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METHOD OF OPERATING GAS TURBINES

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Fig. 1.

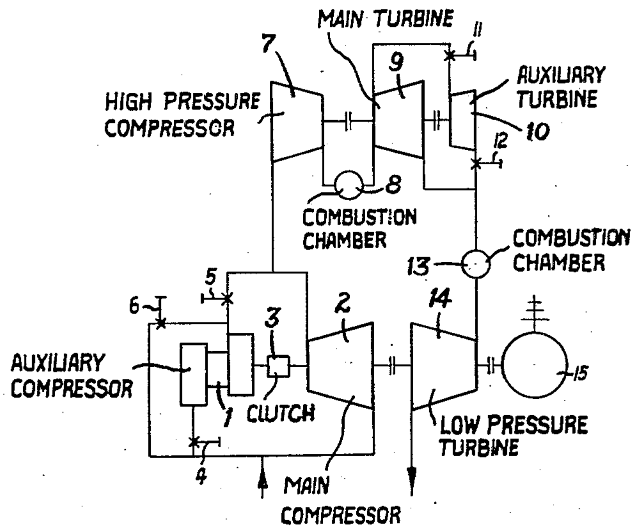
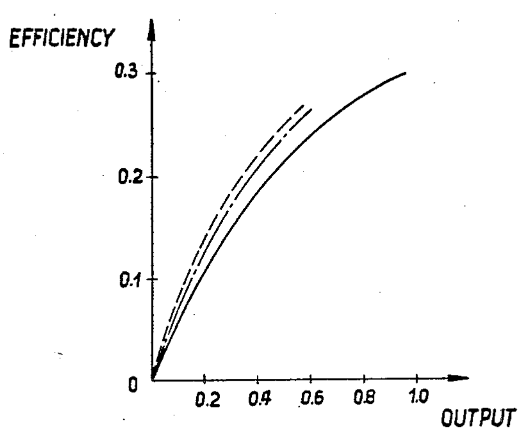


Fig. 2.



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METHOD OF OPERATING GAS TURBINES

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This invention relates to a method of operating gas turbines in an open gas turbine cycle.

It is an object of the invention to provide means for improving the partial load efficiency of gas turbine plants in a certain range of partial load, by changing the throughput or the passage resistance.

As is well known, in an open or incomplete gas turbine cycle, several units of air compressors and gas turbines are connected in series or in parallel, in order to obtain on the one hand high useful outputs and on the other hand a predetermined behavior in operation. In all cases one or more compressors are driven from a gas turbine. The compressor or compressors and the turbine are thus mechanically coupled by the common speed and aerodynamically by the throughput. The turbine represents for the compressor a resistance similar to the resistance of a piping system. In case of a constant counter-pressure and throughput the resistance of the turbine can be controlled with the aid of the initial temperature of the turbine which can be adjusted by the preposed combustion chamber. The counter-pressure, the throughput and the speed in case of fixed starting conditions for the compressor determine the operating point thereof in the diagram of characteristics, whereby its efficiency is defined. The efficiency of the compressor and of the turbine as well as the initial temperature before the turbine are essential factors for the thermal efficiency. The temperature before the turbine in case of a constant counter-pressure can be kept constant only if on the one hand the throughput and on the other hand the drop of pressure and the initial pressure vary in the same way. In general, in this case the characteristic curve in the diagram of the compressor also obtains a position coinciding with the curve of optimum efficiency. In this manner, the output of the turbine can be reduced most economically and all methods of connection aim at the adjustment of partial load in this manner. However, various reasons, e. g. reaching of the pumping limit of the compressors, oftentimes lead to a condition which renders it impossible to adjust a favorable throughput through the turbine. As a remedy, it has already been proposed to by-pass a part of the turbine or the whole turbine with a part of the throughput. However, this measure is not quite satisfactory, the more so as it is uneconomical to blow off the part of the working fluid which does not flow through the turbine.

According to the invention the efficiency at partial load is improved in such a way that the throughput is split up and the working fluid is passed through two or more compressors connected in parallel and/or two or more turbines connected in parallel, disconnecting the parallelly connected auxiliary compressor or compressors or additionally connecting the parallelly arranged auxiliary turbine or turbines as a predetermined partial load point is reached. The main turbine and/or the low pressure compressor are accordingly combined with at least one auxiliary turbine, or compressor, respectively, but the functions of these additional engine units are different. When the required output is reduced, the auxiliary turbine is connected and the auxiliary compressor is disconnected as a predetermined output region is reached. The main turbine and the auxiliary turbine together owing to the increase of cross section have a smaller resistance than the main turbine alone and therefore, if the throughput, the initial pressure and the drop of pressure are maintained, the admission temperature of the turbine can be increased. At the compressor end the throughput is reduced by disconnecting the auxiliary compressor. The auxiliary compressor is advantageously uncoupled mechanically. However, even the mere disconnecting thereof from the gas flow, without mechanical uncoupling, is economical, if the suction side of the compressor is throttled and the compressor operates in vacuum, with atmospheric counter-pressure (1 atmosphere absolute pressure). Here again as a result of the reduction of the throughput the temperature before the turbines is raised and the characteristic curves of the other compressors are placed into regions of better efficiency. By this measure the efficiency at partial load can be raised in a desired range of partial load. The share of the auxiliary compressor in the total throughput must be the larger, the smaller the partial load is at which the efficiency is to be improved.

The main and auxiliary compressors in case of common operation work against the same counter-pressure and with equal speed of rotation. The pressure, the throughput, and the speed of rotation are combined to the characteristic figure of the specific number of revolutions according to the formula $n_q = n.V^{1/2}.H^{-3/4}$, in which n is the normal speed, V is the delivery (throughput) and H is the pressure or delivery head. In order to obtain the best hydraulic or aerodynamic efficiency, the choice of the type of compressor construction should be made according to the ascertained specific number of revolutions. With two compressors, for example, and with a ratio of supply volumes of 1:3, a compressor of the axial flow type is preferred for the main compressor, and a radial flow type for the auxiliary compressor. On the other hand, with a ratio of 1:1, both the main and auxiliary compressors are preferably of the same type, for example, both having axial flow construction.

In order to simplify the stopping of the entire plant in case of emergency, the characteristic diagrams of the main and auxiliary compressors must be of such a nature, that idle running can be attained also without disconnecting the auxiliary compressor. The method according to the present invention has the further advantage that, where compressed air or the expanding gases of a rocket fuel system are available for introduction into the auxiliary turbine, said auxiliary turbine may be employed as a starting device for the plant and, hence, replace the usual starting motor.

The process according to the invention can be carried out by parallel connection of an auxiliary turbine and/or of an auxiliary compressor. The alternative in which only an auxiliary turbine is connected is preferred in case of all those gas turbine plants which show a sharp drop of the temperature in case of partial load.

The invention will be better understood by reference to the following detailed description in connection with the accompanying drawing, in which:

Fig. 1 is a diagram of connections of a gas turbine plant having the invention applied thereto, and

Fig. 2 is a diagram showing the improvement of the efficiency at partial load obtainable by an auxiliary compressor which can be disconnected.

In the diagram of connections according to Figure 1, the auxiliary compressor **1** is connected with the low pressure main compressor **2** by a disengageable clutch **3**. The auxiliary compressor **1** is connected in parallel with the main compressor **2** if the valves **4** and **5** are opened and the valve **6** is closed. It is disconnected if the valve **4** is nearly closed and the valve **5** is entirely closed and valve **6** is opened, i. e. in this case an idle circulation of the gas through the auxiliary compressor **1**, the valve **6** and the throttled valve **4** takes place. Moreover, by the clutch **3** the auxiliary compressor **1** can be disengaged entirely from the main compressor shaft. The entire pre-compressed air is passed to the high pressure compressor **7** and then to the combustion chamber **8** where the fuel is burnt with the highly compressed air; the working gases enter the high pressure turbine **9** where they produce energy as they are expanding. Arranged in parallel to the main turbine **9** is the auxiliary turbine **10** which can be connected and disconnected by the valves **11** and **12**. The working gases from the high pressure turbines **9** and **10** are subjected to an intermediate heating in the combustion chamber **13** and then enter the low pressure turbine

14 which in this case produces useful output, for driving the electric generator 15 in addition to the low pressure compressors 2 and 1.

Referring to Fig. 2, it will be seen that the efficiency of the gas turbine plant is plotted against its output. The full line shows the course of the efficiency with the auxiliary compressor mechanically engaged and connected in the gas flow (clutch 3 engaged, valves 4 and 5 open, valve 6 closed), the dotted line shows the course of the efficiency curve with the auxiliary compressor disconnected and mechanically disengaged (clutch 3 disengaged, valve 4 nearly closed, valve 5 closed, valve 6 open), and the dot and dash line shows the efficiency curve with the auxiliary compressor disconnected from the gas flow but mechanically engaged (clutch 3 engaged, valve 4 nearly closed, valve 5 closed, valve 6 open).

While the invention has been described in detail with respect to a now preferred example and embodiment of the invention it will be understood by those skilled in the art after understanding the invention, that various changes and modifications may be made without departing from the spirit and scope of the invention and it is intended, therefore, to cover all such changes and modifications in the appended claims.

Having thus described the invention, what is claimed is:

1. In an open gas turbine cycle, the method of improving the partial load efficiency, comprising the steps of allotting the throughput at full load among a main compressor and at least one parallelly connected auxiliary compressor and disconnecting the auxiliary compressor as a predetermined partial load is reached for decreasing the effective cross-sectional compressor area.

2. In an open gas turbine cycle, the steps of allotting the entire throughput to one main turbine at full load and allotting a part of the throughput to at least one parallelly connected auxiliary turbine in said cycle as a predetermined partial load is reached for increasing at partial loads the effective cross-sectional turbine area in said cycle for improving the efficiency at partial load.

3. In an open gas turbine cycle, the steps of allotting the throughput at full load among a main compressor and at least one parallelly connected auxiliary compressor and to a single main turbine connected in series therewith, and disconnecting the auxiliary compressor and allotting the throughput of said cycle among the main turbine and at least one parallelly connected auxiliary turbine as the load is reduced to a predetermined partial load for increasing the effective turbine cross-section and decreasing the effective compressor cross-section for improving the efficiency at partial load.

4. In a method of operating an open gas turbine cycle to improve the efficiency thereof at partial loads, the steps of increasing the number of operating parallelly connected turbines to increase the effective cross-section thereof and decreasing the number of operating parallelly connected compressors connected with said turbines to decrease the effective cross-section of said compressors as the load on said cycle is reduced from full load.

5. In a method of operating an open gas turbine cycle having compressors and turbines connected therewith with improved efficiency under partial load conditions, the steps of maintaining under partial load conditions the initial turbine pressure and the turbine pressure gradient of said system substantially constant, decreasing under partial load the effective compressor cross-section in said cycle, and increasing under partial load the effective turbine cross-section in said cycle for improving the operating efficiency of said cycle at partial loads.

6. In a method of operating an open gas turbine cycle having compressors and turbines connected therewith with improved efficiency under partial load conditions, the steps of maintaining under partial load conditions the initial turbine pressure and the turbine pressure gradient of said system substantially constant, decreasing under partial load the effective compressor cross-section in said cycle, and increasing under partial load the effective turbine cross-section in said cycle and increasing the turbine inlet temperature for improving the operating efficiency of said cycle at partial loads.

7. In a method of operating an open gas turbine cycle to improve the efficiency thereof at partial loads, the steps of dividing the total throughput at full load between a main compressor and at least one parallelly connected auxiliary compressor, passing substantially the entire said throughput at full load through a single main turbine connected with said compressors, disconnecting said auxiliary compressor to decrease the effective compressor cross-section in said cycle for less than full load and dividing the throughput at partial load between said main turbine and at least one parallelly connected auxiliary turbine for increasing the effective turbine cross-section in said cycle for less than full load.

8. A method of operating a gas turbine plant having a plurality of parallelly connected compressors in series with a plurality of parallelly connected turbines for increased efficiency at varying loads comprising the steps of dividing the throughput of said plant at full load among a plurality of said parallelly connected compressors, passing substantially the entire throughput at full load through a single one of said plurality of turbines, connecting into said plant under partial load conditions additional said turbines for dividing the throughput at partial load among a plurality of parallelly connected turbines, and disconnecting from said plant under partial load conditions all but one said compressor to pass substantially the entire throughput at partial load through a single compressor.

9. A gas turbine power plant adapted for increased efficiency at partial loads comprising in combination a plurality of gas compressors, a plurality of gas turbines for driving said compressors and for producing power output, means for connecting and disconnecting said turbines in parallel, means for connecting and disconnecting said compressors in parallel, and means for mechanically coupling and uncoupling said compressors.

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