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ORIGINAL ARTICLE

Life cycle evaluation of an intercooled gas turbine plant used in conjunction with renewable energy

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KEYWORDS

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Abstract The life cycle estimation of power plants is important for gas turbine operators. With the introduction of wind energy into the grid, gas turbine operators now operate their plants in Load–Following modes as back-ups to the renewable energy sources which include wind, solar, etc. The motive behind this study is to look at how much life is consumed when an intercooled power plant with 100 MW power output is used in conjunction with wind energy. This operation causes fluctuations because the wind energy is unpredictable and overtime causes adverse effects on the life of the plant – The High Pressure Turbine Blades. Such fluctuations give rise to low cycle fatigue and creep failure of the blades depending on the operating regime used. A performance based model that is capable of estimating the life consumed of an intercooled power plant has been developed. The model has the capability of estimating the life consumed based on seasonal power demands and operations. An in-depth comparison was undertaken on the life consumed during the seasons of operation and arrives at the conclusion that during summer, the creep and low cycle life is consumed higher than the rest periods. A comparison was also made to determine the life consumed between Load–Following and stop/start operating scenarios. It was also observed that daily creep life consumption in summer was higher than the winter period in-spite of having lower average daily operating hours in a Start–Stop operating scenario.

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1. Introduction

There is an increasing interest in operating intermittent Renewable Energy Sources such as wind power and solar energy generation with conventional utility plants [1]. This has been as a result of the unprecedented demands for operational plant flexibility and meeting with the UK Government targets for an 80% reduction in CO_2 emissions by 2050 and beyond [2]. In achieving this, the power sector will have a major role to play. Despite the achievements achieved so far, there'll be a vital role for flexible operation of power plants. A possible way of increasing the plant's flexibility and also in conjunction with renewable energy sources (RES) – wind, is by operating the plant in a load following mode especially during low demand periods of electricity. By operating in this mode, it is beneficial to the plant operator economically, because it saves costs for start-ups and shut-downs and can meet up with the demands of the grid by supplying power quickly when required. That notwithstanding, Load–Following operations has its own consequences. Load–Following operations cause fluctuations over time during operation especially when seasonal scenarios are considered due to different ambient conditions it has to operate under [3]. The transition to load following operations (LFO) causes temperature differences in the rotor and thick-walled components in the hot gas section and results in the production of thermal stresses and deteriorations which can decrease the life of the turbine blades or at worse destroy the turbine [4]. Fatigue and creep due to these thermal stresses during cycling operations constitute to a great extent the underlying problems with almost all power plants. The HPT blades of the hot gas section of gas turbines has always been the life limiting component due to the high level of rotational speeds and turbine entry temperatures it operates on [5]. Also, the GTs will have to cope with the flexibility requirements mainly due to the 'Start–Stop' operations based on the highly fluctuating availability of 'RES' – wind energy (as considered in this study). As part of research, a tool has been developed. This tool has the capability of giving an estimate of how much life is being consumed for Load–Following plants used during seasonal operations.

2. Methodology

An algorithm was developed in 'FORTRAN 90/95' as shown below in the lifing methodology (Figure 1). The lifing model estimates the life – both creep and low cycle fatigue of the intercooled gas turbine power plant with 100 MW capacity. The lifing model comprises of the following modules: Performance simulation module, Stress analysis module, thermal module; material properties module, LCF life module and creep life module. This gives the period between overhaul which in turn is used to estimate the maintenance cost of the gas turbine plant.

2.1. Performance module

Gas turbine performance is characterised by three basic components namely - the mass flow, the firing temperature also known as TET and the pressure ratio [6]. The performance simulation and engine model was carried out using Turbomatch which is a component based gas turbine tool developed at Cranfield University [4]. Performance module initiative as shown in Figure 2. Turbomatch models an engine performance at both design and a range of possible off-design conditions that is usually experienced based on the ambient conditions (Seasons) [7].

For each season considered, input files were constructed based on ambient conditions to obtain the DP and ODP performance for each of the gas turbine plants been used as case studies. The first case study looks at how seasonal changes affect the life of the plant especially when the plant is being integrated to run with wind energy, so the variables considered in this study are:

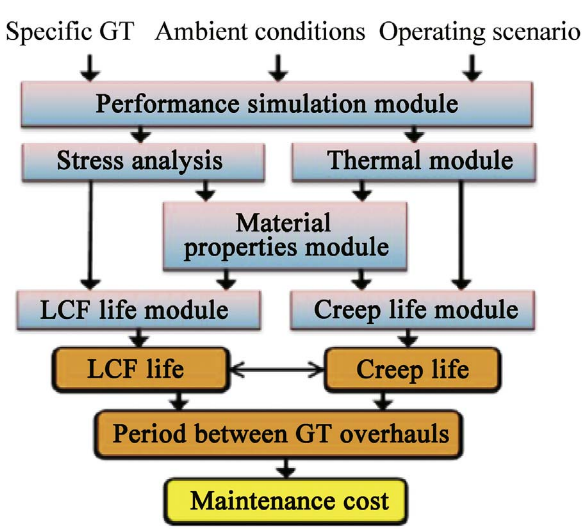

Figure 1 Lifing model methodology.

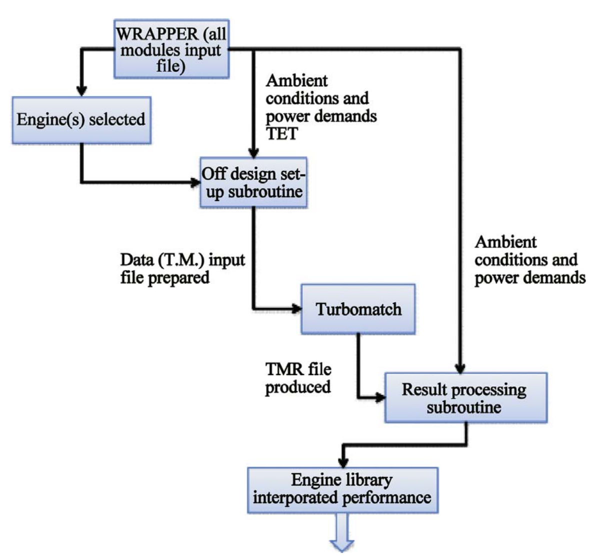

Figure 2 Performance module initiative.

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