduces the Joule losses in the supply circuit (for the case shown in Figure 2, in which the reactive power is fully compensated. The active losses in the supply circuit can be reduced by about 25%).

Table 1. Indicative values of planning levels of P_{st} and P_{lt} in MV and HT networks

Indicator	Planning levels	
	MT	IT
P_{st}	0,9	0,8
P_{lt}	0,7	0,6

Depending on the setting, DSTATCOM may be provided to operate in the control mode of power factor, voltage level, unbalance or voltage fluctuations [3].

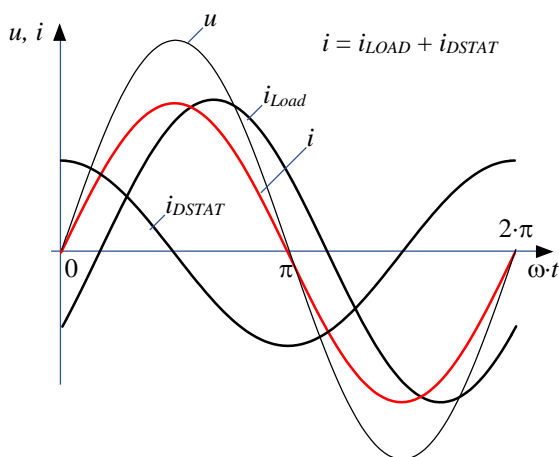


Figure 2. Theoretical variation of the voltage and electric current.

3. Results of the experimental study

The experimental study carried out aimed to assess the disturbances in the form of voltage fluctuations at 6 kV bus bars and 110 kV bus bars during the operation of DSTATCOM and in its absence.

Determinations were made both on the 6 kV line and on the 110 kV power station bars (fig.1), characterized by relatively important variations in short circuit power and the hardness of the node in the electrical network. During the periods when the wind installations are in operation, the input of the rotating sources in the power system is reduced and the short-circuit power drops to below 1500 MVA (in the absence of the wind sources, the short-circuit power reaches 2080 MVA) [4].

During the time intervals in which DSTATCOM was decommissioned for maintenance operations, the voltage at the terminals of the users connected to the 6 kV bus bars showed important variations that disturbed their activity (Figure 3), the level of the short-term flicker indicator reaching values of 6...7.

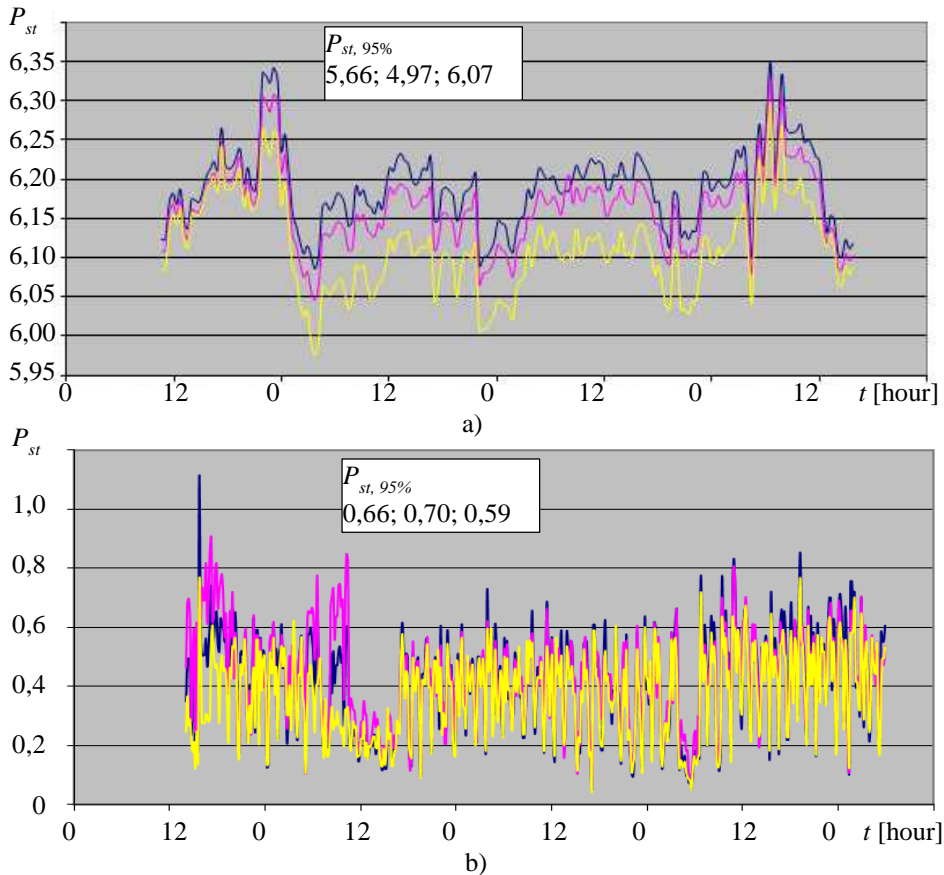


Figure 3. Voltage fluctuations levels at the 6 kV (a) and at the 110 kV bus bars (b) during the operation of the furnace without DSTATCOM:
phase A phase B phase C.

In order to highlight the efficiency of DSTATCOM, determinations were made during the non-operation of the furnace (Figures 4a and 4b), when the furnace is operating, but with DSTATCOM disconnected for maintenance (Figures 3 a and b) and when the furnace is operating with DSTATCOM (Figures 5a and 5b).

The data shown in figure 3 highlight the fact that at the 6 kV bus bars, to which other users are also connected, the short-term flicker indicators far

exceed the values allowed by the standards, disturbing the other users connected to these bus bars. In these circumstances, the power distributor has taken measures to supply the disruptive user separately by using a special supply diagram.

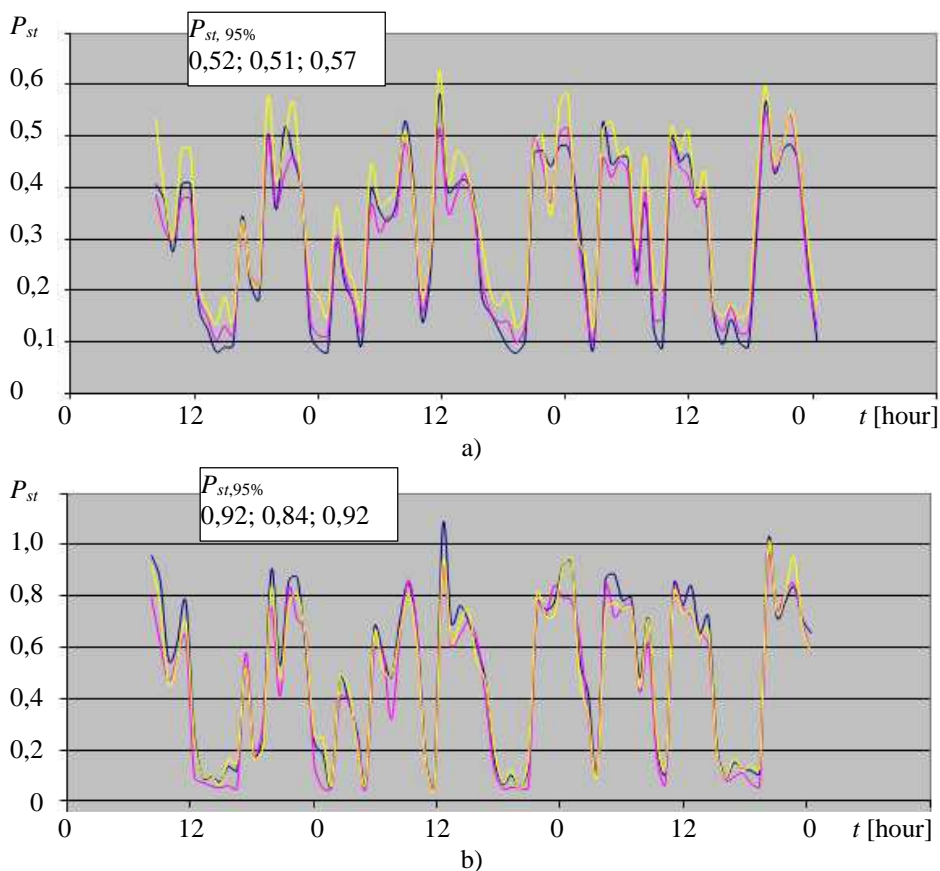


Figure. 4. Levels of voltage fluctuations at the 6 kV (a) and at the 110 kV bus bars (b) during the stationary period of the furnace:
— phase A — phase B — phase C

The P_{st} short-term flicker indicator levels on 110 kV bus bars are within the accepted limits (other users causing disturbances in the form of voltage fluctuations are also included in the 110 kV bus bars).

In order to analyze the influence of the disruptive user during the period when it does not work, measurements were made at the 6 kV and 110 kV bus bars of the diagram (Figure 4).

The analysis of the data in Figure 4 highlights the fact that during the period of non-operation of the user, the level of disturbances in the form of voltage fluctuations, both at the 6 kV bus bars and at the 110 kV bus bars are within the allowed limits (at the 110 kV bus bars other disruptive users are also connected, which sometimes lead to exceeding the allowed limits).

Connecting the DSTATCOM during the operation of the oven leads to the real-time control of the absorbed reactive power, which leads to the mitigation of voltage drops and therefore of voltage fluctuations (Figure 5).

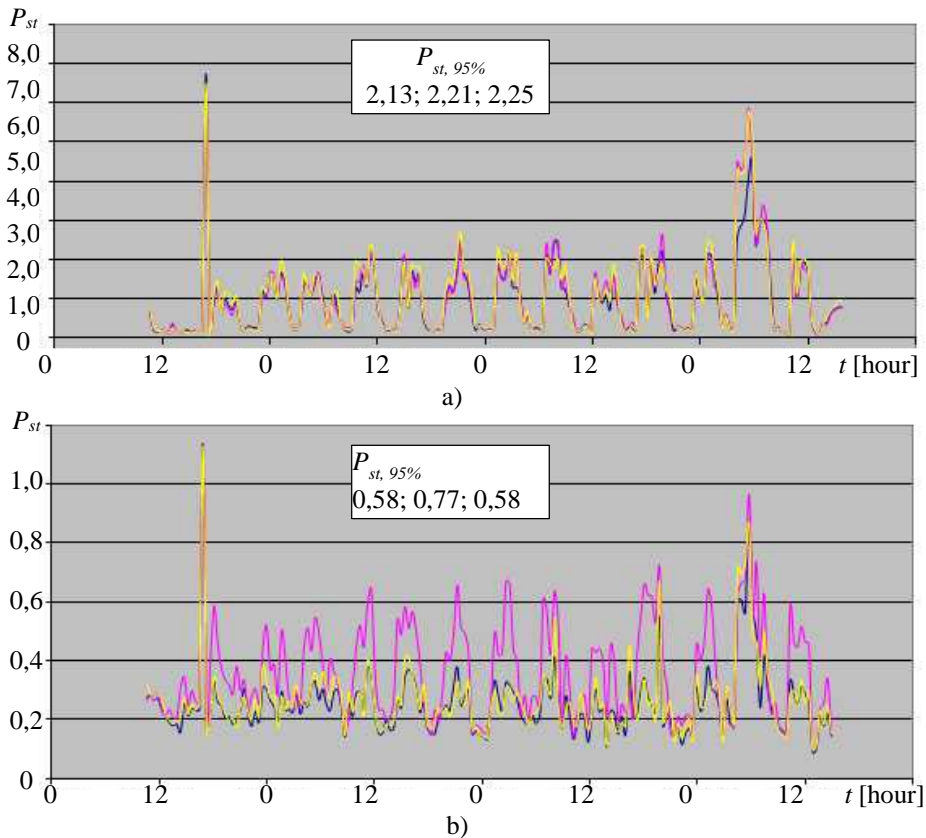


Figure 5. Levels of voltage fluctuations at the 6 kV (a) and at the 110 kV bus bars (b) during furnace operation with DSTATCOM:
phase A phase B phase C

At the 110 kV bus bars, the disturbances in the form of voltage fluctuations fell within the provisions of the regulations in force, and at the 6 kV bus bars, a significant reduction in their level was recorded (about

3 times). In order not to disturb their operation, the users connected to the 6 kV bus bars were transferred to another bus bars.

Figure 6 shows the variation of the reactive power absorbed by the furnace during the operation of the electric arc furnace. The connection of the DSTATCOM at a given moment allowed the compensation of the furnace's reactive power requirement practically in its entirety, which drastically limited the inductive voltage drops and therefore the voltage fluctuations.

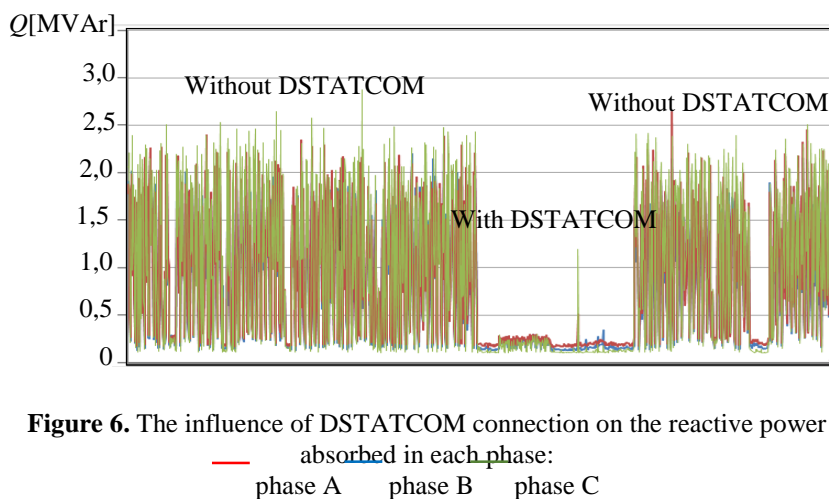


Figure 6. The influence of DSTATCOM connection on the reactive power absorbed in each phase:
— phase A — phase B — phase C

4. Results of the simulation

In order to validate the experimental determinations and for a detailed analysis of the furnace power scheme (Figure 7), a computing platform-program was used, and the results obtained confirmed the conclusions of the experimental study [4]. The theoretical study carried out aimed in particular at establishing the influence of the short-circuit power change in the connection node of the disruptive user.

The results obtained by simulating the power supply scheme through the platform-program highlighted the fact that a reduction of the short-circuit power at the 110 kV bus bars from 2080 MVA to 1050 MVA practically causes a doubling of the short-term flicker indicator $P_{st,95\%}$ (without exceeding the limits indicated in table 1), and at 6 kV bus bars, the indicator results in an increase of about 5%.

The presence of the transformer with high inductance means that the influence of the change in the short-circuit power at the 110 kV bus bars is

relatively reduced. The existence of renewable sources connected to the 6 kV electrical grid by means of frequency converters can have an important effect on the level of disturbances in the medium voltage electrical network.

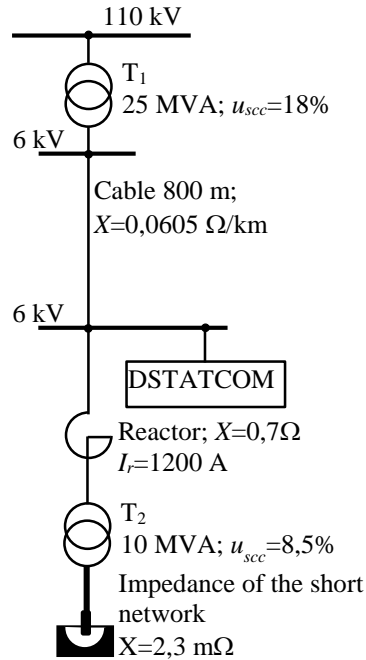


Figure 7. Power scheme analyzed.

5. Conclusions

Based on the results of the measurements and the simulation, some conclusions can be underlined, as follows:

a) It is worth noting the good efficiency of DSTATCOM for limiting reactive power and voltage fluctuations.

b) The reduction of the inertia of the system (hardness of the nodes) along with the increase in the share of renewable sources in relation to the conventional ones, leads to the reduction of the short-circuit power in the supply nodes, which causes higher levels of disturbances in the electrical network. The “rigidity of the mode” is influenced by the share of renewables in the total power produced. The most favorable situation is achieved when the renewables do not work (high S_K). In this case, the interference influence on the bar where the disruptive users are connected is less (P_{st} 95% and P_{lt} 95% have lower values). The measurements were made over long periods of

time (one week), in which both situations (high S_k or low S_k) were possible, respectively wind renewable sources did not work, respectively they worked. From the comparison of the values of the power quality indicators resulting from measurements and simulations, they confirmed the validity of the adapted hypotheses. The high influence of renewables on quality indicators can be felt if they are connected to the voltage level where disruptive users are connected.

c) The DSTATCOM dimensioning must take into account the short-circuit power change in the supply nodes. There are still the following questions that need to be answered: how often does this change occur and who bears the costs?

d) The flicker phenomenon occurs at the 6 kV bus bars, where there are no other consumers, but it is limited to the 110 kV bus bars by the impedance of the 110/6 kV transformer.

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