

METHOD AND PLANT FOR THE COMBINED PRODUCTION OF ELECTRICITY, STEAM AND DESALINATED WATER

The present invention relates to the combined production of electricity, steam and desalinated water.

The invention relates to desalinated water production facilities in which combined heat and/or power (CHP) technologies are also used.

Such facilities are known in the prior art. US 5 096 543 and US 5 346 592 describe seawater desalination plants in which the heat required to treat the seawater is obtained from the steam issuing from a steam turbine.

GB 1 182 021 describes a steam turbine generating electricity, from which the steam is used in an evaporator for producing distilled water from seawater. At the outlet of this evaporator, the steam condensate is introduced into the boiler for producing steam for supplying the steam turbine.

The problem of the prior art facilities is that they are designed to produce predefined quantities of electricity, desalinated water and/or steam. In fact, the demand for these raw materials may vary over time, particularly electricity demand. The prior art facilities do not allow the adjustment of the three different productions according to their respective demands. Furthermore, the surplus electricity generated in excess of demand cannot be stored.

It is therefore the object of the present invention to propose a method for the combined production of electricity, desalinated water and steam that is adaptable to variations in demand for these three products and particularly for electricity.

For this purpose, the invention relates to a method for producing electricity, steam and desalinated water using a steam generation unit, a steam turbine and a seawater desalination unit, wherein:

- the steam generation unit generates steam,
- the steam turbine uses at least part of the steam generated by the steam generation unit and generates electricity and steam, and
- the seawater desalination unit produces desalinated water by vaporization of seawater by heat exchange with at least part of the steam generated by the steam turbine,

and wherein the quantity of steam generated by the recovery unit to be supplied to the steam turbine is controlled according to the electricity demand, the desalinated water demand and the steam demand.

The inventive method comprises the use of a steam generation unit or boiler. Such a unit generally consists of a combustion device generating heat to convert water to steam: it comprises a series of heat exchangers, for example coils, in which water flows

and is contacted with the heat generated by combustion. The steam generated by this steam generation unit is at high pressure, that is, at a pressure suitable for supplying a steam turbine. The value of this pressure also depends on the electric power required. In general, this pressure depends on the temperature required for thermal desalination, which, as a minimum, corresponds to saturated steam at 2 bar gauge.

This steam generated by the steam generation unit is used to supply a steam turbine: in this way, the pressure of the steam generated by the boiler drops in a steam turbine in order to generate electricity. Lower pressure steam is extracted from this steam turbine: for a back-pressure steam turbine (steam generated at $P > P_{atm}$), the steam is extracted from its final stage, and for a steam condensation turbine producing hot water (or steam at $P < P_{atm}$), the steam is extracted at an intermediate stage. The steam issues from the steam turbine at a pressure lower than the inlet pressure. Preferably, the turbine used is a back-pressure steam turbine.

The steam leaving the steam turbine is then used to vaporize the seawater in a thermal seawater desalination process. This vaporization takes place using heat exchangers to exchange the heat between this steam and the cold seawater. In general, the seawater is evaporated in a succession of vessels, each under a lower pressure than the previous one. Since the evaporation temperature decreases as the pressure decreases, the steam evaporated in one vessel can be used to heat the next. Only the first vessel having the highest pressure requires an external heat input; this heat input is supplied by the steam issuing from the steam turbine.

According to embodiments of the present invention, the quantity of steam generated by the steam generation unit to be supplied to the steam turbine is controlled according to the electricity demand, the desalinated water demand and the steam demand. Thus, if electricity demand decreases, a smaller quantity of steam is introduced into the steam turbine. The portion of steam generated by the steam generation unit which is not supplied to the steam turbine is mixed with the steam expanded in the steam turbine. Thus, the seawater desalination unit produces desalinated water by vaporization of seawater by heat exchange with this portion of the mixture of steams generated by the steam generation unit and steam generated by the steam turbine. Thus, the surplus steam is not lost, but utilized in the seawater desalination unit.

If electricity demand increases, a larger quantity of steam issuing from the steam generation unit is introduced into the steam turbine.

In general, in order to optimize the energy recovery in the process, the following alternatives are employed:

- after having vaporized the seawater, the steam generated by the steam turbine becomes a steam condensate which is used as an auxiliary water source by the steam generation unit,
- part of the desalinated water is used as an auxiliary water source by the steam generation unit,
- the method uses a gas turbine generating part of the electricity, the steam generation unit using the heat of the flue gases from the gas turbine. The term "gas turbine" means a device comprising at least one air compressor, a combustion chamber and an expansion turbine. In the gas turbine, the compressed air produced is introduced with at least one fuel into the combustion chamber of the turbine, and the flue gases produced pass through the expansion turbine to generate electricity via a generator. In general, these gases then pass through a waste heat boiler to generate steam. The fuel of the gas turbine is usually natural gas or a liquid hydrocarbon fuel. The steam generation unit can recover the heat from the flue gases from the gas turbine,
- the seawater desalination unit can produce desalinated water partly by a reverse osmosis technology using the electricity generated by the steam turbine.

The invention also relates to a plant for producing electricity, steam and desalinated water comprising:

- a steam generation unit,
- a steam turbine,
- a seawater desalination unit,
- means for supplying the steam generated by the steam generation unit to the steam turbine,
- and
- means for supplying at least part of the steam generated by the steam turbine to the seawater desalination unit,

wherein the means for supplying the steam generated by the steam generation unit to the steam turbine is equipped with means for controlling the quantity of steam supplied to the steam turbine.

The said means for controlling the quantity of steam supplied to the steam turbine comprises a bypass placed on the means for supplying the steam generated by the steam generation unit to the steam turbine suitable for diverting part of the steam generated by the steam generation unit. This bypass is generally equipped with a valve for controlling the quantity of steam supplied to the steam turbine. Preferably, this bypass diverts part of the steam generated by the steam generation unit to the means for supplying at least part of the steam generated by the steam turbine to the seawater desalination unit. According to a preferred embodiment, this bypass is a butterfly valve with an isenthalpic expansion

of the steam. An isenthalpic expansion enables the gas to increase or decrease its temperature by allowing the said gas to expand freely at constant enthalpy (which means that no heat is transferred to or from the gas, and that no external work is extracted (via a turbine, for example)). In practice, for isenthalpic expansion to take place, it is preferable for the steam to expand through a relief valve, which must be properly insulated to prevent any heat transfer to or from the steam.

The plant may also comprise a gas turbine and means for supplying flue gases from the gas turbine to the steam generation unit.

Figure 1 illustrates the plant and the inventive method. This plant comprises a gas turbine 1 supplied with a fuel 12 and generating electricity 9. This gas turbine discharges hot flue gases 5. These hot gases 5 are introduced into a steam generation unit 2. This unit 2 is supplied with water 13, 14; it burns the fuel 12 to convert the water to high pressure steam 6. The high pressure steam 6 is introduced into a steam turbine 3 to generate electricity 9. The steam turbine 3 discharges low pressure steam 15 and a steam condensate 16 produced by the condenser of the steam turbine 3; this condensate 16 is used as feedwater 14 for the steam generation unit 2. The high pressure steam 6 produced by the steam generation unit 12 and the steam 15 discharged by the steam turbine 3 are mixed. Part 7 of this mixture is used in the seawater desalination unit 4 to evaporate the seawater 17 by heat exchange. Following the heat exchange, this steam 7 is converted to a condensate 20 which is used as feedwater 14 for the steam generation unit 2. The desalination unit produces brine 18, drinking water 11 and/or deionized water 13 and/or process water 19 of lower grade than the drinking water. The deionized water 13 is used to supply water to the steam generation unit 2 to offset the losses in the steam generation circuit. Part of the process water 19 is sent to the cooling tower 22 to supply cold water 23 to the condenser of the steam turbine 3. The valve 24 serves to divert part of the high pressure steam 6 generated by the steam generation unit 2 before its introduction into the steam turbine 3. If this valve 24 is closed, all the high pressure steam 6 generated is introduced into the steam turbine 2, generating a large quantity of electricity 9. If the valve 24 is open, a smaller quantity of steam 6 is sent to the turbine 3; the turbine therefore generates less electricity. On the other hand, the industrial facility produces more steam 10. In the valve 24, the high pressure steam undergoes an isenthalpic expansion: it is cooled with water 25 derived from the feedwater of the steam generation unit 2 so that the steam has the same temperature as the low pressure steam 15 generated by the steam turbine 3.

The invention serves to improve the thermal and electrical efficiency of a plant incorporating means for the cogeneration of heat and electricity with a seawater desalination plant using steam continuously. This invention is a profitable solution in energy terms for responding to rapid changes in steam and/or electricity demand. The use of steam with low level heat content in the desalination evaporators provides means for efficiently adjusting the generation of heat and electricity. The desalination unit is a flexible and ecological form of storing electricity because it permits an adjustment of the electricity generation. The desalination unit also produces water with various degrees of desalination usable by the neighbouring municipalities or industries. The salt that is produced can be sold in the chlorine and caustic soda industries. Nearly all the heat generated in the inventive method is used because the steam used in the desalination evaporators is then recovered as steam condensate in the degasser of the steam generation unit. Finally, the deionized water produced by desalination is used as auxiliary feedwater for the steam generation unit.

The invention serves to adjust generation to variations in electricity costs: thus, if the cost of the electricity is low, less steam is sent to the turbine and more steam is sent to the desalination unit via the bypass: in this way, more desalinated water is produced because more heat is available for seawater evaporation (because of the isenthalpic expansion); this water has the advantage of being storable, contrary to electricity. If electricity demand and price are high, the plant can produce less desalinated water because less steam is available for seawater evaporation, but this economic loss is offset by the high price of electricity and by the fact that more desalinated water has been produced during a period when the cost of electricity was low, since the desalinated water is storable.

The variations in demand for the three products - electricity, steam and desalinated water - generally display very different behaviours with regard to the frequency and gradient of such variations. Whereas the usual systems are difficult to adapt simultaneously to these variations in demand, the invention serves to accomplish an effective, economical, rapid and technically flexible adjustment faced with such scenarios, because the invention has elements which, by working in coordination, serve to absorb or to adjust the inertia of the electricity, steam and water systems optimally.

CLAIMS

1. A method for producing electricity, steam and desalinated water using a steam generation unit, a steam turbine and a seawater desalination unit in, wherein:

- the steam generation unit generates steam,
- the steam turbine uses at least part of the steam generated by the steam generation unit and generates electricity and steam,
- the seawater desalination unit produces desalinated water by vaporization of seawater by heat exchange with at least part of the steam generated by the steam turbine,

and wherein the quantity of steam generated by the steam generation unit to be supplied to the steam turbine is controlled according to the electricity demand, the desalinated water demand and the steam demand.

2. The method according to claim 1, characterized in that the part of the steam generated by the steam generation unit that is not supplied to the steam turbine is mixed with the steam generated by the steam turbine.

3. The method according to claim 1, characterized in that the seawater desalination unit produces desalinated water by vaporization of seawater by heat exchange with part of the mixture of steam generated by the steam generation unit and steam generated by the steam turbine.

4. The method according to one of the preceding claims, characterized in that after having vaporized the seawater, the steam generated by the steam turbine becomes a steam condensate which is used as an auxiliary water source by the steam generation unit,

5. The method according to one of the preceding claims, characterized in that part of the desalinated water is used as an auxiliary water source by the steam generation unit.

6. The method according to one of the preceding claims, characterized in that the steam condensate produced by the steam turbine is used as an auxiliary water source by the steam generation unit.

7. The method according to one of the preceding claims, characterized in that it uses a gas turbine generating part of the electricity, the steam generation unit using the heat of the flue gases from the gas turbine.

8. The method according to one of the preceding claims, characterized in that the seawater desalination unit produces desalinated water partly by a reverse osmosis technology using the electricity generated by the steam turbine.

9. A plant for producing electricity, steam and desalinated water, the plant comprising:

- a steam generation unit,
 - a steam turbine,
 - a seawater desalination unit,
 - means for supplying the steam generated by the steam generation unit to the steam turbine,
- and
- means for supplying at least part of the steam generated by the steam turbine to the seawater desalination unit,

characterized in that the means for supplying the steam generated by the steam generation unit to the steam turbine is equipped with means for controlling the quantity of steam supplied to the steam turbine.

10. The plant according to the preceding claim, characterized in that the means for controlling the quantity of steam supplied to the steam turbine comprises a bypass placed on the means for supplying the steam generated by the steam generation unit to the steam turbine suitable for diverting part of the steam generated by the steam generation unit.

11. The plant according to claim 10, characterized in that the bypass diverts part of the steam generated by the steam generation unit to the means for supplying at least part of the steam generated by the steam turbine to the seawater desalination unit.

12. The plant according to one of Claims 9 to 11, characterized in that the means for controlling the quantity of steam supplied to the steam turbine comprises an isenthalpic relief valve.

13. The plant according to one of Claims 9 to 12, characterized in that it comprises a gas turbine and means for supplying flue gases from the gas turbine to the steam generation unit.