Flowmaster
Fluid thinking for systems engineers

Case Study

Power Generation

Siemens

Siemens and Flowmaster working together - for enhanced secondary air systems.

Siemens heavy duty gas turbines have been well known for their high power output combined with high efficiency and reliability for more than 30 years. Offering state of the art technology at all times, the requirements of the cooling and sealing air systems have increased with technological development over the years. In particular, the increase of turbine inlet temperature and reduced nitrous oxides emissions requirements demand a highly efficient cooling and sealing air system.

The new Vx4.3A family with an ISO turbine inlet temperature of 1190 C in the power range of 70 to 240 MW uses an effective film cooling technique for the first and second turbine stages to ensure the minimum cooling air requirement. Additionally, film cooling allows a simpler cooling system. For example, no intercooler and no cooling air booster for the first turbine vane are needed in the new family.

This case study describes the internal system which supplies cooling and sealing air. It gives a general overview and describes some of the problems and their solutions. Furthermore, a state of the art calculation system, based on Flowmaster, is described. This makes extensive use of the External Component Model facility within Flowmaster to model the

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internal air system.

Introduction

Since the introduction of the gas turbine, manufacturers have paid scant attention to the amount of cooling and leakage air. The impact on performance measures such as thermal efficiency and power output was neglected and the effect on nitrous oxides emissions was not even discussed. This changed with the introduction of combined cycle gas turbine plant for base load power generation. The high thermal efficiency for the combined cycle plant demands high turbine inlet temperatures. These lead to a dramatic increase in cooling and sealing air requirement which adversely affects the three main performance measures.

Cooling air is required to keep the material temperature of components in the hot flows below the maximum allowable temperature. If this is exceeded, then the physical properties, such as tensile strength and creep limits are severely reduced. Sealing air is used to prevent the clearances between rotor and stator from hot gas ingestion.

The designers' goal is to keep the amount of cooling and sealing air to a minimum. In this way, the work done by the machine on each amount of air saved can be used to generate power and increase the thermal efficiency. Therefore the selection of cooling and sealing air extraction and the sizing is of critical importance. The splined disk construction used by Siemens permits easy selection of the air extraction points conferring great advantages for blade and vane cooling.

The Cooling and Sealing System of the Siemens Vx4.3A Family

Apart from the main or primary air flow path through a gas turbine which passes through the compressor, combustion chamber and turbine, there are several other secondary flow paths which provide cooling and sealing air. In the V84.3A there are five extraction points for cooling and sealing air. Three of these are in the outer casing - outer extractions - and the remainder provide flow paths into the hollow rotor.

The turbine blades are cooled by a combination of film, impingement and convection cooling. The type and degree of cooling depends on the severity of blade duty. The turbine vanes use different cooling techniques. Further air is used to seal the clearances between the rotor and stator. This prevents high pressure, high temperature flows from passing through the clearances with resulting loss in efficiency.

The Calculation System

Standard calculation methods may be used for the vanes as they are non-rotating. The turbine blades need more complex calculation techniques which take into account the circumferential velocity component as an additional dependent variable. Flowmaster, which was designed to calculate 1-D flows, has been applied to calculate the flow path and the interaction of the flow through the different sections of the internal air system. Flowmaster allows groups of components to be treated as sub-systems. Each of these sub-systems represents the flow through one component of the internal air system. The sub-systems are combined into a single network which is solved for pressures, temperatures and flow rates.

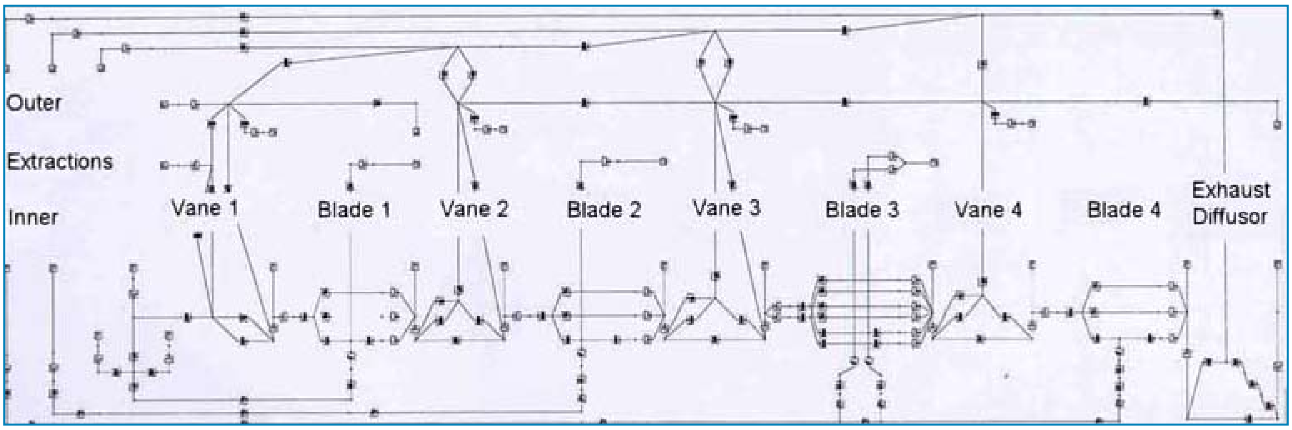
However, as the flows are different from normal Flowmaster applications, the solution must be extended. This is done by using the External Component Model (ECM) facility. The ECM facility allows you to connect and analyse your own FORTRAN or C models in Flowmaster networks. They enable an end-user to build their own application specific component models and use them in Flowmaster. Once added to Flowmaster networks, ECMs may use standard data entry forms and results processing. They may also be reused in any network.

For axi-symmetric flows the flow vector is treated as a two-dimensional vector with components in the circumferential and meridional directions. In the gas turbine there are axi-symmetric passages of varying radii where the circumferential velocity can develop freely and differ significantly from the rotational speed of the walls. Therefore it is essential for the description of the flow through the secondary air system that the two velocity components are treated separately. It is believed that Flowmaster is the only commercially available 1-D code that permits such a treatment of the flow vector.

Application to Secondary Air Systems

As Flowmaster was designed for 1-D flows, flow phenomena caused by multi-dimensional effects like heat transfer, flow field losses and flow turning must be incorporated into the solution by correlations. The correlations applied to the sub-systems are determined from results of experimental tests and generally available experimental data. Siemens are able to obtain experimental results from a gas turbine test bed and specially designed test rigs at their factory in Berlin. Siemens engineers have also derived equations for the correlations for total pressure loss, total temperature change due to heat transfer and the deviation of the flow in the circumferential direction. The use of these equations in ECMs allows Siemens to model the flow characteristics of the blades and vanes in the gas turbine.

A complete gas turbine requires about 15 sub-groups combined into a network of about 200 components. This network is solved by Flowmaster to determine the flow rates, pressures and temperatures in each component.



Conclusions

As shown by the latest test bed results, Flowmaster has been successfully applied for the prediction of flow rates, pressures and temperatures in Siemens gas turbine secondary air systems. Calculation methods and correlations were developed for the secondary air flow through the rotating blades. Flowmaster has been extended by writing ECMs to make it applicable for this. This work has resulted in a design model that enables complete cooling and sealing air flows to be studied.

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