A study on compressor performance degradation of heavy duty gas turbines using compressor map adaptation

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Long Abstract

Introduction

Gas turbine performance degrades with increasing operating time. The major causes of performance degradation are fouling, erosion, corrosion, abrasion, FOD , and so on [1]. In industrial gas turbines, particles larger than 10 μm are eliminated by a filtration system [2]. Therefore, the performance degradation in industrial gas turbines is mainly generated by fouling caused by soft particles smaller than 10 μm [2]. In this study, degradations of compressor and turbine of a power generation gas turbine were estimated using measured performance data and the results were compared with the trend of power output variation of the gas turbine.

Method and Result

Figure 1 shows the layout of the gas turbine analyzed in this study. It is an F-class heavy duty gas turbine of a simple cycle type. Firstly, the simulation of its design performance was made to reproduce the design specifications. The GateCycle [3] was used for the simulation. The power output and efficiency of the gas turbine were 165.4 MW and 36.2%. For modeling of each component, mass and energy balances were applied. Then, gas path analysis based on off-design analysis was performed to calculate non-measured temperatures and pressures from measured data. The values of component characteristic parameters, such as efficiencies of compressor and turbine, air flow, and pressure ratio, were also predicted. Turbine operation in off-design condition was modeled by the following choking equation, which has been widely used for simulation of industrial gas turbines [3]

$$\left.\frac{\dot{m}_3\sqrt{T_3}}{\kappa A_3 P_3}\right)_T = \text{constant},\ \kappa = \sqrt{\frac{\gamma}{R}\left(\frac{2}{\gamma+1}\right)^{\frac{\gamma+1}{\gamma-1}}}$$

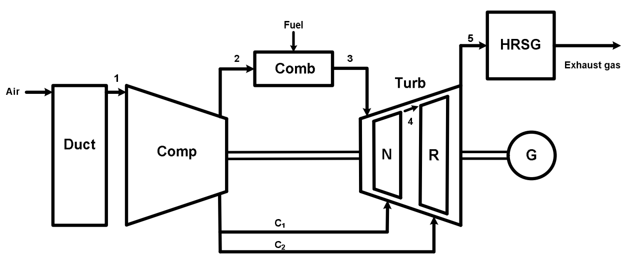

Figure 1. Layout of the gas turbine

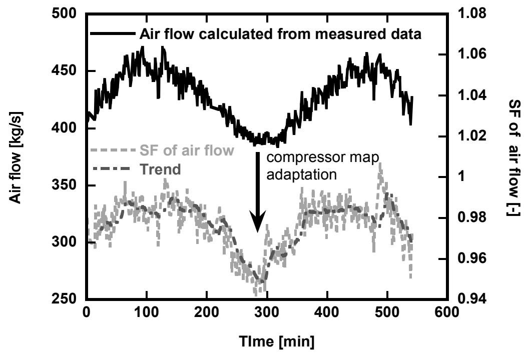

Figure 2. Variations in air flow and SFs with operating time

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The object of analysis was an F-class gas turbine of a combined power plant operating in Korea. The full-load data obtained from 04-Oct-2012 to 31-Mar-2014 were used. Full-load means operationg with a fully opened inlet guide vane (IGV) angle. Data selection frequency was one day (i.e. one point per a day). Parameters used for analysis were ambient conditions (such as the inlet temperature, pressure, humidity), fuel conditions (such as the fuel temperature and flow) and gas turbine performance parameters (such as the gas turbine power output, turbine exhaust temperature, compressor discharge temperature and pressure). Figure 2 shows the variation in air flow at compressor inlet with operating time. The result includes effects of both the change in ambient conditions and the compressor degradation. To predict the trend of compressor degradation which does not include effect of chage in ambient condition, an adaptive method of compressor map was introduced, which shifts the reference compressor map to the values of the predicted air flow, pressure ratio, and compressor efficiency from measured data, as shown in Figure 3. The calculated degradation scailing factor (SF) of the air flow which is defined as follows is shown in Figure 2.

$$SF_{flow\ rate} = \frac{Flow\ rate_{degraded}}{Flow\ rate_{New\ and\ Clean}}$$

The trend of calculated values was predicted using a 20-day moving average. The SF of air flow was compared with gas turbine power output. The gas turbine power output was correted to ISO condition power output using correction curves given by the manufacturer, and divided by maximum values. Figure 4 shows that the trend of compressor performance degradation synchronized with that of the corrected gas turbine power output, which means that the gas turbine power degradation is mainly due to the compressor degradation.

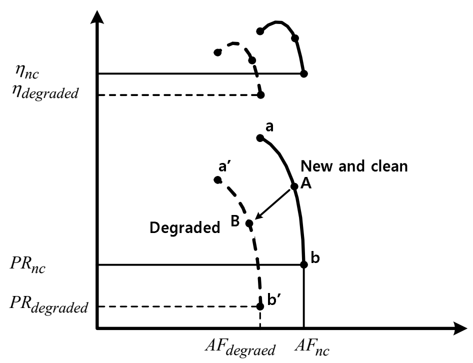

Figure 3. Adaptive method of compressors map

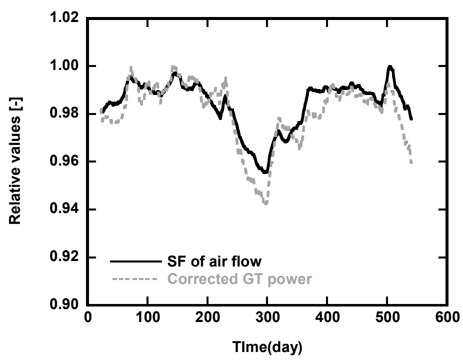

Figure 4. Comparison of relative values of corrected GT power output and SF of air flow

Acknowledgment

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