THE FUTURE OF GAS TURBINE TECHNOLOGY

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COLLECTION OF ABSTRACTS

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TECHNICAL SESSION 1: OPERATION & MAINTENANCE 1 (THEATRE)

THE EFFECT OF AIR FILTRATION ON GAS TURBINE PERFORMANCE DEGRADATION - ISO16890 AND ITS APPLICATION TO REAL ENGINE DATA

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Abstract

The degradation of gas turbine power output and compressor efficiency over time is strongly influenced by the amount and composition of particles entering the compressor. This amount is on one side affected by the chosen air filtration layout, i.e. by filter classes, filter configuration, volume flow per filter etc. and on the other side by the size distribution, mass and chemical composition of particles in the ambient air.

The introduction of the new global standard ISO 16890:2016 [1] brought a different approach to evaluate the filtration efficiency as a basis for filter classification: filter efficiencies will be determined with regard to separation efficiencies for particulate fractions PM1, PM2.5 and PM10, which are also used as evaluation parameters by the WHO (World Health Organization) and environmental authorities. This paper describes the correlation between power output, respectively compressor efficiency degradation, the performance of installed air filters according to the new ISO 16890 standard and the concentration and mass distribution of dust particles at the gas turbine's specific location. Such a correlation in combination with public available particle concentration data and Freudenberg's effect

software (electronic Freudenberg Filter Efficiency Calculation Tool) allows determining the economically best filtration layout for any given power plant.

A DIGITALIZED APPROACH FOR COMBINING DIAGNOSTIC CAPABILITIES AND MAINTENANCE RISK-BASED INSIGHTS TO IMPROVE MACHINE OPERATION

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Abstract

The emergence of the Industrial Internet of Things (IIoT) and Big Data and the associated predictive analytics in industrial sectors where assets represent a high-value component, drives opportunity to increase profitability and leads to the Asset Performance Management (APM), a new integrate approach to run the assets at best, maximizing their operational and financial results.

This paper presents a case study which integrates the predictive capabilities of a Monitoring and Diagnostic (M&D) service with a risk analysis carried out on the asset and the information on maintenance activities performed on site, thus resulting in a new enhanced service.

The aim of traditional M&D is to process the field data using analytics, to deliver insights on equipment health and suggest actions. We support these recommendations with a quantitative assessment coming from the risk analysis, reporting the benefits associated to the suggested actions, expressed in risk reduction, and the effects may happen if no action is taken. Moreover, for certain failures, the recommendations are automatically retrieved from the risk analysis.

Maintenance strategy revision is also performed, having as objective to turn the initial time-based preventive plan into a risk-based predictive one. This is enabled by both the risk analysis outcomes and the availability of M&D. For example, for a not critical item whose functioning can be easily monitored remotely, time-based maintenance activities may be saved.

The other component of the extended M&D work process is the creation of some components for a dynamic maintenance strategy, enabled by analytics. Data on maintenance activities, e.g. failure

frequencies, are used for suggesting that the maintenance plan or the risk analysis need a revision. It is also suggested when to implement a new M&D recommendation within the running maintenance plan.

We applied this strategy to an Oil&Gas plant and the results of the integrated service delivered have been observed for several months, providing feedback on the methodology as well as points of reflection for further enhancements.

ORAP®: THE FOUNDATION FOR PREDICTIVE ANALYTICS

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Abstract

The focus of this presentation is field experience data, past and present, collected through the Operational Reliability Analysis Program® (ORAP). The presentation will review the need for and the value of high fidelity equipment data – at a component level of detail; supporting product evolution and Operations & Maintenance (O&M) advancement. Included in the presentation will be a review of current and historical performance of both Aeroderivative and Heavy-Duty plants/units in commercial operation today, available through ORAP. In addition, a discussion of the process improvements made to ORAP, to simplify and improve the data collection process from the plant, called ORAP Asset Insight™, will be discussed. The presentation will show the benefit of automating and transforming the near real-time data, available through plant historians into "time; capacity; age; and events." This will lead to lower cost of labor to capture and report plant data, while improving the fidelity and value for effective outage planning.

TECHNICAL SESSION 2: ADVANCED CYCLES (VERSAILLES)

STATUS OF THE 10 MWe SUPERCRITICAL TRANSORMATIONAL ELECTRIC POWER (STEP) PROGRAM

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Abstract

Supercritical CO2 (sCO2) power cycles can offer several benefits: (1) Higher cycle efficiencies due to the unique thermodynamic properties of sCO2; (2) Reduced emissions resulting from lower fuel usage; (3) Compact turbomachinery, resulting in lower capex, reduced plant size/footprint, and more rapid response to load transients; (4) Reduced water usage, including water-free capability in dry-cooling applications; and (5) Heat source flexibility. These benefits can be achieved in a wide range of power applications including gas- and coal-fired power plants, bottoming cycles, industrial waste heat recovery, concentrated solar power, shipboard propulsion, biomass power plants, geothermal power, and nuclear power. Advancements to date have been limited to laboratory-scale test loops under 1 MWe. To facilitate further advancement and commercial deployment of the technology, pilot-scale testing is required to validate both component and system performance under realistic cycle conditions at sufficient scale.

The Supercritical Transformational Electric Power (STEP) project is a significant scale-up (to 10 MWe) of a fully integrated and functional electric power plant and in its execution, several technical risks and challenges will be mitigated, including (1) Turbomachinery (aerodynamics, seals, durability); (2) Recuperators (design, size, fabrication, durability); (3) Materials (corrosion, creep, fatigue); and (4) Cycle operability (startup, transients, load following).

FAST START AND CYCLING HRSGS: SIEMENS DRUMPLUS™ TECHNOLOGY

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Abstract

Fluctuating renewable power generation is structurally changing the electricity markets in almost every country or region. In the past, traditional Gas Turbine Combined Cycle Power Plants (CCPPs) were practically only running in base load operations, providing electricity to the grid for a large part of the year, and only a limited number of start/stops had to be made per annum. However, the market changes require CCPPs to adapt to a new reality. The market demands quick and flexible power generation, especially from fossil fuel power generation capacity.

Traditional Large CCPPs, with F-class or higher capacity gas turbines, are limited in both the startup time (which can be up to an hour or more) and the number of starts/stops. Until a few years ago, most of the CCPPs in Europe where running for more than 5,000 hours per year and where only stopped and started for 50 – 100 times annually. Now, CCPPs are running only a couple of thousand hours – if being lucky - and have to be stopped and started often on a daily basis. This new world gives huge challenges to large CCPPs, but it also provides new opportunities.

The need for flexibility and ever more powerful gas turbines requires HRSGs that are robust, have large pressure parts and are capable to start up fast. These characteristics seem to conflict as larger and thicker pressure parts do not create flexibility, but a lack thereof.

However, Siemens HTT fast start design ensures unrestricted GT ramp-up and long lifetime, also for the latest high output GT models. This means that the HRSG is no longer limiting the gas turbine in CCPP operations, and it can ramp-up as fast as possible.

The HRSG is designed so that peak stresses are significantly reduced. This results in a boiler that is capable of rapid cycling operation. In the DrumPlus™ HRSG, the High Pressure drum has a small wall thickness as a result of the small drum diameter, and nozzle sizes are minimized, allowing for unrestricted GT ramp-up. Key is the external location of the secondary water-/steam–separators, allowing an optimal separator design without the limits set by the confined space in the drum. The El

Segundo CCPP in California is the world's first large CCPP with fast start and cycling HRSG capabilities of its kind.

The fast start power plant offers higher plant efficiency and significantly more kilowatt-hours for commercial use during the first hour of its operation. Fast ramp up also allows gas turbines to reach low NOx and low CO operating loads quickly. As a result, demanding environmental permits are complied more easily and a quicker response to power demand is achieved.

TOWARDS HIGHLY-FLEXIBLE CARBON-CLEAN POWER PRODUCTION USING GAS TURBINES: EXHAUST GAS RECIRCULATION AND CYCLE HUMIDIFICATION

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Abstract

The current shift in electrical power generation towards more renewable production strengthens the need for highly-flexible, preferably carbon-clean, production units. These units need to provide the flexibility to the system necessary to compensate for the intermittent nature of the renewable energy production. Of all fossil-based power production units, Gas Turbines (GTs) are the only units capable of

offering this flexibility, but they still require carbon capture to reduce the CO_2 exhaust, resulting in rather low efficiencies. More advanced GT cycles, i.e. cycle humidification possibly in combination with Exhaust Gas Recirculation (EGR), offer a solution; however, their performance is not yet fully identified and experimental data is still lacking. Applying these concepts first on small-scale, using micro Gas Turbines (mGTs), to show the potential of these cycle concepts, has some advantages; however, again numerical and especially experimental data are still missing. In this paper, two models predicting the potential of EGR and cycle humidification applied on a typical mGT, the Turbec T100, with post-combustion carbon capture have been compared and experimentally validated. Simulation results indicated that the impact of the advanced cycles on the mGT performance of both models is predicted in a similar way. In addition, numerical results show little difference with experimental data, validating both models. Finally, both numerical analyses highlighted that combining EGR with the micro Humid Air Turbine (mHAT) concept results in most efficient cycle layout, suggesting this as a promising application.

TECHNICAL SESSION 3: DATA ANALYTICS FOR OPTIMISED OPERATIONS (ESTEREL)

AN ADVANCED EARLY FAULT DETECTION TOOL FOR PREDICTIVE MAINTENANCE OF A FLEET OF INDUSTRIAL GAS TURBINES

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Abstract

Manufacturers of gas turbines for energy production are shifting their business from selling the turbines to selling the energy production rate, with heavy economic penalties whenever the rate requirement is not achieved. Predictive maintenance becomes mandatory for this new business, to profitably manage gas turbine fleets. Predictive maintenance allows early detecting the incipient degradation process of the turbine, assessing the turbine degradation state, predicting the future degradation evolution toward failure and, on the basis of the predictions, optimizing fleet operation by a proper, dynamic scheduling of the maintenance interventions. In this work, we propose a tool that exploits IoT devices for remotely monitoring the turbines and dedicated advanced statistical and machine learning algorithms for the treatment of the information contained in the data, with the objectives of early detecting the turbines incipient degradation, thus providing early alert messages to the operators. Based on this information, the operators can intervene by promptly maintaining the degrading turbines for reducing the maintenance intervention times, increasing the fleet overall availability and avoiding severe, if not catastrophic, consequences. The tool for Early Fault Detection is therefore expected to yield a profit improvement for both the turbine manufacturers and energy producers.

USING DATA FOR A SMARTER OPERATION OF A GAS TRANSMISSION NETWORK – KEEPING THE GAS FLOWING

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Abstract

National Grid owns and operates 7,500 miles of high pressure gas transmission pipeline in the United Kingdom. Helping to move and compress the gas are 71 compressors, 62 of these are gas turbine driven, located at 24 different compressor stations and terminals. When the network was built the flow of gas was predominantly north to south, now with the introduction of LNG terminals the network therefore needs to be more flexible to meet the new mix of supply and demand. A lot of data is available on the operation of the machines and there are data driven innovation projects designed to help improve the efficiency of operations. National Grid recognise that there is a lot to learn from the data they have and this can be used to optimise the maintenance and repair of their assets.

Digital data is at the forefront of these innovation projects and there is a lot of data available which up until recently has been simply “filed away”.

National Grid have partnered with DNVGL to collect and analyse this data to assist in their goal for more efficient operation and maintenance of their aging machines. Data acquisition hardware is installed at each compressor station collecting machine and process information, this data and systems are used for condition monitoring, emissions reporting and compliance. The data which was collected included running data (vibration, temperatures, pressures, flows), operational data (starts, stops trips), maintenance data (routine, repairs and failures), and failures log. Once collected the data was checked and cleansed and additional character added (is the point in alarm, increasing, decreasing or deviating) and then analytics performed to look for characteristics around known maintenance and failures from

the operational logs. The collected data can then be used to allow National Grid to manage the operation and maintenance of its whole fleet.

REFERENCE STRESS ESTIMATION FOR ANISOTROPIC MATERIALS USING LINEAR ELASTIC FINITE ELEMENT RESULTS

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Abstract

Components in the hot section of a gas turbine engine experience extended high temperature dwells and cycles composed of multiple starts, changes in load, and variable duration. These loading profiles can lead to damage from cyclic viscoplasticity which is heavily path dependent as dwell stress, yield strength, and stress range change constantly during operation. Since an accurate prediction of accumulated damage is critical to managing an engine, reduced order methods for tracking material behavior over complex operation cycles are necessary tools to help avoid unplanned down time and optimize cost over the operational period.

One method for tracking the material behavior during path dependent cyclic viscoplasticity requires the use of reference stress. Reference stress is a bulk representative stress that can be used in conjunction with various lifing methodologies to determine component durability. Previous papers provided a method for calculating reference stress for isotropic materials using limit load estimation. The goal of this paper is to extend these methodologies to a reference stress estimation method for anisotropic materials to estimate life for single crystal turbine blades. Derived equations will be shown and results from simple Finite Element (FE) test cases will be discussed to demonstrate the accuracy of the anisotropic reference stress estimation.

Once reference stress is obtained, the long term forward creep stress of a component can be estimated for any given initial stress state. This approach can be used to calculate damage during shakedown resulting from redistribution and relaxation due to plasticity and creep, which can be critical for accurately predicting remaining useful life and optimizing engine management.

TECHNICAL SESSION 4: OPERATION & MAINTENANCE 2 (THEATRE)

PERFORMANCE ANALYSIS OF A TWIN-SHAFT GAS TURBINE WITH FAULT IN THE VARIABLE STATOR GUIDE VANE SYSTEM OF THE AXIAL COMPRESSOR

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Abstract

In this study, an analysis of the performance of a twin-shaft industrial gas turbine (IGT) with a fault in the mechanism of the compressor that changes the position of variable stator guide vanes (VSGVs) is carried out. Measured field data of a twin-shaft engine denoting a difference (offset) between the demanded inlet guide vane (IGV) angle and the measured IGV angle in the axial compressor have been considered for the analysis. A validated Simulink model which simulates the performance of the twin-shaft engine has been considered for the analysis of the fault in the VSGV system. The Simulink model architecture comprises an axial compressor module and considers a multi-stage compressor performance map at optimal conditions (new & clean). The results demonstrate that it is possible to predict the physical parameters such as pressure and temperature measured across the different

stations of the engine during the offset of the IGV angle. The effect of the IGV offset on the compressor performance is discussed as well. The change in compressor air flow and compressor efficiency at different IGV offset is discussed, as during a low power engine operation and fault within the VSGV system, the surge line may drift close to the compressor running operation line.

THE CHALLENGE OF BURNING DIESEL FUEL IN AERO-DERIVATIVE GAS TURBINES OFF-SHORE

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Abstract

Behind the common idea that diesel fuel is a standard and regular product which is easily available and used to run gas turbines, an Oil & Gas operator is well positioned to confirm that burning diesel fuel in aero-derivative gas turbine is, in fact, a real challenge. If the diesel fuel treatment system of a gas turbine is not properly designed, the life of a turbine running with diesel can be reduced to a few minutes. To avoid issues arising from burning diesel fuel, it is required to understand its nature, the fact that it is a "living substance", and adopt specific designs and operation practices. The objective of this technical paper is to share the experience accumulated in this field by an Oil and Gas operator off-shore. Firstly, some parameters of fuels are discussed. Secondly, the liquid fuel specifications of aero derivative gas turbines are reviewed and the gap with respect to standard fuels available on the market is highlighted. Thirdly, different operational issues and symptoms that were observed when operating aero engines with diesel fuel are presented. These issues may come from the supply, storage, treatment, or turbine fuel system and its control. Finally, a set of guidelines to obtain a robust diesel fuel storage, treatment and overall turbine fuel system for dual fuel operation is proposed. These guidelines include design and operating rules based on the knowledge of the diesel fuel presented in section one, and that have proven to be effective in solving the issues described in section two.

EXTENDING THE LIFE OF F-CLASS GAS TURBINE ROTORS FOR IMPROVED OPERATIONAL & MAINTENANCE LIFE CYCLE COSTS

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Abstract

F-Class heavy-duty gas turbines have been in commercial operation in excess of 25 years. While being a workhorse in the power generation market during that time, the market has evolved dramatically, resulting in the change of operational modes of these units. Switching form baseload to cyclic operations, failure mechanisms unforeseen on earlier E-Class units are starting to emerge. Furthermore, larger components such as the rotor, are fast approaching, or have reached, the OEM recommended lifetime from either a starts or hours-based perspective. As such, the reliability and maintenance of such capital components are on the forefront of many operators minds. To address this issue, operators are turning to OEMs and third party service providers to replace or evaluate the continued operation beyond that of the original recommended service life. While limited end of life (EOL) inspections have been sufficient on older technology, recent comprehensive inspections on multiple OEM F-Class units have revealed significant drawbacks of limited inspections. Utilizing a comprehensive set of inspections, multiple life-limiting indications have recently been discovered at various locations throughout F-Class rotors. These indications will be detailed, as well as the repair and/or replacement solutions provided to successfully return the units to service beyond that of the OEM recommendation.

TECHNICAL SESSION 5: DISTRIBUTED GENERATION TECHNOLOGIES (VERSAILLES)

INTEGRATED SOLAR COMBINED CYCLE POWER PLANT USING ORGANIC RANKINE CYCLE FOR RELIABLE, DISPATCHABLE, LOW CARBON ELECTRICITY

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Abstract

Renewable energy has a significant role to play in helping the world to achieve the greenhouse gas emission reduction necessary to achieve the pathway to a 2°C increase in global temperature. Electricity generation from wind and solar resources can contribute immensely to the de-carbonization of power generation, but these resources are intermittent. High penetration of intermittent renewable power generation can cause grid stability and control issues for network operators, with fast response fossil fuel power plant necessary to provide security of supply and maintain grid stability. Increasingly natural gas-fueled distributed power generation is being installed to provide the necessary grid support.

However, hybrid power plants comprised of a fossil fuel power generating system, a renewable power generation system and energy storage can provide both the low CO2 electricity required to meet environmental constraints, and the dispatchability and stability required by grid operators. Integrated Solar Combined Cycle Power Plants (ISCCs), comprising a Concentrated Solar Power plant and a natural gas fired combined cycle plant, have the potential to simultaneously reduce fossil fuel consumption, provide secure, highly predictable electricity generation, and reduce the cost of integrating renewable energy into a power system.

While a number of ISCCs have been built at a larger scale (above 150 MW power output), the concept has rarely been adopted for smaller scale distributed power applications. In addition, the traditional ISCC concept uses a steam bottoming cycle, which consumes water, and often locations where distributed ISCC could be utilized suffer from a scarcity of fresh water.

This paper evaluates whether replacing the steam bottoming cycle with an Organic Rankine Cycle (ORC) alternative can provide a simpler, lower cost distributed ISCC solution that can be utilized on

smaller and island grid systems, or mini- and micro-grids, to provide an affordable, water-free, low carbon power generation system.

AN INNOVATIVE FLEET CONDITION MONITORING CONCEPT FOR A 2MW GAS TURBINE

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Abstract

Deterioration of gas turbine component condition leads to degradation of performance, efficiency, reliability and safety. Accurate monitoring and advanced analysis of gas turbine performance offers great potential to minimize life cycle costs and maximize performance and availability and thereby revenues. Implementing advanced performance monitoring tools for a fleet of engines can save millions of dollars by improving availability and reliability of the machines. OPRA Turbines has more than 100 of its OP16 2MW class gas turbines installed worldwide. Using B&B-AGEMA's GTPtracker software, an online real-time condition monitoring and prognostics system has been developed. A detailed model of the OP16 engine has been used to simulate deterioration and failure effects, generating signatures for condition assessment on component level. The signatures are stored in the GTPtracker monitoring database in the form of rule sets that can be correlated also to condition monitoring information from different disciplines such as vibration and lubrication. Performance data matching a rule set indicates specific component deterioration and failure modes. Rule set matches are automatically detected and translated into maintenance decision support information, thereby helping to minimize life cycle costs. The concept is used for both diagnostics, detecting and isolating current engine problems, and prognostics for predicting problems by extrapolating trend functions. The system is highly flexible and end user configurable. The paper gives an overview of the system and methodologies applied with generic examples. For the OPRA OP16 gas turbine, two case studies are presented demonstrating specific component deterioration detection and sensor fault isolation.

HYBRID GAS TURBINE (GT) MECH DRIVE FROM BHGE

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Abstract

This paper describes the advantages, here below summarized, of a GT and an electrical reversible machine that operate in combination:

- Power increase without flange to flange and additional emissions impacts.
- Use of the electric energy, i.e. from renewable sources, reducing fuel and consequently emissions.
- Use the electric energy to improve the life of the GT components.

Since the VFD and motor are reversible systems, they can operate as generator too. This function can be used when the driven compressor load is lower than GT nominal power, reinjecting into the electrical network all the power excess. In this way, the gas turbine can run at the perfect condition to maximize its efficiency and reducing the impact on the emission too. In addition, the electric power can be used to feed electricity to the compression station for opex reduction, for example by the shutdown of the electric station generator or by keeping the compressor station powered in the case of a grid fault that is a typical situation in remote locations where the grid is often unreliable. Also, an advantage in terms of the maintenance life extension can be obtained by the application of this hybrid system.

All possible solutions are tailored on the operator needs.

TECHNICAL SESSION 6: DIGITALISATION TECHNOLOGIES (ESTEREL)

INDUSTRIAL INTERNET: THE NEXT AGE OF PRODUCTIVITY FOR EUROPEAN GT BASED PLANTS

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Abstract

Lately, there has been a lot of discussion on how Industry 4.0 and digitalisation are challenging traditional business models and provide new opportunities to gain competitive advantage. The energy sector as well as the Oil&Gas sector have been early adopters of digital technologies. Since the 70's, digital techniques were introduced for decision support and process improvement and have been commonly used for well over a decade now. So, what is the recent fuss around digitalisation all about? Is it just a new buzzword for more of the same or are we really at the start of a new age of productivity? In a series of workshops, the ETN technical committees 4 and 5 have been exploring this question.

It became clear that many of the digital initiatives in the past got stuck in the information generation phase, without really providing the insights required to improve the business result. Causes for this were related to IT infrastructure and data handling issues. Recent developments, such as improved connectivity, cloud data storage, software as a service, advanced algorithms and improved sensors address many of these historic roadblocks. Industrial IT has completely re-invented itself and offers new opportunities by providing insights required to go closer to the limits of the equipment, eliminate inefficiencies and enhance the human work experience. Any new development comes however with risks that need to be carefully managed in the implementation phase to unlock the full value.

OVERVIEW OF DIGITAL ASSET MANAGEMENT FOR INDUSTRIAL GAS TURBINE APPLICATIONS

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Abstract

Industrial gas turbines require operational flexibility and availability to be successful in the current business environment. Traditionally, operational risk is managed, in part, through scheduled maintenance (based on operation hours), which is typically formulated through a combination of experience and engineering assumptions. These assumptions are usually inherently conservative and therefore limiting to operational flexibility. Customers are often limited to finite operational hours, starts, firing temperatures and/or rotor speeds. Recent advances in Physics-based Modelling (PBM) and Data Analytics, combined with secure machine data acquisition technologies have provided a platform for the development of Digital Assets. These Digital Assets are created to mirror actual physical assets operating in the field. Digital Assets are a key technology in the implementation of the industrial internet of things (iIOT), providing the flexibility to respond to changes in operation or identify opportunities to optimize the asset's performance during operation, while also maximizing availability.

This paper presents an overview of the critical technologies and approaches needed to successfully build and deploy a functional, efficient Digital Asset, which accomplishes the above goals, in addition to optimizing the life cycle cost of industrial gas turbines. The paper considers a series of key contributing factors, starting with the efficient and secure acquisition of machine data to the development and

application of physics-based models, statistical models, and data analytics which utilize the machine data and generate value through a framework of People, Process and Technology.

DATA DRIVEN PREDICTIVE MAINTENANCE INFORMATION TO ENHANCE HUMAN DECISION MAKING IN GAS TURBINE OPERATION & MAINTENANCE

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Abstract

An effective way to mitigate or reduce the increasing risk of both technical and human error in gas turbine operation & maintenance is to establish a solid and reliable technical baseline for the GT installation and to support the GT operation & maintenance decision making process at all management levels with a dedicated decision support solution based on data driven predictive maintenance information.

This paper describes how a technical audit and subsequent improvement program can establish a solid technical baseline for a GT operation and it illustrates this with the outcomes of a technical audit and improvement program at a major Oil & Gas operator in Europe.

It also describes how raw GT engine operation data can be enriched through automated analysis (with the help of a tailor-made digital engine model) and can be enhanced by expert interpretation (experienced GT maintenance engineers) to transform these raw engine data into effective predictive maintenance information in a cyber secure way.

This predictive maintenance information is presented to the GT operation & maintenance staff on site in the form of practical & easy-to-understand recommendations and dashboards to enhance the quality of human decision making in gas turbine operation & maintenance.

The paper concludes with a case study how this tailormade form of decision support has contributed to improved O&M decision making and reduced unscheduled stops at a major Oil & Gas operation in the North Sea.

TECHNICAL SESSION 7: MANUFACTURING & REPAIR (THEATRE)

DEVELOPMENT OF LIFE PREDICTIVE METHODS ON NOVALT16 COMBUSTOR WITH SIMPLIFIED PHYSICS BASED MODELS

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Abstract

Simplified physics based models are becoming increasingly important in the Oil and Gas industry, especially in the framework of life prediction methods. The use of these analytically lean models is primarily driven by the adoption of digital twin paradigm within the industry but it’s also pushed ahead by design or manufacturing related issues, such as the need of supporting new product introduction more promptly, or expediting the resolution of the RCA’s. The study presented herein reports a description of methods and models used to create the life prediction platform of NovaLT16 combustor liners. Simplified thermal models have been developed, tuned against test data and then used to predict the temperature distribution on liners as a function of the machine actual operating conditions. Following the definition of the most critical area on the outer liner in terms of durability, a stress model of that location has been also created, providing the primary input for the LCF and crack growth models. All these models, in series, had given sound support for the combustor development and can be also easily connected to remote diagnostic and asset management systems to predict the durability of the liners as a function of gas turbine operating parameters.

HOT SECTION LIFE MANAGEMENT THROUGH IMPROVED MATERIAL PROPERTY RECOVERY

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Abstract

Nickel-based superalloys are extensively used in manufacturing hot gas path components in industrial gas turbines used for power generation. Specifically, GTD-111 DS is one of the widely used alloys used in manufacturing the hot gas path rotating components. These components are subjected to extreme operating environments resulting in creep, oxidation, and fatigue of the components during operation. After continued operation, these damage modes need to be repaired and the components go through extensive repair processes, which include several heat treatments to recover the mechanical properties of the base material (GTD-111 DS) lost during operation. The heat treatments used during repair by the different repair vendors can vary widely in terms of temperature, time and the sequence as well. This study focuses on understanding the differences in the effects of the heat treatments (partial solution, full solution, HIP and full solution) to the base material in terms of microstructure-mechanical property relationships. Results indicate that HIP and full solution resulted in refined microstructures and improved mechanical properties compared to the heat treatments involving partial solution or full solution only. Microstructure-mechanical property relationships suggest that components that need to be repaired beyond OEM recommended repair intervals benefit from the HIP and full solution heat treatments.

The originality is that this study links the LCF and stress rupture properties of the GTD-111 DS of material from real life components before and after different heat treatments**.**

Keywords:

GTD-111 DS, Combustion turbine, Hot Isostatic Pressing (HIP), Repair, Solution heat treatment, Mechanical properties

INDUSTRIALIZATION AND CURRENT FIELD EXPERIENCE OF ADDITIVELY MANUFACTURED GAS TURBINE COMPONENTS

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Abstract

During the last years, a new revolutionary way of manufacturing - Additive Manufacturing (AM) has emerged the industry and is considered as a game-changer. This technology enables OEMs to manufacture and repair gas turbine components faster and at the same time with enhanced functionality and performance. Currently Siemens Power Generation is using this technology for prototyping, manufacturing, repair of gas turbine components, and spare part manufacturing [1-3]. Industrialization of the AM technology at Siemens Power Generation and current accumulated field experience of AM manufactured components will be discussed in this article.

Siemens applied AM technology for the repair of gas turbine components in particular for burners of the SGT-700 and SGT-800 industrial gas turbines. It was shown that the replacement of conventional repair with AM resulted in significant reduction of repair time. Moreover, modifications and upgrades opportunities can be incorporated in the repairs.

Another successful application of AM technology at Siemens is the manufacturing of advanced burner swirl for SGT-750 industrial gas turbine. In this case AM was the only technology which enabled manufacturing of this design of the swirl.

An excellent example of the effective application of AM technology for re-manufacturing of obsolete components was demonstrated by AM manufacturing of a water pump impeller, part of the fire protection system at one of the nuclear power station in Slovenia. In this case the 3D model of the impeller was obtained by X-ray tomography followed by digital 'repair' of the scanned model to original geometry and subsequent 3D-printing including qualification.

At Siemens the concept of 'Spare parts on demands' was launched by 3D-printed SGT-1000F burners tips for a district heating power station in Czech Republic.

INTERNALLY COOLED & LIGHTWEIGHT RADIAL TURBINE WHEELS FOR GAS TURBINES

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Abstract

By increasing the operating temperature of a MGT such that TiT are 1200C, cycle efficiencies of >40% are possible.

In collaboration with the University of Bath, HiETA Technologies have designed, manufactured and physically tested a lightweight and internally cooled radial turbine wheel, theoretically capable of operating at 1200°C TiT.

Exploiting the design freedoms of AM, together with the capability to process the Nickel Super Alloy CM247LC, a novel design was created combining the required internal structure of the wheel with a targeted internal cooling method. Topology optimisation was used to guide the required structural requirements, whilst a full conjugate heat transfer CFD model was created to model the effect of cooling on the wheel.

Taking a standard automotive turbo charger as a baseline to reference against, the AM cooled wheel was tested back to back with the solid wheel, at the same design point using the same test hardware.

Due to limitations on the hot gas stand, it was not possible to test at 1200°C inlet temperatures, and so the wheels were tested at 720°C TiT and 70,000rpm. Compared to the solid wheel baseline, the cooled wheel showed a LE temperature reduction of 60°C, a TE reduction of 100C and mid blade

reduction of 90-100°C, whilst being 22% lighter. The results from the test correlated very closely to the CFD results, validating the accuracy of the model.

CFD was then used to predict the temperature reduction at 1200C turbine inlet temperature. At this condition it is expected that temperature reductions of 200°C at LE, 250°C at TE and 180-200°C at the mid blade would be presented, bringing the wheel well within the operating temperature range of CM247LC**.**

TECHNICAL SESSION 8: NEW COMPONENT DEVELOPMENTS (VERSAILLES)

AMMONIA GAS TURBINES (AGT): REVIEW

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Abstract

Ammonia can potentially become a breakthrough chemical for power generation, cooling, storage and distribution of energy through hydrogen. Gas turbines are potential candidates for the use of the resource in an efficient way that will enable commissioning of combined cycles to power communities around Europe and around the world while serving as sources of heat and chemical storage. Therefore, development of these systems will bring to the market a safer, zero carbon fuel that can be used for multiple purposes, thus decentralizing power generation and increasing sustainability in the communities of the future whilst positioning the developing and manufacturing companies as global leaders of a new generation of energy devices.

Therefore, this review highlights attempts and ongoing research to use this chemical as a viable energy vector for power applications, emphasizing the challenges that ammonia gas turbines have faced over the years and details of current research conducted across the globe to allow implementation and commercial deployment of micro, small, medium and large systems for power and propulsion purposes.

“FUTURE-PROOFING” TODAY’S INDUSTRIAL GAS TURBINES: COMBUSTION SYSTEM FUEL FLEXIBILITY IMPROVEMENTS FOR HYDROGEN CONSUMPTION IN A RENEWABLE DOMINATED MARKETPLACE

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Abstract

Renewable energy has disrupted the energy market place. Fuel is free for renewables, and coupled typically with “must run” governmental requirements, they are the first to be dispatched on the power grid. Wind and solar are a function of the weather and can experience rapid swings in load. The result of this type of highly variable power demand is that gas turbine power plants must effectively respond to the load swings and capture periods of profitability. It’s called “chasing renewables” and

is highlighting operational limitations of the installed base of gas turbine power plants in a time where reducing maintenance cost are more critical to maintain profitability.

Alternative fuel combustion offers the potential of a low cost energy source for power generation. Some of these fuels, such as those produced as by-products at petrochemical plants and refineries, can be readily available, and absent the ability to 'flare this gas', it awaits the implementation of robust gas turbine combustion systems to harness their energy in a meaningful way. Additionally, Hydrogen also has the ability to be a 'battery fuel' as excess energy produced by wind and solar can be used to produce hydrogen through electrolysis.

Pertaining to gas turbine combustion, hydrogen is a highly reactive fuel and presents challenges for industry standard dry low NOx combustors to switch between natural gas and hydrogen fuel blends while remaining stable and with NOx emissions always below stringent emission limits. Significant concerns regarding emissions compliance, combustion dynamics and stability must be addressed prior to operation on these fuels.

This paper will highlight successful retrofit solutions for both E-class and F-class combustion turbines that are in commercial operation today, offering significant benefit to the operators and the environment.

DEVELOPMENT OF HYDROGEN AND NATURAL GAS CO-FIRING GAS TURBINE

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Abstract

The introduction of hydrogen energy is an effective option to obtain sustainable development of economic activity while helping prevent global warming.

The Mitsubishi Heavy Industries Ltd. (MHI) Group is promoting research and development of a large gas turbine with hydrogen and natural gas co-firing capabilities. This effort is supported by the New Energy and Industrial Technology Development Organization (NEDO).

With a newly developed combustor, a 30vol% of hydrogen co-firing test has been successfully completed. This co-firing capability results in a reduction in carbon dioxide (CO2) emissions of 10% when compared to conventional natural gas thermal power plant.

REDUCING EMISSIONS FROM COMPRESSOR SEAL LEAKAGE

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Abstract

The three main types of natural gas compressor used at a pumping station are as follows:

- Centrifugal compressor driven by a high voltage electric motor.
- Centrifugal compressor powered by a gas turbine, which is fired by natural gas from the pipeline itself.
- Reciprocating compressor powered by a reciprocating engine. This engine is also fuelled by natural gas from the pipeline.

Each type of gas compressor uses seals, either wet or dry, as part of its construction. Regardless of what type of compressor, or what type of seal is used, gas leakage occurs. To prevent natural gas venting to the atmosphere, pumping stations either flare the gas or recompress it and inject it back into the pipeline.

In this paper we provide a solution whereby a microturbine is used to consume the leakage gas rather than flaring or reinjecting the gas.

TECHNICAL SESSION 9: PUMP-HEAT TECHNOLOGY (ESTEREL)

INTEGRATION OF HEAT PUMP AND GAS TURBINE COMBINED CYCLE: LAYOUT AND MARKET OPPORTUNITY

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Abstract

The increase share of non-dispatchable renewables envisaged in the generation mix of Europe requires conventional plants to take on additional tasks. A higher flexibility of natural gas fired Combined Cycle (CC) power plants, which are currently the backbone of EU electrical grid, has become mandatory.

To increase the flexibility, and to further enhance turn-down ratio and power ramp capabilities of power-oriented CCs, an innovative concept based on the coupling of a highly efficient heat pump (HP) with CCs is proposed, featuring thermal storage and advanced control concept for smart scheduling.

A preliminary analysis of this integrated system is performed, evaluating the feasibility and the economic sustainability, along with the economic competitiveness with actual Combined Heat and Power plants, based on the analysis of the Energy Market trend.

COMBINED CYCLES INTEGRATED WITH A HEAT PUMP AND THERMAL ENERGY STORAGE SYSTEM FOR AIR PRE-COOLING – A TECHNO-ECONOMIC ANALYSIS

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Abstract

The present study analyses the influence that market has on determining the optimum combined cycle plant layout integrated with heat pump and cold storage that maximizes profits (in terms of sizing and operation strategies) for a given location nearby Turin, Italy, for which hourly electricity and heat prices, as well as meteorological data, have been gathered. A techno-economic modeling of the proposed layout has been implemented and a subsequent sensitivity study was performed to show the trade-off between minimizing investment and maximizing profits when varying critical size-related parameters (e.g. heat-pump power capacities and storage size), together with power-cycle design and operating strategies. Results are shown by means of a comparative analysis against the state-of-the art combined cycle. It is shown that the proposed heat-pump and cold storage integration layout for inlet temperature cooling would indeed be able to increase the power produced during periods of high electricity prices, but still it is shown that for the case-study considered (Turin), the added revenues during high-peaks do not compensate for the required investment, at least under the control strategies and economic assumptions undertaken in the study. Nevertheless, it is suggested that under different market conditions, and more specifically electricity price schemes with larger peak to off-peak variation, the proposed configuration could significantly enhance the profitability of power-oriented combined cycles.

HIGH TEMPERATURE HEAT PUMP – A NOVEL APPROACH TO INCREASE FLEXIBILITY AND EFFICIENCY OF CCGT AND CHP POWER PLANTS

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Abstract

The increasing global energy demand together with the need for more sustainability and security of supply and competitive energy cost has led to considerable changes in energy policies all around the world. Over the past decade especially in Germany but also in the entire Europe the penetration of renewable energy sources (RES) became remarkably visible for the electric grid. The intermittent character of the RES and their massive introductions call for new measures for balancing the grid and reducing the consequent cost burden. Combined cycle power plants (CCGT) are obliged to operate more flexible to counteract the intermittent production of electricity by RES. At the same time, measures to decrease the environmental impact of CCGT, like co-generation to increase the energy efficiency are encouraged.

This paper presents a novel approach to increase the flexibility and efficiency of CCGT power plants and to increase flexibility of combined heat and power (CHP) generation systems. The high temperature heat pump (HTHP) uses “waste heat” to produce steam which can be used e.g. for industrial applications. Hence, the HTHP is operated above the temperature limits of conventional heat pumps. The paper offers the different integration options of the HTHP in the CCGT power plant or the CHP energy system including the district heating network (DHN). To give an example, waste heat from the moist flue gas of the CCGT including the condensation heat can be used as heat source for the HTHP which can produce steam for an industrial process plant which is located nearby. Alternatively, the HTHP can produce heat at an appropriate temperature level for the DHN. Therefore, the energy efficiency of the CCGT is increased. A second application option for the HTHP is to use heat from the DHN to produce steam at an industrial site which is connected to the DHN. In this way, the whole CHP energy system including CHP power plant, DHN, HTHP and steam consumer can be operated more flexible with regard to fluctuations of the electricity production from RES. In times of high RES production, the HTHP can utilise electricity from RES and heat from the

DHN to produce steam. Simultaneously, the CHP power plant can increase heat production and decrease electricity production in case electricity prices are low at these times.

The presented work is part of the research project PUMP-HEAT which is funded by the EU within the Horizon 2020 framework programme. Besides Mitsubishi Hitachi Power Systems Europe GmbH (MHPSE), 13 industry and research partners participate in this project. The results refer to the milestone of “definition of layout options for HTHP”. Investigations about the improvement of flexibility and performance of CCGT power plants with HTHP will be performed by MHPSE until the next milestone which will be in September 2018. At the time of preparation of this paper, no final results concerning flexibility and performance of CCGT power plants are available.

INTELLIGENT PREDICTIVE CONTROL OF A PUMP-HEAT COMBINED CYCLE: INTRODUCTION AND FIRST RESULTS

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Abstract

The main objective of the PUMP-HEAT H2020 project is the Development of an integrated, flexibility-oriented Combined Cycle Balance of Plant concept, the PUMP-HEAT Combined Cycle (PHCC). This innovative plant layout is based on the integration of heat pumps and thermal energy storage, to un-tap combined cycle potential flexibility through low-CAPEX balance of plant innovations. In order to assess the added value of using thermal energy storage in the combined cycle, different layouts will be defined at the early stage of PUMP-HEAT. Some will include cold, warm or even hot thermal storage and some will include the latest phase change material (PCM) technologies. To manage this kind of plant, a control algorithm to achieve the best thermo-economic performances considering market requirements, plant efficiency, thermal storage level and operational constraints is mandatory. For this reason, project partners are investigating and developing different control algorithms for the PHCC integrated systems, focusing on flexibility enhancement and power grid operability. Within this framework, Model Predictive Control (MPC) algorithm for real-time supervision and management of the PHCC is being investigating and will be prototyped, virtually tested at simulation level, verified in hardware-in-the-loop and implemented in the demonstration site. The purpose of this paper is to introduce the global objectives of the project and to give details of control approaches, as well as to present the first results.