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Analysis of the influence of the parameters of the power supply network on the operating modes of the electric drives of the stands of the hot rolling mill 1700 of ArcelorMittal Temirtau JSC

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Abstract. The finishing group of stands of the 1700 SRS-1 continuous mill of ArcelorMittal Temirtau JSC is characterized by high rolling speeds and high productivity. The use of DC motors as power sources for the main drives of the stands of high-power thyristor converter units significantly affects the nature of the operating modes of the power supply system and the quality of electricity on the buses of the SRS-1 substation. Experiments were performed to study the electricity grid supply substation in which the basic indexes of quality of electric energy and the built waveform voltage SAG during rolling. Voltage dips are observed throughout the rolling process and reach 10% of the rated network voltage. Due to the complexity of removing individual parameters of electric drives and conducting experiments on a real mill, an adequate model of the electric drive of the stand of the finishing group of the 1700 SRS-1 mill was developed and built.

1. Introduction

A modern metallurgical rolling mill is a complex set of various mechanisms that are different in purpose and operating modes [1].

The continuous broadband hot rolling mill of 1700 sheet rolling shop No. 1 (SRS-1) of Arcelor Mittal Temirtau JSC is characterized by high rolling speeds and productivity. At a high speed of rolling, the metal temperature does not have time to significantly decrease, as a result of which rolling is carried out at a high average temperature, which leads to the required quality of rolled products and an increase in the service life of the work rolls of the stands [2].

A feature of rolling in the finishing group of the mill stands is that it is carried out simultaneously in all stands of the group and the metal passes in one direction while it is crimped in each working stand [3].

The rolling process at the 1700 mill is accompanied by a significant level of electrical energy consumption and accounts for 90% of the total power consumption of the 110/10 kV two-transformer substation MSDS 1A with installed power transformers 63MVA [4].

Thyristor converters that feed the main drives of the mill stands significantly affect the operating modes of the power supply system and the quality of electricity on the busbars of the substation SRS 1.

The operating modes of the thyristor converters of the main drives of the 1700 mill are characterized by sharply variable consumption of electric energy, generation of higher harmonic oscillations into the electric network. This causes a discrepancy, voltage fluctuation of the network, distortion of the shape of the voltage curve, which is confirmed by the results of the experiments.

The rolling of energy-intensive profiles causes voltage drops at substation No. 6 with a voltage of 10 kV, which exceed the maximum permissible values of State Standard 32144–2013 [5]. As a result of tripping of protection against voltage surges and thyristor converters Simoreg from Siemens, an emergency shutdown of the main and auxiliary drives of the mill occurs.

2. Methods

In the course of experiments to study the power supply network of substation No. 6, from which the main drives of the mill 1700-SRS-1 are supplied with the help of the 'Resurs-UF' measuring device, the main indicators of the quality of electric energy are determined and voltage dips during rolling are constructed. The analysis of experiments showed that the average voltage drop exceeds the maximum permissible values of State Standard 32144-2013 [5] (over 10%). One of the registers is shown in Figure 1.

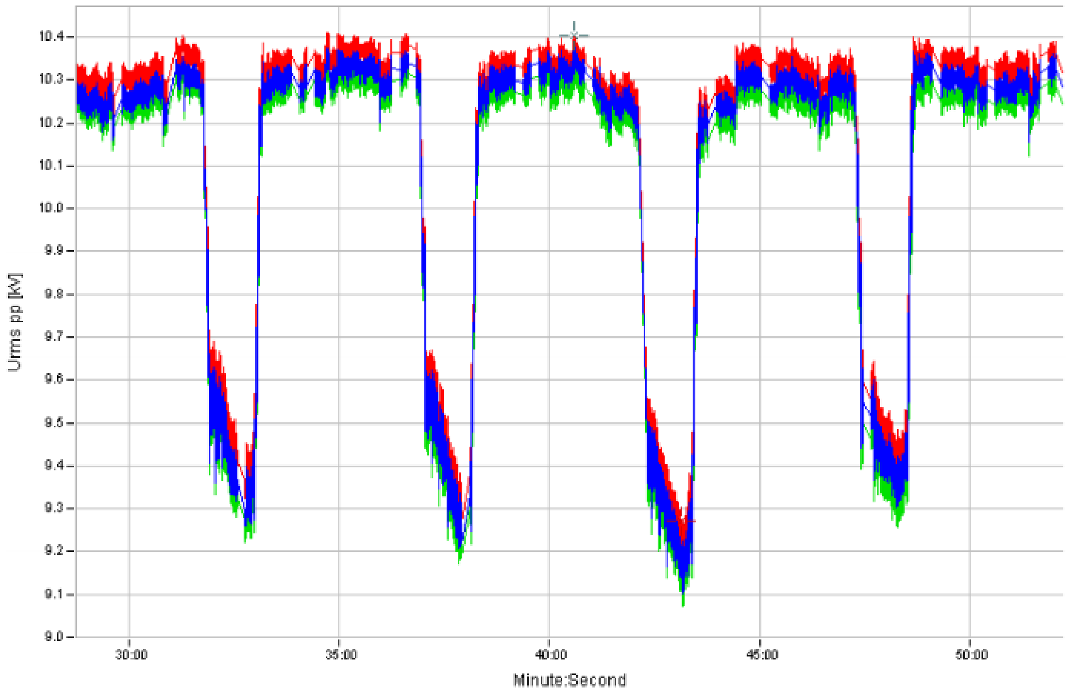

Figure 1. The voltage register on the busbars of the substation No. 6.

As can be seen from the register, voltage dips are observed during the entire rolling process. When the metal enters the rolls, a shock application of the load occurs, which causes a voltage drop, while the shock surge and load shedding are clearly traced on the register.

3. Results and discussion

Due to the difficulty of taking individual parameters of electric drives and conducting experiments on a real mill, a mathematical simulation model was developed on the example of an electric drive of stand No. 6 of the finishing group of the hot rolling mill 1700 SRS-1 of ArcelorMittal Temirtau JSC.

To build the model, a scheme for replacing a DC machine is made under generally accepted assumptions (the armature circuit and eddy currents are not taken into account). The excitation circuits are also not taken into account, since a DC machine with independent excitation is used and there is no control over the excitation circuit.

An equivalent substitution scheme of the electric machine armature circuit is shown in Figure 2 [6].

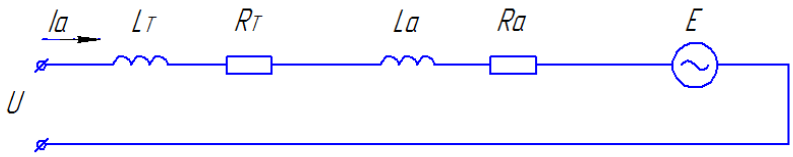

Figure 2. The equivalent substitution scheme of the armature circuit of a DC machine.

In Figure 2: U – the voltage of the supply network; R_T – the active resistance of the power transformer; R_a – active resistance of the electric machine armature circuit; L_T – inductive resistance of the power transformer; L_a – inductive resistance of the electric machine armature circuit; E – electromotive force (EMF) electric machine I_a – current of the armature circuit

The system of equations corresponding to the substitution scheme has the form:

$$\begin{cases} U = I_a R_a + L_a \dfrac{dI_a}{dt} + c\Phi\omega + I_a R_T + L_T \dfrac{dI_a}{dt} \\ U - I_a R_T - L_T \dfrac{dI_a}{dt} = I_a R_a + L_a \dfrac{dI_a}{dt} + c\Phi\omega \\ U - I_a(R_T + L_T p) = I_a(R_a + L_a p) + c\Phi\omega \end{cases} \quad (1)$$

where ω – the angular velocity of the electric machine; c – EMF coefficient at Φ = const; cΦω – electric machine EMF; i_a – the current of the armature circuit; p – Laplace operator.

Based on the above system of equations (1), a simulation model of the electric drive of the stand of the hot rolling mill has been developed. The simulation model is a dual-circuit automatic control system, which is built on the principle of subordinate regulation.

The internal (subordinate) circuit is the current circuit, the external circuit is the speed circuit [7, 8]. The following notations are used on the model: '*Rw*1'is the proportional part of the speed controller; '*Rw*' is the integral part of the speed controller; '*Ri*1' is the proportional part of the current regulator; '*Ri*' is the integral part of the current regulator; 'Engine' is the electric part of the electric machine; 'Engine 1'is the mechanical part of the electric machine; Kw is the feedback coefficient of the speed; Ki is the feedback coefficient of the current; 'R_T', 'L_T' is the blocks that take into account the parameters of the supply network, namely the active and inductive resistance of the power transformer.

The structure and parameters of the model correspond to the electric drive and parameters of stand No. 6 of the finishing group of mill 1700 SRS-1 of ArcelorMittal Temirtau JSC. This model is implemented using a software package for solving MATLAB technical computing problems in the Simulink software simulation complex [9, 10].

The developed block diagram and model, taking into account the joint operation of the stand drive and power transformer, are presented in Figure 3.

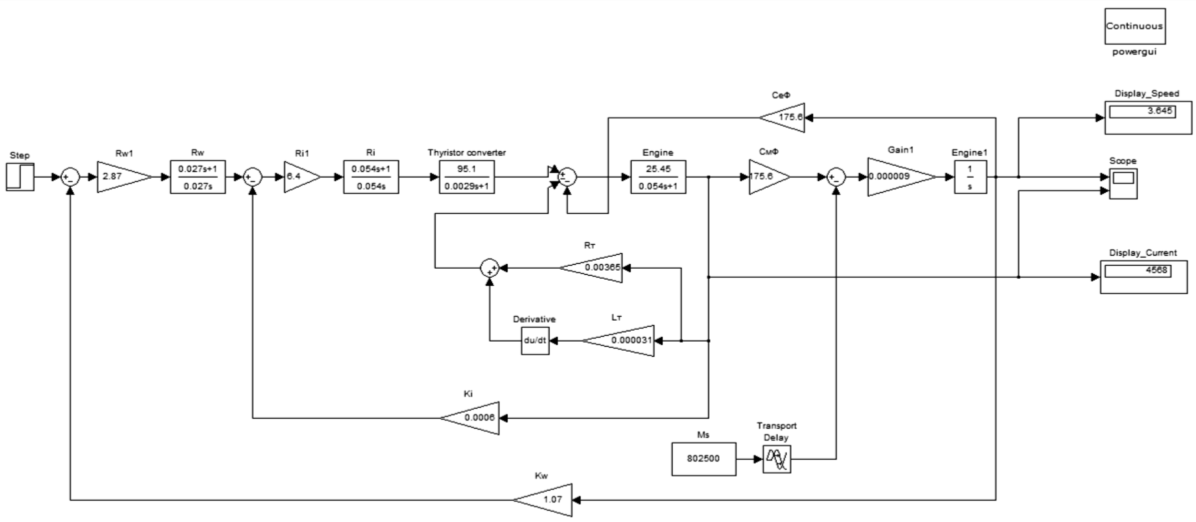

Figure 3. Structural diagram of the model taking into account the supply network.

Based on the simulation results, transient graphs were obtained, presented in Figure 4, and Table 1 shows the comparative data of the simulation results and the electric machine rated parameters.

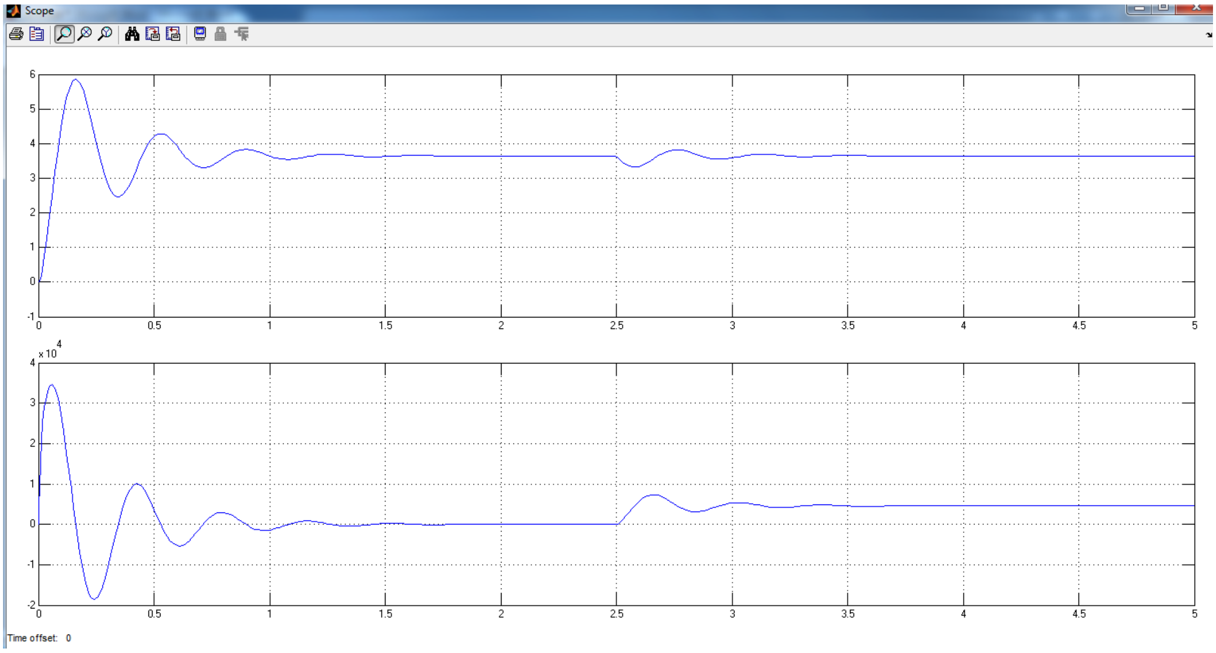

Figure 4. Transient graphs of the model taking into account the supply network.

Figure 4 above shows a graph of the transient in the velocity loop $w = f(t)$, rad/s; below is a graph of the transient in the current loop $I_a = f(t)$, A.

According to the results of processing data from real and simulation experiments, the discrepancy between the values of the speed of the electric machine and the current in the armature circuit obtained in a real network and in a simulation model is not more than 10%. This confirms the adequacy of the presented simulation model.

Table 1. The results of simulation and nominal data of the electric machine 2P25/105-3.15.

Parameter Name	Rated current of the electric machine armature circuit, I_a, A	Rated electric machine speed, w, rad/s
Rated parameters of the electric machine	4580	3.92
Simulation Results	4568	3.645
Discrepancy, Δ, %	0.262	7.02

Thus, transients (Figure 4) with a sufficient degree of accuracy reflect the real processes occurring in electric drives of stands of hot rolling mill 1700 of ArcelorMittal Temirtau JSC under shock application of load. The nature of these processes is important for continuous rolling, especially when rolling at high speeds and at small distances between stands.

4. Conclusions

The nature of the transient processes, with a surge in power as a result of the application of shock load, confirms a decrease in the quality of transient processes. In this case, the influence of the power transformer as an element of the supply network is obvious. According to the graphs presented in Figure 4, it can be seen that when the load occurs when the metal enters the crate, taking into account the influence of the supply network, the time of dynamic subsidence increases, while the nature of the transition process is delayed, which leads to a deterioration in the quality of rolled products.

Significant in time changing in the rolling speed leads to non-compliance with the temperature regime, the tension of the metal in the inter-stand spaces, which leads to the release of low-quality products [11].

The negative influence of the power supply network on the operation of power receivers of the hot rolling mill 1700 requires research and development of methods for controlling the electric drives of the stands of the finishing group in order to solve the problems of their electromagnetic compatibility with the power supply network.

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