# HYBRIDE ENERGY TECHNOLOGIES FOR AN EFFICIENT GEOTHERMAL HEAT UTILIZATION

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## ABSTRACT

The demand for more intensive utilization of energy sources is getting more important with the forthcoming European Union membership of Slovak republic. Their low feasibility can be a very difficult problem for the energy policy. Therefore it is important to use technical solutions to minimize or eliminate this problem. The most beneficial progress could be achieved in Košice basin where geothermal energy could have effective and multi-purpose use.

**Keywords:** geothermal energy, combined cycle power plant, heat pump

## 1. Introduction

Slovakia is extremely poor in fossil fuels and is consequently dependent (in 90%) on imported energy sources. The adverse of this fact is more significant because the national economy shows high energy intensiveness of gross domestic product (GDP), which is approximately three times higher than the average of the EU. The intensification of local renewable sources and the increasing of effectiveness should be then the main priorities of the energy and environmental policy.

Considering the relatively good conditions for energy conversion of biomass its utilization should be as usual as that of hydro energy potential. In addition to this it is necessary to focus on usage of solar and geothermal energy since they are currently the least utilized energy sources (6% and 2%), if we do not take into account the almost negligible potential of wind energy. While solar energy is suitable for use in projects in the range of some kW, due to its low concentration, the power output from geothermal projects is significantly higher, and can be used for major projects. The idea of geothermal project in Košice to utilize about 100 MW of geothermal output and to provide the city with 2500 TJ/year from 8 geothermal doublets is undoubtedly one of the boldest initiatives of its type in the world today. It could change the energy balance of the country in a relatively short period of time. As presented in [3] and [6] it seems that the company GEOTERM is prepared to solve the problems pertinent to exploitation and transportation of geothermal water into the area of company TEKO (owner of the heating plant in Košice). Now it is the turn of this company to find a proper solution to utilize this source that would not worsen but would improve the economic effectiveness in comparison with the simple utilization of fossil fuel. The results of the study [4] show that it seems to be unreal in case of direct use of geothermal heat in the District Heating Network (DHN). It is possible to increase the competitiveness of the only direct use through a heat pump that would intense the utilization of disposable enthalpy potential. The way to improve the efficiency of the geothermal project in Košice is by changing the basic philosophy. All the possible solution alternatives should be technically and economically analyzed and compared in a feasibility study.

The aim to replace a part of TEKO that is reaching the end of its working life, with a combined cycle CHP plant lead us to think upon an untraditional use of geothermal source to support the combined heat and power production. This could cause increase in power output for constant fossil fuel consumption or decrease in fossil fuel consumption for constant power output. This concept expects realization of combined cycle power plant of new generation – namely of a combined cycle power plant with heat extraction and integrated geothermal support. This is in other words a hybrid combined cycle power plant with heat extraction.

## 2. The idea of combined cycle power plant with heat extraction and integrated geothermal support

Technical solution of combined cycle power plant with heat extraction and integrated geothermal support may have many variants. The main idea of this hybrid concept is to use geothermal energy for heating the feed water in the steam cycle, which is more advantageous than mere direct use in the DHN for the following reasons:

- The temperature of the condensate in the steam cycle is 30 K lower than the temperature of the returning primary water in the DHN, which allows significantly better use of the enthalpy of secondary geothermal water, in our case by 50 %. It means that the same geothermal output can be obtained from the half of geothermal doublets. It means saving on investments and running costs by 50 %.
- The use of this output is much higher because the power production is provided in the course of a year, while heating has seasonal character.

Such integration of geothermal source into combined cycle power plant can be combined with direct supply of the DHN. This seems to be advantageous also in the case of the geothermal project in Košice. The idea of hybrid combined cycle power plant for heat and power production could be based on the same particular processes for each variant. The point of these processes is clear from *Fig. 1*.

The flow of the secondary carrier of geothermal heat (secondary geothermal water) $\dot{m}_{SCGH}$ would be divided into two parts. One of them $\dot{m}_{FWH}$ would be used for heating the feed water (condensate) in the heat exchanger HEC between the condenser C of the steam turbine and feed water tank VE. The second one $\dot{m}_{DHN}$ would be used directly in the DHN. After mixing the returning flows that were cooled down to different degrees, the heat will be pumped from the resulting flow, using the heat pump HP for indirect utilization in the DHN. The heating water in the condenser of the heat pump can be overheated as required in the waste heat boiler WHB, as it is assumed in [1]. It seems to be more reasonable the use of extracted steam from the low pressure stage of steam turbine STL for heating in the heat exchangers HE1 and HE2 in spite of decrease in geothermal output that can be used for heating the feed water in winter period. In the evaporator of the heat pump the secondary geothermal water can be cooled down to such an extent that it can be used for cooling the condenser C of steam turbine. From the condenser C part of heat losses can branch away. Realization of this arrangement would be justified especially in summer period. Finally, in the waste heat boiler WHB the secondary geothermal water can be heated by the heat losses from the outgoing flue gases at the same temperature as it is assumed in the case of only direct utilization in the DHN. The flue gases can be cooled down in this way below the dew temperature and in addition to the sensible heat also the latent heat of the flue gases can branch away. It is conditional on a solution of many technical problems that can increase the investment intensiveness. The heat losses of the waste heat boiler and condenser, which constitute a substantial part of the heat losses for standard design of combined cycle, will be accumulated through the geothermal water being reinjected into the earth's crust. However, it would be better at least partly to use it in recreational facilities or agriculture (this was not assumed in *Fig. 1*). The temperature of returning secondary geothermal water must correspond to the demand on optimal reinjection of primary water.

The parameters of steam cycle should be adjusted to the described processes. The power output of steam cycle would be determined by amount of condensate and indirectly by flow of secondary geothermal water used for heating the feed water. Considering the high demands on effectiveness of conversion of natural gas on power, when the maximum of geothermal heat would be used, such stream is expected when at least two pressure levels of superheated steam would be dealt with.

The heat pump being integrated into the combined heat and power production system plays a key role in its effective function with the geothermal source. Therefore its solution must be adjusted to this request. The first results show that the heat pump should be designed at least in two stages, but it is necessary to analyze whether the economic contribution of a more effective three stage design would not be higher than the increase in investment intensiveness. If the machinery of the combined cycle power plant would be on one shaft with the machinery of the heat pump, the investment intensiveness would be reduced. In the case of described concept progressive energy technologies allow very effective use of geothermal heat in comparison with only direct use in the DHN, especially in summer period (shown in *Fig. 2*).

The operation of direct use in the DHN and of the steam extraction can be stopped during summer, when there is lower demand on temperature and lower heat consumption for heating the feed water is desired. This would bring an increase in the power output of steam turbine and would free significant geothermal potential of high temperature that could be used for absorption cold production in absorption chillers AC and then for warming up the heating water in heat exchanger HE3. The necessary thermal output in the DHN can be obtained from the geothermal source using heat pump HP and heat exchanger HE3 operating together. In the condenser of the heat pump the heating water would be warmed to 60 °C by the heat pumped from the secondary geothermal water that would be cooled in the heat exchangers HEC and HE3. Then it would be overheated to the desired temperature in the heat exchanger by secondary geothermal water previously used for absorption cooling.

Absorption chillers are commonly used for air conditioning which is justified only for higher ambient temperatures with relatively short duration. In this case, the use of this cooling capacity for cooling the air entering the compressor in the heat exchanger HEA would be more rational since this could operate already for ambient temperature under 15 °C. Decrease of air temperature by 10 K results in increase of power output of the gas turbine GT by about 6 %. This absorption cold production system can be effectively used as power source for consumption peaks, since the ambient temperature is higher for load peaks. Such unusual conversion of geothermal heat to power, when heat losses from absorption cooling could be removed through the secondary geothermal water. Heat losses of absorption cold production systems constitute approximately 170 % of thermal input used for its operation and their branch away requires significant investments.

## 3. Perspectives of the integration of geothermal sources of Košice basin into the structure of hybrid combined cycle power plant with heat extraction

The results of the analysis show that use of geothermal source could be realized in a hybrid combined cycle power plant with heat extraction based on a gas turbine with 260 MW power output (ISO conditions) without additional burning of fuel. If capacity of 4 geothermal doublets instead planned 8 doublets would be utilized and the flow of secondary geothermal water $\dot{m}_{SCHH}$ = 240 kg/s would be divided in the ratio $\dot{m}_{DHN} : \dot{m}_{FWH}$ = 5:3, the power output of the steam turbine in winter period would be approximately 120 MW and in summer period for 15 °C ambient temperature approx. 135 MW. The total thermal output would be about 150 MW in winter period and 45 MW in summer period.

In summer period the heat from fossil fuel (natural gas) would be used only for power production. The power required for compression in the heat pump is about 7 MW. If the total unused capacity of geothermal source (about 12 MW) would be used for absorption cold production, the air at the inlet of the compressor would be cooled by 12 K. For ambient temperatures above 20 °C it would result in increase of power output by 19 MW. This indirect conversion of geothermal heat is much more efficient than technologies of direct conversion of low-temperature heat sources (for example Organic Rankine Cycle or Kalina Cycle) operating with about 10 % efficiency.

The described concept would make possible the use of about 90 MW geothermal output in summer period for heating the feed water, for warming up the heating water and for absorption cooling. Therefore, the required thermal output of the city for domestic hot water is about 45 MW.

The main contribution of operation of hybrid combined cycle power plant with heat extraction that would replace the block of TEKO reaching the end of its working life, would be that more than 2500 TJ/year from 4 doublets in the DHN only during the processes of heating would be utilized instead use less thermal energy from 8 geothermal doublets in case of only direct use. In comparison with the aim described in [3] it means saving on investment costs about 25 mil. USD and running costs could be reduced by about 50 %. The selling price of geothermal heat could be significantly lower so that it would be used to invest into the rebuilding of TEKO.

Except in heating processes the secondary geothermal water would also be used in cooling processes. The useful cooling effect in the condenser of the steam turbine and in the absorption refrigerating system would positively affect the economic efficiency of the operation of plant. If the heat losses would be used and/or the amount of consumed geothermal heat would be measured at the input of the plant, the economic efficiency could be even higher. At all events the thermal load of the environment would be lower and through the accumulation of heat losses the operating life of the geothermal doublets would be longer.

Finally, the hybrid combined cycle power plant with described structure would be environmentally much cleaner than any source based on fossil fuel. Therefore this plant could have strong position on liberalized energy market.

## 4. Conclusions

The principle of hybrid geothermal power plant is already well known. But there is probably only one operating plant of this type. It is located in Honey Lake, California and has power output 35 MW. It is a steam cycle power plant that differs from the standard design by its source of primary energy, which is wood waste called biomass. For heating the feed water 22 kg/s of geothermal water of 118 °C is used. Desiring these parameteres the maximum geothermal output can be about 8 MW.

Hybrid combined cycle power plant based on the described concept would be a more significant plant. About 90 mil. $m^3$ of natural gas could be saved, which would bring reduction of $CO_2$ by 220 000 t/year. The real savings would be higher depending on the emissions produced by the plant being replaced. Realization of such unique plant would improve the energetic and environmental contribution to one of the most effective conversions of energy of fossil fuels to useful energy forms using geothermal energy. This would be a chance to improve the credibility of energy policy since the progress of cogeneration systems and more intensive use of renewable sources belong to priorities.

The specification of the optimal variant of this concept and also the overall evaluation of its power supply, economic and environmental potential must form the subject of a very serious feasibility study. In spite of the possible contribution of the described concept to the environmental policy the interest of Slovak engineers is surprisingly low.

Hybrid combined cycle power plants are the new generation of combined cycle power plants. They allow effective use of fossil and renewable sources. Consequently they allow power production fewer environmental impacts than any standard plant. Therefore realization of concepts that were only in written form up to this time is expected. Košice basin has advantageous natural conditions to realize such concept. Its realization in comparison with any other would have more significant contribution to fulfil the aims of energy policy. At the same time when the closing of nuclear power plant in Jaslovské Bohunice and of other old coal-based power plants are being planned, this possibility should not be ignored. The declaration of support to more intensive utilization of local renewable sources would then remain a promise. Moreover, the chance to fulfil the strategic aims of the EU in the field of energy and environmental protection and to use the financial support would be wasted.

***"Supported by Arany János Foundation"***

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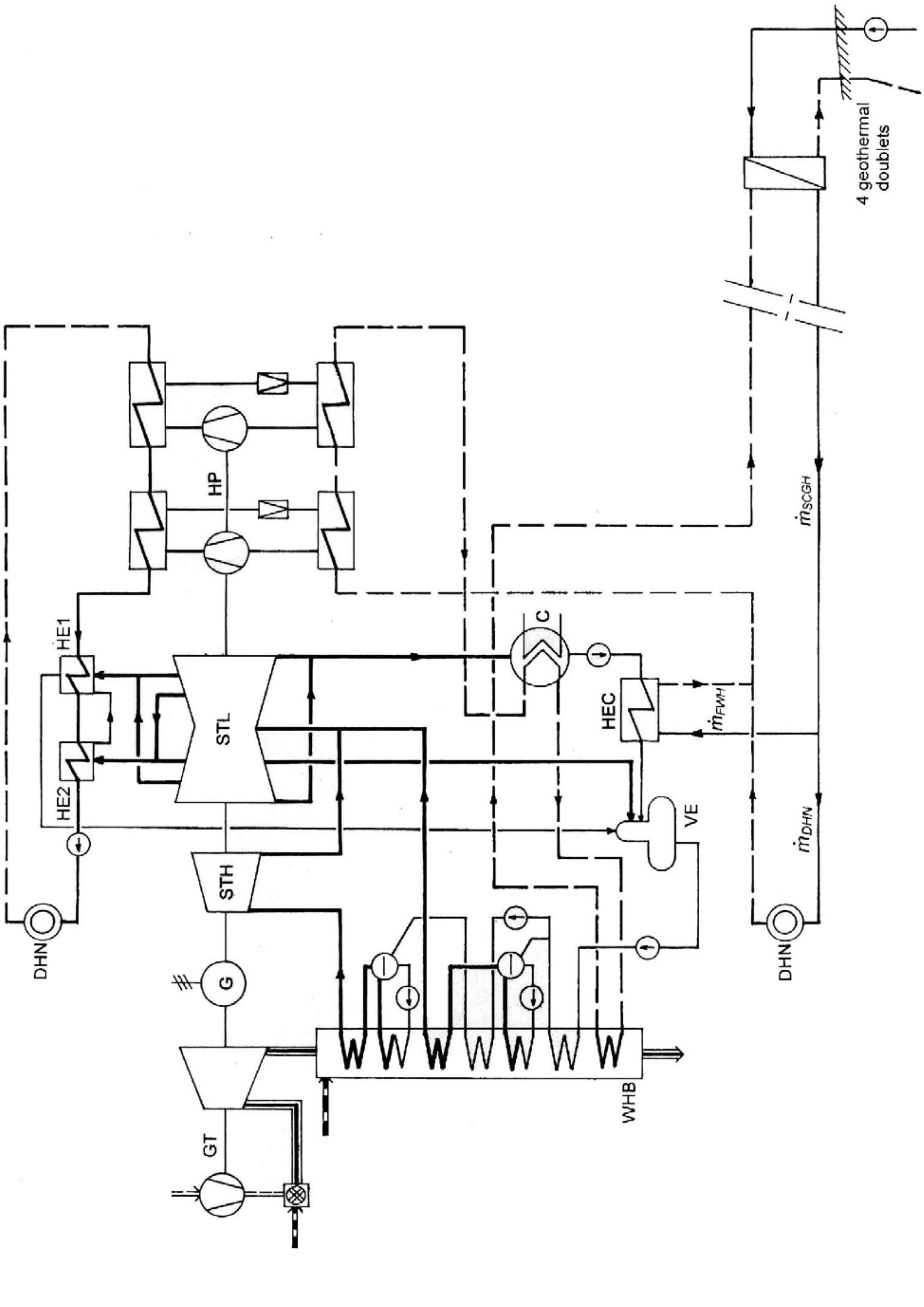

*Fig. 1 Principal scheme of combined cycle power plant with heat extraction and geothermal support - for working in winter period*

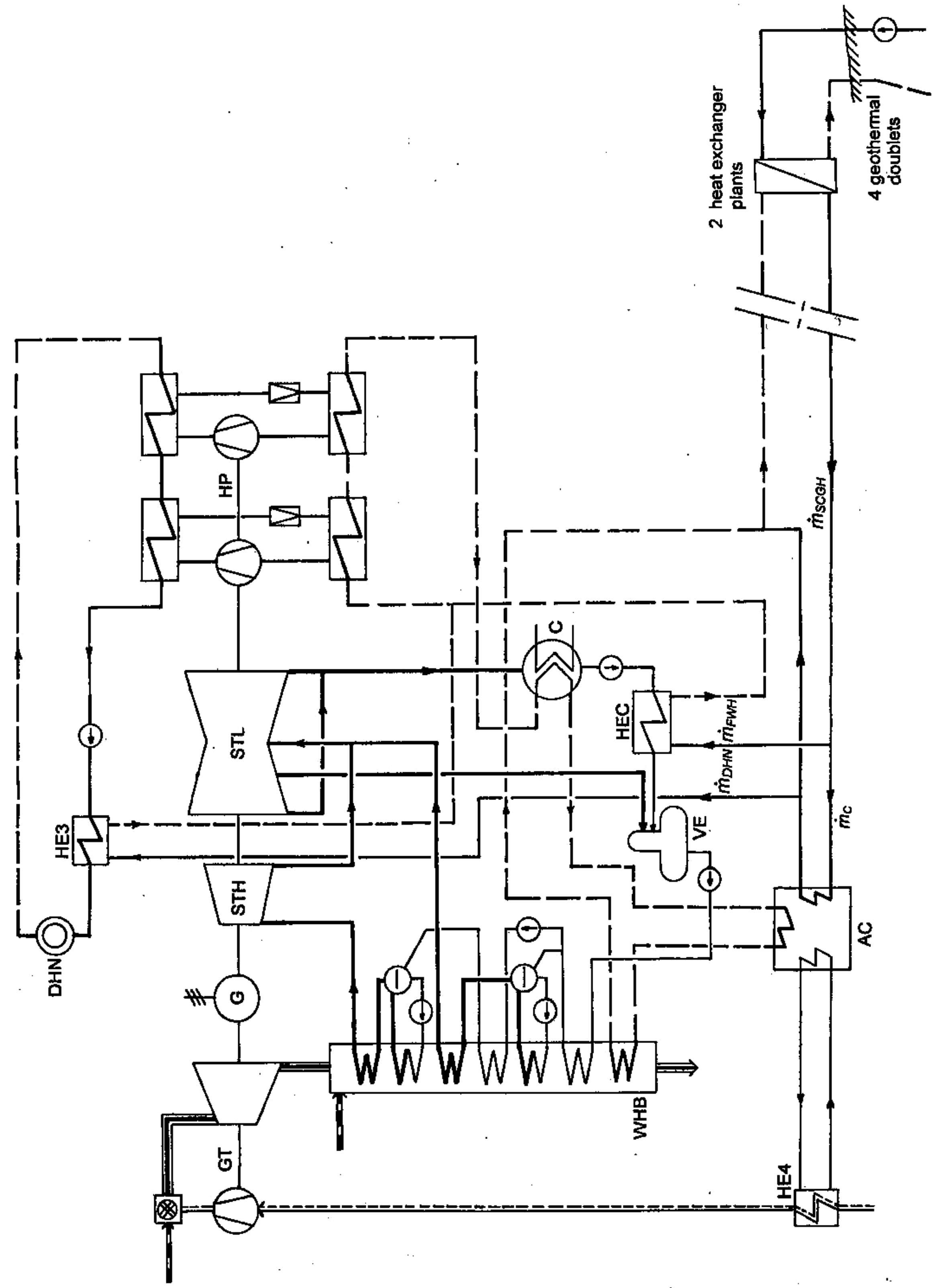


*Fig. 2 Principal scheme of combined cycle power plant with geothermal support - for working in summer period*