

Modeling of a gas turbine by injection of water vapor upstream of the combustion chamber

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1 Introduction

Nowadays, almost all countries are facing the problem of insufficient electrical energy production. An additional difficulty arises from the need for environmental protection regulations and standards defined worldwide.

Gas turbine has a high sensitivity to the influence of ambient air temperature which varies considerably between day and night, summer and winter, which affects the thermal efficiency of operation of these machines.

The cycle of a gas turbine is a very flexible cycle so that its performance parameters, i.e. efficiency and specific net work, can be improved by adding additional components to a simple cycle.

In this work, the combustion process in the combustion chamber of the gas turbine is carried out in the presence of an additional quantity of water vapor. This has been injected upstream of the combustion chamber. This method leads to an improvement in the efficiency and the available useful power of a simple cycle gas turbine. The increase in turbine efficiency and power output is a consequence of the additional mass passing through the turbine.

An attempt is made by modeling a simple cycle by recovering heat from the exhaust gases (putting an evaporator) in order to obtain superheated steam for use, considering all the factors that actually affect the performance of a real cycle. For this purpose, the physical properties of the working fluid have been taken as real (function of temperature and pressure). There are several sources of energy. Some renewable energies have been known for a very long time, such as solar and wind. Other, more recent energies such as marine energy.



2 **Resume**

The use of steam for gas turbine propulsion in the Brayton cycle has been analyzed. In the considered modernization, the steam generated in the heat recovery steam generator unit is directed into the gas turbine combustion chamber, which results in an increase in the Brayton cycle power.

In this perspective, the method of injecting water vapor upstream of the combustion chamber of a gas turbine has been proposed, studied and compared with a simple cycle.

The main objective of this work is to carry out a program to calculate the influence of ambient conditions on the characteristics of the various components of the gas turbine, such as compression, combustion and expansion. Once the optimal operating parameters are known, the recalculation of the plant performance was carried out by injecting suitable quantities of water vapor upstream of the combustion chamber. The results obtained from the influence of ambient conditions on the gas turbine performance without steam injection and the influence of standard conditions on the start of injection, according to those found in the literature simulated by the thermodynamic calculation code 'Thermoptim', are in good agreement with the qualitative variation of these conditions, in the case of normal operation without steam injection. These results are represented in the form of curves.



1.1.1.1 Description of the model and formulation of the problem

Operating Principle of the Steam Injection Gas Turbine

Fig.5c shows an installation of a steam-injected cycle. Air is discharged downstream of the compressor at a pressure, combustion takes place in the combustion chamber where fuel is injected in the presence of an additional quantity of water vapor whose physical properties are calculated for injection conditions upstream of the combustion chamber.

Generally, the heat recovery steam generator is constructed in a similar way to the combined cycle, i.e. an economizer heating the pressurized water, an evaporator generating water vapor and a superheater bringing the steam to the superheated state.

- Air is compressed in the compressor.
- Fuel, steam and air are supplied into the combustion chamber forming a high temperature steam/gas mixture.
- The gas/steam mixture expands in the turbine
- Steam is generated in the HRSG, while cooling the gas/steam exhaust.
- Net power and efficiency of the steam injection gas turbine.

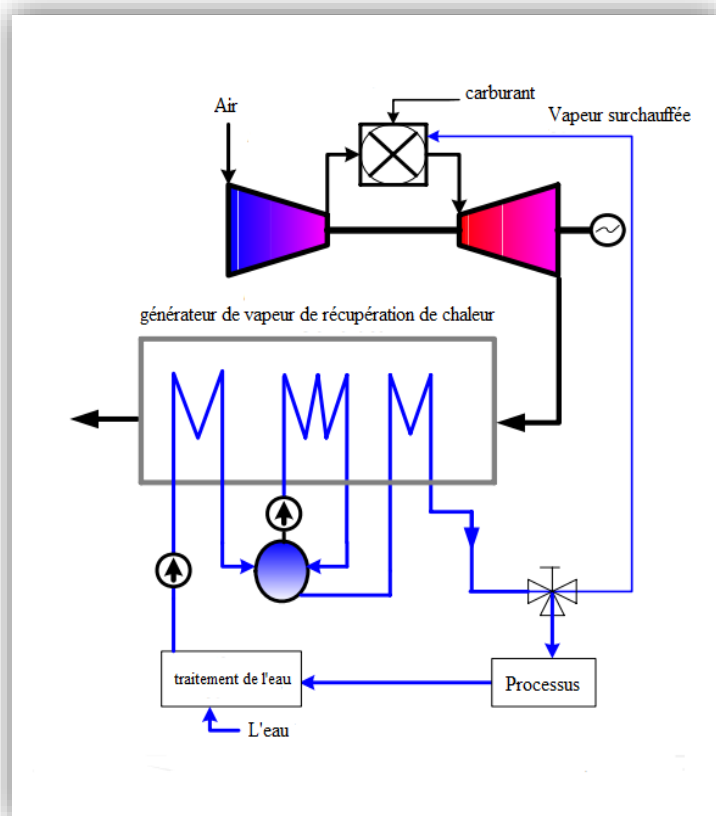


Fig.5c : represents Flow diagram of a steam injection gas turbine.



- Steam generated by heat recovery is injected into the combustion chamber of a gas turbine increasing the flow through the turbine.
- Steam injection increases the power output of a gas turbine and the electrical efficiency.
- Steam injection reduces the NOX emission in a gas turbine.
- The steam injection gas turbine has a lower investment cost than a common combined cycle and is suitable for process industries, due to the flexible operating conditions.
- There are limits to the amount of steam that can be injected.
- The steam entering the combustion chamber is in a superheated state, being an energy carrier of the heat recovered by the hot exhaust gases.
- The pressure of the injected steam must be slightly higher than the pressure of the air coming from the combustion chamber.
- To maintain the turbine inlet temperature, more fuel is added in a steam injection gas turbine to compensate for the increased mass in the combustion chamber.
- When steam is injected before the turbine, the mass flow rate at will be higher than without steam injection.
- The specific heat of superheated steam is about twice as large as the specific heat of the flue gas; therefore, the average for the gas mixture and C_p passing through the turbine will be higher than without steam injection.
- The compressor work, is practically not affected by steam injection.
- The turbine inlet temperature is the same as without injection and the turbine outlet temperature will remain at a similar value.
- The conclusion is therefore that the output power of the steam-injected gas turbine will be higher than for the same gas turbine without injection.
- For a steam-injected gas turbine, the power gain is relatively large, but it depends on the steam injection temperature as well as the amount of steam injected.



The superheated steam, which is injected into the combustion chamber, contains a significant amount of energy that has been recovered from the hot gas turbine exhaust in the HRSG.

A steam injection gas turbine can achieve an electrical efficiency of 40% to 45% (maximum steam injection).

However, the steam injection gas turbine cannot achieve the high electrical efficiency of a combined cycle since the water in the form of steam goes into the stack and thus the (latent) heat of vaporization of water in the gas/steam flow is lost.

For a steam injection gas turbine, there is no need for a steam turbine or a condenser system, but the efficiency is relatively high, which reduces the investment cost.

In the investment of a steam injection gas turbine, it is necessary to consider the cost of the water treatment plant.

To keep the investment cost low, it is assumed that there is no shortage of water, if there is not enough water available, the HRSG flue gases may need to be condensed to recover the water content, and the installation cost of this piece of equipment can be expensive.

The quality of the water to be used for injection is very important.

For the turbine parameters, new calculations are made. To keep the combustion chamber outlet temperature constant, in the presence of water vapor (including injection parameters T_{inj} , P_{inj}), we need to add even more fuel. So to calculate these ratios (fuel flow and the amount of injected steam), we need to make a thermal balance at the combustion chamber level.

