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ScienceDirect

Procedia Engineering 150 (2016) 3 – 10

Procedia Engineering

www.elsevier.com/locate/procedia

Conference on Industrial Engineering, ICIE 2016

Conceptual Area of Development of Power Saving Thyristor Electric Drives of Rolling Mills

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Abstract

Thyristor electric drives of the rolling mills are known to be the most power-intensive consumers at the iron and steel works. Obviously, significant losses of electric power are connected with consumption of reactive power that depends on the value of the reserve of rectified EDV of the thyristor converter. The paper mentions characteristic dynamic modes providing a maximum reserve of the rectified EDV. It estimates the influence of the rectified EDV on the value of reserve for overcorrection in the impact-loading mode. Experiments have proven the impact of the network voltage deviation in amount of 10–12% decreasingly. The reserve of the rectified EDV has been divided into components. The paper provides a defined concept for generation of the power-saving systems of two-region speed control based on the principles of rearranging the reserve of the rectified EDV in the steady state and dynamic modes. It considers the method and system of two-region dependent speed control as a function of the rectified EDV of the thyristor converter. The system is proved to provide a constant reserve of the rectified EDV of the thyristor converter within the load range of the electric drive that is lower than the rated one. It is reasonable to develop the system of two-region speed control providing power saving due to reduction of the rectified EDV reserve in all dynamic modes during rolling cycle.

Peer-review under responsibility of the organizing committee of ICIE 2016

Keywords: wide-strip hot-rolling mill; thyristor electric drive; two-region speed control; energy indicators; reactive power; reserve of the rectified EDV; analysis; constituents; power saving concept; power-saving electric drive.

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Peer-review under responsibility of the organizing committee of ICIE 2016
doi:10.1016/j.proeng.2016.07.272

1. Introduction

High power consumption of the iron and steel production accompanied by continuous cost escalation of power resources stipulates primary importance of power saving for its all process stages [1]. The main consumer of the electric power at the iron and steel facilities is an electric drive (ED). The total capacity of electric motors at the iron and steel facilities amounts about 87% of power of all equipment, while their power consumption – makes up about 65% of the total one [2, 3]. Thus, highest power savings may be obtained due to improved energy indexes of electric drives, in the first turn– that of – thyristor EDs of the rolling mills. Energy indexes of thyristor EDs are mainly deteriorated due to the reactive power consumption caused by phase control of the rectified voltage (rectified EDV).

Improvement of energy indexes of electric drives of the rolling mills is a challenging issue due to their high power consumption. It should be noted that the total power of the equipment of the 2,000 mm wide-strip hot-rolling mill at OJSC Magnitogorsk Iron and Steel Works is 362 MVA [4]. The power of the stands' electric drives is 139 MW, of which over 96b MW (26.6%) falls to the share of the main EDs of the finishing train. Unit output of an electric drive of the finishing stand is over 14 MW. Energy indexes of similar drives are far from the optimal ones. It follows that search for power saving reserves in such powerful consumers is an important scientific and practical task.

The task of power loss reduction is even more relevant because of the switching wide-strip mills to production of thick strips of difficult-to-form steels [5, 6]. Thus, hollow bullet (up to 18 mm thick strip of up to 300 mm thick slab) is rolled at the 2,000 mm mill. Transition to production of up to 25 mm thick hot-rolled strips at modern WSHRMs is a world-wide trend. Hollow bullet is rolled at low speeds and high slabbing, that is, high non-uniform load of electric drives. The studies of modes of rolling these strips are provided in [7, 8]. This rolling is connected with risk of loss of electric drive control because of opening the speed control circuit.

2. Problem statement

The most national wide-strip hot-rolling mills (WSHRMs) are equipped with DC electric drives with two-region speed control. The highest demands relative to high-speed response and stable operation at processing dynamic modes during rolling are imposed upon them. These requirements are met if they provide the required dynamic margin of the control system, primarily, reserve of the rectified EDV of the thyristor converter (TS). This may be explained with the fact that loss of control over an electric drive (for ED of the stand – loss of speed control because of the thyristor converter saturation) is an emergency mode for continuous process lines. An additional margin increase provides improvement of ED stability but may lead to deterioration of energy indexes. This is caused by increased consumption of reactive power depending on the extent of control of the rectified EDV.

Peculiarities of dynamic loads of the main WSHRM electric drives are directly connected to maintenance of process flow. The heaviest duty dynamic modes are:

- shock loading mode at the strip gripping;
- drive under load at rolling with acceleration.

The impact-loading mode is accompanied by overcorrection of the rectified EDV of the thyristor converter (TC). The overcorrection value depends on speed and current loop settings under similar conditions of strip gripping. For single-integrating system of speed control, it is (16–18)%, for double-integrating one – (19–22)% [9]. The maximum rectified EDV E_{d0} of the TC is selected with due regard to mode optimization without opening the speed control circuit, that is, without TC saturation. The relation between E_{d0} and the actual rectified EDV E_d defines the value of reserve of the rectified EDV. Margin increase results in boosting reactive power consumption Q, which depends at constant load current I_d on the extent of control C_P of the rectified EDV E_d [10, 11]:

$$Q = I_d U_d \sin\alpha = \frac{P}{C_P}\sqrt{1-C_P^2} = \frac{E_d I_d}{C_P}\sqrt{1-C_P^2},$$

where α – delay angle; P – active power;