Available online at www.sciencedirect.com

ScienceDirect

Procedia Engineering 129 (2015) 915 – 921

Procedia Engineering

www.elsevier.com/locate/procedia

International Conference on Industrial Engineering

Analysis of a doubly fed induction motor in electric drives of pumping stations

Bochkarev I.V.*

Kyrgyz State Technical University named after I. Razzakov, Mira av. 66, Bishkek, 720044, Kyrgyzstan

Abstract

The investigation of a doubly fed induction motor in electric drives of pumping stations is conducted in this paper. The effect of non-sinusoidal rotor supply is considered in the analysis as well. The current total harmonic distortion (THD) is evaluated with respect to the selected voltage modulation in a thyristor frequency converter (TFC) as well as on motor duty cycle. A novel method of reactive power regulation with constant rotor current $I_2=I_{2н}$=constant is proposed. It is shown that the proposed method considerably improves motor performance in the whole operation range. The proposed analytical method is verified with laboratory measurements.

Keywords: pumping station; centrifugal pump; doubly fed induction motor; slip power; frequency converter; current THD; efficiency.

1. Intoduction

An uninterrupted water supply is often required for efficient and continuous work of many industrial processes. Many industries, such as metallurgical and metalworking plants, are also one of the major consumers of water. The pumping stations used for supplying water to the plants are energy-demanding and thus by improving their performance, a more efficient operation of the entire plant can be achieved.

The today's electric drives in pumping stations employ squirrel cage induction motors. Further, in the vast majority of pumping stations, the motors operate at constant speed. The power and pressure are changed by

* Corresponding author. Tel.: +0312-56-15-58.
E-mail address: elmech@mail.ru

doi:10.1016/j.proeng.2015.12.133

switching on and off the pumps or by adjusting the valves. These control methods are not desirable as far as the energy efficiency of the system is concerned [1].

2. Problem description

The conducted investigation showed that the speed of pumps normally varies in the range of 50-100% of its nominal value. For this speed range, the use of doubly fed induction motors (DFIM) can particularly be advantageous for improving the system efficiency. The DFIM is a type of induction motor with wound rotor whose stator terminals are directly connected to a 6/10 kV grid, while rotor is connected to the grid through a frequency converter. In the cascade regulation, only the slip power, proportional to a DFIM slip and stator power, is being controlled. Furthermore, the inverter employed in the system operates at low voltages, i.e. below 1000 V. This can applied in electric drives with nearly any power rating without increasing complexity of the inverter topology.

Additionally, by controlling the reactive power flow through stator, the high efficiency of an entire system can be achieved. Due the mentioned reasons, these types of systems applied in pumps are particularly beneficial as compared to the frequency control of squirrel cage induction motors

Fig.1 depicts an electric circuit of a centrifugal pump connected to grid. The stator winding of the DFIM is directly connected to the grid, while rotor is connected though a rectifier (R), an inverter (Inv), and a step-down transformer (Tr). The step-down transformer is introduced in the system to adjust the high voltage of the grid (3.6, 10 kV) to the low-voltage supplied to the rotor winding. To smoothen the current waveform and improve operation of the inverter, an adjustable inductor AI is added between the inverter and rectifier sides of the frequency converter.

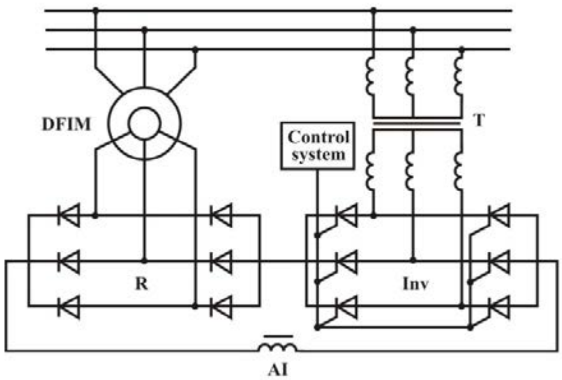

Fig. 1. An electric circuit of a centrifugal pump connected to the grid.

The rotor slip power is controlled by adjusting the back electromagnetic force (EMF) which is obtained by selecting an appropriate firing angle of thyristors β. In such a way, in the studied centrifugal pump with doubly fed induction motor, the voltage is rectified by means of a rectifier R, the waveform is further smoothened with varying inductor AI and finally modulated back a 50 Hz AC. The slip power is fed back to the grid though a transformer Tr.

Due to the applied signal modulation, the output inverter voltage contains high-order harmonics. The presence of these harmonics can lead to an increased copper and iron loss of motor as well as transformer.

This can eventually lead to the unwanted overheating and can negatively affect the entire system efficiency. To make the voltages and currents more sinusoidal, different inverter topologies can be applied (e.g. with higher number of pulses), low-pass filters, and various methods of modulation. The total harmonic distortion (THD) of current and voltage waveforms should be obtained before selection of the modulation method. The most common duty cycle of a motor in the centrifugal pump is a continuous cycle with nearly constant load. Therefore, the conducted investigation covers only the steady state conditions of the motor and converter.