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Innovation and development in geothermal turbine maintenance based on Icelandic experience

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ABSTRACT

Efficient maintenance of heavy machinery is of utmost importance in geothermal power plants. Icelandic geothermal power plants are striving to domesticate its maintenance procedures to decrease foreign dependency. This study shows which problems are most frequently observed in turbines at the largest geothermal power plant in Iceland, Hellisheidi. It also describes how the turbines are monitored and how such monitoring effects the maintenance planning. The purpose of this study is to describe and analyse the methods used when planning turbine maintenance in a practical manner as they have diverted from original recommendations from the turbine manufacturer. The results can then be used by other power plants when planning the turbine maintenance. Findings show that scaling on first step of the turbine, bearing condition, blade and diaphragm condition is monitored most closely. The frequency of major maintenance on most important parts on the turbine is also shown to be between 4 and 8 years. Erosion is a problem in need of a sharp attention as it causes wear on parts and requires intrusion into turbines for inspection while producing no output. How Reykjavik Energy, the owner of the plant studied, is attempting to solve the most prominent problems is then described. This article depicts how turbine monitoring is currently used and how it affects maintenance planning at the Hellisheidi geothermal power plant, operated by Reykjavik Energy, Icelands largest geothermal energy utiliser.

1. Introduction

Turbines are the most crucial parts of a geothermal power plant. During turbine overhaul, the energy company operating any given geothermal power plant is not producing output from that particular turbine and therefore not making financial profit. It is therefore of the utmost importance to conduct the turbine maintenance in the most effective manner possible. This is known to maintenance engineers, but the methods of conducting, or planning maintenance often differ. The turbine manufacturer provides guidelines on how turbines should be maintained. However, after certain period, experience gathered by the maintenance engineers starts to affect such guidelines and methods of maintenance evolve. This is the centre of gravity in this paper. In order to compare the means of planning turbine maintenance, it is essential to document the methods currently used and how condition monitoring is used to plan maintenance. In this study, we analyse which monitoring takes place on the geothermal turbines at Hellisheidi geothermal power plant and how, or if, such monitoring is used to plan maintenance before it is conducted. As the Icelandic geothermal industry has been shown to operate power plants in an efficient manner (Atlason and Unnthorsson, 2013, 2013), the additional knowledge should therefore prove valuable to other power plants looking for alternative ways to plan the turbine maintenance. We subsequently attempt to identify low hanging fruits with regards to improvements and scout the literature for solutions to those problems.

1.1. Geothermal power plants operated by Reykjavik Energy

The Hellisheidi geothermal power plant is owned by Reykjavik Energy and inaugurated its electricity production in 2006 (Jonsson and Sigurdsson, 2008). The plant is located on the southern part of the Hengill geothermal field. It produces approximately 303 MW of electric power (MW_e) and 133 MW of hot water (MW_t) through a double flash process. Around 50 wells have been drilled to harness hot water for the power production (Jonsson and Sigurdsson, 2008). Reykjavik Energy provided data about the fluid chemical composition when it leaves the separators. One can see that the brine consists mostly of SiO_2 (822 mg/kg), Na (213 mg/kg), Cl

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(170 mg/kg), K (38.4 mg/kg), and SO_4 (19 mg/kg) (Gunnlaugsson, 2013). Emitted gas calculated from gas concentration in steam consists mostly of CO_2 (58.1%), H_2S (29.4%), H_2 (12.3%) and CH_4 (0.2%) (Gunnarsson et al., 2013). Also located on the Hengill geothermal field, Nesjavellir geothermal power plant produces 120 MW_e and 300 MW_t. Experimental wells were drilled, where each well was providing up to 60 MW_t, with a usable 30 MW_t. Construction of the plant began in 1987 where the first phase was completed in 1990. In the same year, four holes, generating 100 MW_t were connected to the production. In 1995 an additional hole was drilled and connected. Today, 26 holes have been drilled. Temperatures at Nesjavellir have been recorded as high as 380 °C. The gas concentration measured in the same way as at Hellisheidi is: CO_2 (43%), H_2S (33.9%), H_2 (23%) and CH_4 (0.2%) (Gunnarsson et al., 2013). It is estimated that the current production can continue for the next 30 years (OR, 2006). The brine at Nesjavellir consists mostly of SiO_2 (822 mg/kg), Na (159 mg/kg), Cl (139 mg/kg) and SO_4 (64.5 mg/kg). Even though the main focus of this article is on Hellisheidi geothermal power plant, the maintenance procedures at Nesjavellir were inspected to gain a deeper understanding on the maintenance protocols used at Reykjavik Energy.

1.2. Geothermal steam turbines

Steam turbines are designed to convert the vapour enthalpy to shaft work, and eventually electric power (Valdimarsson, 2011). Turbines at geothermal power plants are in essence the same as regular steam turbines (Thorhallsson, 2005). They have however been modified to deal with geothermal conditions, which mainly entails dirtier steam. Single inlet turbines are the ones most utilised. However, double flash power plants have been shown to get more power output where the liquid is flashed for the second time to lower pressure, vapourising extra steam which is then diverted to the turbine (Thorhallsson, 2005). This does however often lead to scaling, the hardware therefore needs to be monitored more closely. A steam turbine consists of a rotor with multiple levels of blades. The speed of the turbine is controlled and kept constant by a so-called governor which controls the turbine control valve (Thorhallsson, 2005). Through the first stage nozzle, which is non rotating, the steam is subsequently distributed over the turbine circumference, before entering the following stages.

1.3. Geothermal steam turbines at Hellisheidi

At Hellisheidi, seven steam turbines are currently in operation. Six of which are high pressure turbines manufactured by Mitsubishi, and one low-pressure manufactured by Toshiba. The high-pressure turbines are a Single-Cylinder, single flow, impulse reaction, axial exhaust, condensing turbines. The steam is approximately 167 °C when it enters the turbine and around 7.5 bar. At the outlet, the temperature of the steam is approximately 45 °C at 0.1 bar(a). The rated output of each of the six high-pressure turbines is 40 MW_e where the maximum output is 45 MW_e. The turbines have six stages where the last stage has blades reaching 762 mm (Industries, 2007) (Fig. 1).

1.4. Frequent problems in geothermal steam turbines

Although the steam turbines used in geothermal power plants resemble conventional steam turbines, there are some fundamental differences. In a geothermal power plant, a brine from the earth is brought into lower pressure which releases steam. This is referred to as flashing. The steam released is then lead through separators who have the role of removing mist containing minerals before it enters the turbines. Even though the separators do an excellent job at removing mist containing minerals, some amount is prone to get

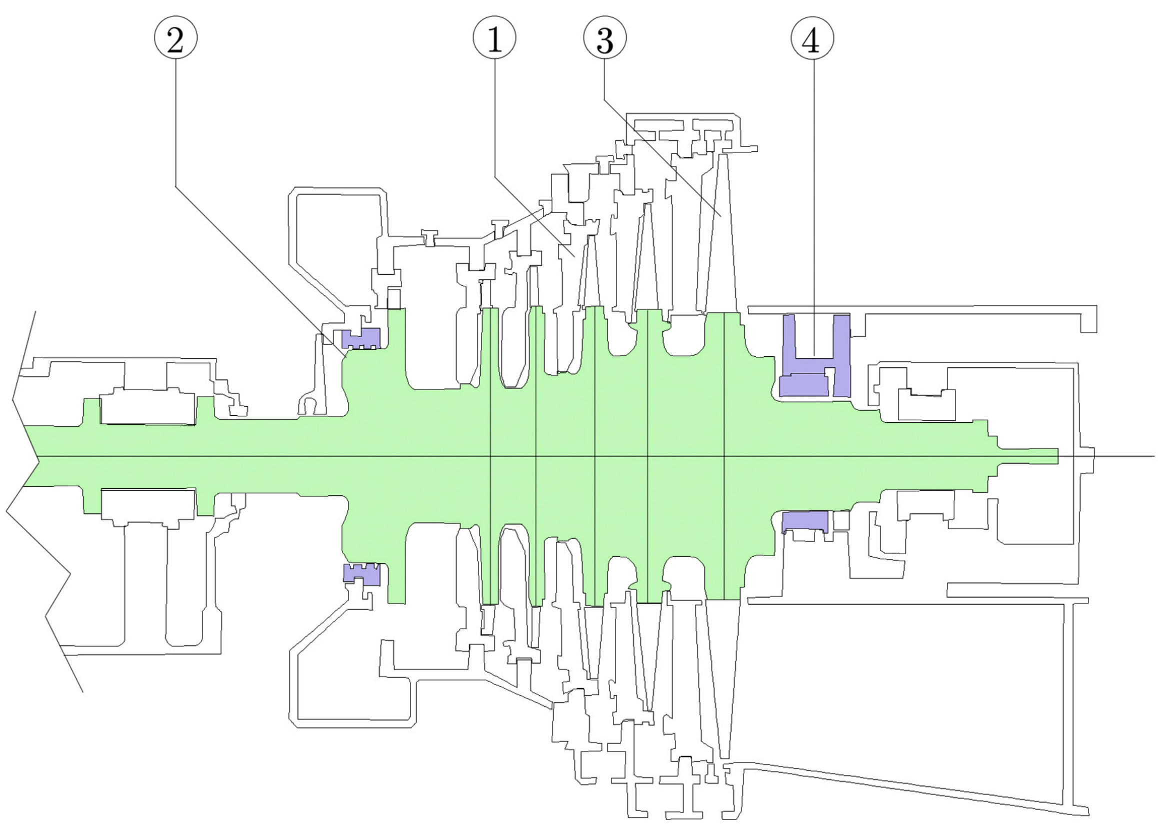

Fig. 1. Schematic image of a high pressure Mitsubishi turbine. Numbers indicate correlating monitoring points explained in Table 1.