

System and method for using Organic Rankine Cycle to recover electrolyte waste heat for electricity generation

Technical Field

The present invention relates to the field of electrolysis, in particular to the field of waste heat recovery in a water electrolysis apparatus, and relates to a system and method for using an Organic Rankine Cycle to recover electrolyte waste heat for electricity generation.

Background Art

The electrolysis of water to produce hydrogen and oxygen has many applications in industry. For example, high-purity oxygen and hydrogen are used in the semiconductor industry; hydrogen serves as a clean and efficient new source of energy, and hydrogen is used as a starting material in petrochemical industry. Ever since the phenomenon of water electrolysis was observed in 1789, water electrolysis technology has been continuously developing. At present, three different types of electrolyser are commonly used, specifically alkaline electrolysers, polymer membrane electrolysers and solid oxide electrolysers, and the electrolytic efficiency has been increased to 70% - 90%.

The type of electrolyser which is most mature technically, most economical and easiest to operate is the alkaline electrolyser. The electrolyte used is generally a 10wt% - 30wt% potassium hydroxide solution (KOH). Once DC electricity is passed into the electrolyser, hydrogen is produced at the cathode and oxygen is produced at the anode, and this process consumes a large amount of electrical energy. For example, an electrolyser with a hydrogen output of 1000 Nm³/h needs to consume about 5.0 MWh of electricity. Thus, there is a need for a method that increases the electrolytic efficiency and/or reduces the consumption of electricity.

US patent publication US2018/0171870A1 has disclosed a system that integrates an electrolyser, an engine, an Organic Rankine Cycle and a generator. Hydrogen produced by the electrolysis of water is supplied to the engine as a fuel; hot waste gas produced by the engine undergoes heat exchange with a working medium in the Organic Rankine Cycle, causing it to evaporate. The evaporated working medium stream does work by expanding, thus driving the generator to generate electricity; the AC electricity

outputted is converted to DC electricity, which is passed into the electrolyser. This system needs to use an additional engine in order to achieve the transformation and utilization of energy.

As can be seen, methods for recovering and utilizing energy in the process of electrolysis, especially electrolysis of water, have not been fully researched and disclosed in the prior art.

Summary of the Invention

In view of the shortcomings in the prior art mentioned above, an object of the present invention is to provide a system and method for converting waste heat contained in an electrolyte to electrical energy and utilizing same.

In one aspect, the present invention discloses a system for recovering electrolyte waste heat; the system comprises at least one electrolyte cycle loop and at least one Organic Rankine Cycle loop, wherein an electrolyte heat exchanger is simultaneously located in the two cycle loops, and an electrolyte circulating stream flowing in the electrolyte cycle loop exchanges heat via the electrolyte heat exchanger with an organic working medium stream flowing in the Organic Rankine Cycle loop.

Optionally, the organic working medium stream comprises tetrafluoroethane or Freon.

Furthermore, the electrolyte cycle loop in the present invention further comprises an electrolyser and an electrolyte circulation pump, wherein the electrolyte circulating stream flowing out of the electrolyser is conveyed into the electrolyte heat exchanger via the electrolyte circulation pump, and flows back to the electrolyser after being cooled by the organic working medium stream flowing in the Organic Rankine Cycle loop, having a temperature of approximately 85 - 90°C after being cooled.

Furthermore, the Organic Rankine Cycle loop in the present invention comprises a Rankine expander and a generator coupled thereto, a Rankine Cycle economizer, a Rankine Cycle condenser, a Rankine Cycle pump and the electrolyte heat exchanger, wherein the organic working medium stream is heated and vaporized by the electrolyte circulating stream in the electrolyte heat exchanger, forming a gaseous working medium stream which does work by expanding in the Rankine expander and is then cooled by a condensed working medium stream in the Rankine Cycle economizer, and is then condensed by cooling water in the Rankine Cycle condenser to obtain the condensed

working medium stream, which is conveyed by the Rankine Cycle pump into the Rankine Cycle economizer in which it is heated by the gaseous working medium stream before being conveyed into the electrolyte heat exchanger again, thus forming a cycle; and the generator coupled to the expander converts the work of expansion to electrical energy, which is converted to DC electricity and then inputted to the electrolyser or directly incorporated into a power grid.

In another aspect, the present invention further discloses a method for using the system described above to recover electrolyte waste heat; at least one electrolyte cycle loop and at least one Organic Rankine Cycle loop are provided, wherein an electrolyte heat exchanger is simultaneously located in the two cycle loops, and an electrolyte circulating stream flowing in the electrolyte cycle loop exchanges heat via the electrolyte heat exchanger with an organic working medium stream flowing in the Organic Rankine Cycle loop.

Furthermore, in the electrolyte cycle loop, the electrolyte circulating stream flowing out of an electrolyser is conveyed into the electrolyte heat exchanger via an electrolyte circulation pump, and flows back to the electrolyser after being cooled by the organic working medium stream flowing in the Organic Rankine Cycle loop.

Furthermore, a Rankine expander and a generator coupled thereto, a Rankine Cycle economizer, a Rankine Cycle condenser and a Rankine Cycle pump are further provided in the Organic Rankine Cycle loop, wherein the organic working medium stream is heated and vaporized by the electrolyte circulating stream in the electrolyte heat exchanger, forming a gaseous working medium stream which does work by expanding in the Rankine expander and is then cooled by a condensed working medium stream in the Rankine Cycle economizer, and is then condensed by cooling water in the Rankine Cycle condenser to obtain the condensed working medium stream, which is conveyed by the Rankine Cycle pump into the Rankine Cycle economizer in which it is heated by the gaseous working medium stream before being conveyed into the electrolyte heat exchanger again, thus forming a cycle; and the generator coupled to the expander converts the work of expansion to electrical energy, which is converted to DC electricity and then inputted to the electrolyser or directly incorporated into a power grid.

Compared with the prior art, the technical solution provided in the present invention has the following advantages:

There is no need for major changes to an existing electrolyte cycle loop in an

electrolyser, so costs are reduced.

In the prior art, an electrolyte stream is generally cooled by cooling water, whereas the present invention replaces cooling water with the organic working medium stream in the Organic Rankine Cycle, thus reducing the amount of cooling water used.

In response to the electrolyte circulating stream having a low temperature (generally lower than 100°C) and a low heat grade, the present invention adds the Rankine Cycle economizer in the Organic Rankine Cycle, thus increasing the heat exchange efficiency.

By using the system and method of the present invention to convey the electrical energy generated in the Organic Rankine Cycle back to the electrolyser, the amount of electrical energy consumed in the process of water electrolysis can be reduced by 3% - 4%.

Brief description of the drawings

Further understanding of the advantages and spirit of the present invention can be gained through the following detailed description of the invention and accompanying drawings.

Fig. 1 is a schematic flow diagram of the present invention.

Key to the drawings:

E1, E2, E3 - three independent electrolysers; P1, P2, P3 - electrolyte circulation pumps; LE1, LE2, LE3 - electrolyte heat exchangers; V1, V2, V3 - Rankine Cycle control valves; EX - Rankine expander; G - generator; EC - Rankine Cycle economizer; CD - Rankine Cycle condenser; PO - Rankine Cycle pump; ST - liquid storage tank;

1, 2, 3 - first, second and third organic working medium streams; 4 - gaseous working medium stream; 5 - cooled working medium stream; 6 - condensed working medium stream; 7 - cooling water; 8 - Organic Rankine Cycle loop; 10 - electrolyte cycle loop; 11, 12, 13 - first, second and third electrolyte circulating streams.

Detailed description of the invention

Specific embodiments of the present invention are explained in detail below in conjunction with the accompanying drawings. However, the present invention should be understood to not be limited to embodiments such as those described below, and the technical concept of the present invention may be implemented in combination with other well-known technologies or other technologies having the same function as those well-

known technologies.

In the explanation of particular embodiments below, in order to clearly demonstrate the structure and manner of operation of the present invention, many directional words will be used for description, but words such as “front”, “rear”, “left”, “right”, “outer”, “inner”, “outward”, “inward”, “axial” and “radial” should be understood as being terms of convenience rather than defining words.

In the explanation of particular embodiments below, it must be understood that orientational or positional relationships indicated by terms such as “length”, “width”, “up”, “down”, “front”, “rear”, “left”, “right”, “vertical”, “horizontal”, “top”, “bottom”, “inner” and “outer” are based on the orientational or positional relationships shown in the drawings, and are merely intended to facilitate and simplify the description of the present invention, without indicating or implying that the apparatus or element referred to must have a specific orientation or be constructed and operated in a specific orientation, and therefore should not be understood as limiting the present invention.

The terms “upstream” and “downstream” indicate a relative positional relationship between a number of steps, devices or a number of device parts. In the present invention, a step that is performed first or a device that is used first according to the flow of a process is positioned upstream of a subsequent step or device.

In the present invention, unless otherwise clearly specified and defined, terms such as “installed”, “connected together”, “connected” and “fixed” should be understood in a broad sense, e.g. may mean connected in a fixed manner, but may also mean removably connected, or forming a single piece; may mean mechanically connected, but may also mean electrically connected; may mean directly connected together, but may also mean connected indirectly via an intermediate medium; and may mean internal communication between two elements, or an interactive relationship between two elements. Those skilled in the art can understand the specific meaning of the above terms in the present invention according to the specific circumstances.

Unless clearly indicated otherwise, each aspect or embodiment defined here can be combined with any other aspect(s) or embodiment(s). In particular, any preferred or advantageous feature indicated can be combined with any other preferred or advantageous feature indicated.

An electrolysis apparatus is an apparatus that is connected to a DC power supply and electrolyses water to produce O₂ and H₂. All kinds of electrolysis apparatus,

including alkaline electrolysis apparatuses, acidic electrolysis apparatuses and proton exchange membrane electrolysis apparatuses, etc., are suitable for the present invention. Taking an alkaline electrolysis apparatus as an example, a 10% - 30% aqueous solution of KOH is used as an electrolyte, and the following reaction takes place in the electrolyser:

at the anode: $4\text{OH}^- \rightarrow \text{O}_2 + 2\text{H}_2\text{O} + 4\text{e}^-$;

at the cathode: $4\text{H}_2\text{O} + 4\text{e}^- \rightarrow 4\text{OH}^- + 2\text{H}_2$;

overall reaction: $2\text{H}_2\text{O} \rightarrow 2\text{H}_2 + \text{O}_2$

The structure of a typical alkaline electrolysis apparatus is well known to those skilled in the art, and includes an electrolyser, an electrolyte, a cathode, an anode and a diaphragm. The diaphragm is generally formed of asbestos, and the main function thereof is to separate gases. The electricity consumption per unit gas output, i.e. the efficiency of the electrolyser, depends on the electrolysis voltage and the impedance of the electrolyte. The higher the reaction temperature, the lower the impedance of the electrolyte; therefore, in the prior art, electrolyzers have an operating temperature of 70 - 95°C, more preferably 80 - 90°C.

In an alkaline electrolysis apparatus, the steps by which hydrogen and oxygen are obtained by the electrolysis of water are as follows: the gases produced in the vicinity of the electrodes are separately passed through pipelines, together with the electrolyte, into a cathode gas/electrolyte separator and an anode gas/electrolyte separator. In each separator, the mixture of electrolyte and gas is heated so that the gas is separated from the mixture. The electrolyte remaining after separation is mixed with desalinated water that is added for the purpose of replenishing water consumed through electrolysis, and sent back to the electrolyser via an electrolyte circulation pump and an electrolyte cooler, optionally including a filter, for circulation and electrolysis. The electrolyte cooler uses cooling water to control the temperature of the refluxed electrolyte.

An Organic Rankine Cycle (ORC for short) is a Rankine Cycle that uses an organic substance with a low boiling point as a working medium, and is favourably suited to low-temperature waste heat recovery. In the prior art, the main components thereof include a heat exchanger, an expander, a condenser and a working medium pump, and the principle of operation thereof is as follows: the organic working medium absorbs heat from a waste heat stream in the heat exchanger, generating vapour having a certain pressure and temperature, and the vapour then enters the expander to do work by

expanding, thereby driving a generator. The vapour discharged from the expander releases heat to cooling water in the condenser, being condensed to a liquid state, and is finally returned to the heat exchanger by means of the working medium pump; this cycle is repeated continuously. An example of a suitable working medium is tetrafluoroethane or Freon.

In the present invention, the organic working medium exchanges heat with a circulating stream of electrolyte with a temperature not exceeding 100°C, said stream having a low heat grade. Thus, in order to ensure vaporization of the organic working medium, the present invention differs from the prior art in having a Rankine Cycle economizer (i.e. a type of heat exchanger) added after the expander but before the condenser. After expansion but before condensation, an organic working medium stream exchanges heat with a condensed working medium stream in the Rankine Cycle economizer, further transferring a portion of contained waste heat to the latter, thus raising the temperature of said stream, so that subsequent vaporization thereof is easier, and at the same time correspondingly reducing the amount of cooling water used.

A specific embodiment of the present invention is explained in detail below in conjunction with Fig. 1.

Fig. 1 is a schematic diagram of the principles of using an Organic Rankine Cycle to recover waste heat from an electrolyte cycle loop, and using this to generate electricity. Fig. 1 includes an electrolyte cycle loop 10 and an Organic Rankine Cycle loop 8. In the electrolyte cycle loop 10, three parallel water electrolysis apparatuses are set out schematically; in each apparatus, only an electrolyser (E1, E2, E3), an electrolyte circulation pump (P1, P2, P3) and an electrolyte heat exchanger (LE1, LE2, LE3) are labelled simply, while certain other components familiar to those skilled in the art are omitted. In order to recover waste heat contained in the electrolytes from the three water electrolysis apparatuses simultaneously, a condensed working medium stream 6 is split into three streams after being heated in a Rankine Cycle economizer (EC), specifically a first organic working medium stream 1, a second organic working medium stream 2 and a third organic working medium stream 3, which enter the electrolyte heat exchangers LE1, LE2 and LE3 respectively, and exchange heat with a first electrolyte circulating stream 11, a second electrolyte circulating stream 12 and a third electrolyte circulating stream 13 respectively. After cooling, the first, second and third electrolyte circulating streams are at a temperature of 85 - 90°C, and are conveyed back to the

electrolyser by the electrolyte circulation pump, thus forming a cycle. Having absorbed waste heat from the electrolyte circulating streams, the three organic working medium streams 1, 2, 3 are vaporized by evaporation and then combine to form a gaseous working medium stream 4, which enters a Rankine expander EX to do work by expanding, thus driving a coupled generator G. The electricity generated by the generator G can be converted to DC electricity for the water electrolysis apparatuses, or passed into a power grid. After expansion, the gaseous working medium stream 4 transfers a portion of heat to the condensed working medium stream 6 in the Rankine Cycle economizer EC, itself becoming a cooled working medium stream 5. The cooled working medium stream 5 is condensed by cooling water 7 in a Rankine Cycle condenser CD, thus becoming the condensed working medium stream 6, which is pumped by a Rankine Cycle pump PO into the Rankine Cycle economizer (EC) to be heated, and is then split into three streams, specifically the first organic working medium stream 1, the second organic working medium stream 2 and the third organic working medium stream 3; this cycle is repeated continuously. Optionally, a liquid storage tank ST is provided between the Rankine Cycle pump PO and the Rankine Cycle condenser CD, and Rankine Cycle control valves V1, V2, V3 are provided on the first, second and third organic working medium streams respectively. When the apparatus and method of the present invention are used, the amount of electricity produced by the generator G is equivalent to 3% - 4% of the total amount of electricity required by the water electrolysis apparatuses, so the economic benefit is considerable.

[0039] The above are merely preferred particular embodiments of the present invention, which are merely intended to illustrate the technical solution of the present invention without limiting the present invention. All technical solutions obtainable by those skilled in the art according to the concept of the present invention by logical analysis, reasoning or limited experiment should be included in the scope of the present invention.

CLAIMS

1. A system for using an Organic Rankine Cycle to recover electrolyte waste heat for electricity generation, characterized in that the system comprises at least one electrolyte cycle loop and at least one Organic Rankine Cycle loop, wherein an electrolyte heat exchanger is simultaneously located in the two cycle loops, and an electrolyte circulating stream flowing in the electrolyte cycle loop exchanges heat via the electrolyte heat exchanger with an organic working medium stream flowing in the Organic Rankine Cycle loop.
2. A system according to Claim 1, characterized in that the organic working medium stream comprises tetrafluoroethane or Freon.
3. A system according to Claim 1, characterized in that the electrolyte cycle loop further comprises an electrolyser and an electrolyte circulation pump, wherein the electrolyte circulating stream flowing out of the electrolyser is conveyed into the electrolyte heat exchanger via the electrolyte circulation pump, and flows back to the electrolyser after being cooled by the organic working medium stream flowing in the Organic Rankine Cycle loop.
4. A system according to Claim 3, characterized in that the electrolyte circulating stream has a temperature of 85 - 90°C after being cooled in the electrolyte heat exchanger.
5. A system according to Claim 1, characterized in that the Organic Rankine Cycle loop comprises a Rankine expander and a generator coupled thereto, a Rankine Cycle economizer, a Rankine Cycle condenser, a Rankine Cycle pump and the electrolyte heat exchanger, wherein the organic working medium stream is heated and vaporized by the electrolyte circulating stream in the electrolyte heat exchanger, forming a gaseous working medium stream which does work by expanding in the Rankine expander and is then cooled by a condensed working medium stream in the Rankine Cycle economizer, and is then condensed by cooling water in the Rankine Cycle condenser to obtain the condensed working medium stream, which is conveyed by the Rankine Cycle pump into the Rankine Cycle economizer in which it is heated by the gaseous working medium stream before being conveyed into the electrolyte heat exchanger again, thus forming a cycle; and the generator coupled to the expander converts the work of expansion to electrical energy.
6. A method for using the system according to Claim 1 to recover electrolyte waste heat,

characterized in that at least one electrolyte cycle loop and at least one Organic Rankine Cycle loop are provided, wherein an electrolyte heat exchanger is simultaneously located in the two cycle loops, and an electrolyte circulating stream flowing in the electrolyte cycle loop exchanges heat via the electrolyte heat exchanger with an organic working medium stream flowing in the Organic Rankine Cycle loop.

7. A method according to Claim 6, characterized in that the organic working medium stream comprises tetrafluoroethane or Freon.
8. A method according to Claim 6, characterized in that the electrolyte circulating stream has a temperature of 85 - 90°C after being cooled in the electrolyte heat exchanger.
9. A method according to Claim 6, characterized in that an electrolyser and an electrolyte circulation pump are further provided in the electrolyte cycle loop, wherein the electrolyte circulating stream flowing out of the electrolyser is conveyed into the electrolyte heat exchanger via the electrolyte circulation pump, and flows back to the electrolyser after being cooled by the organic working medium stream flowing in the Organic Rankine Cycle loop.
10. A method according to Claim 6, characterized in that a Rankine expander and a generator coupled thereto, a Rankine Cycle economizer, a Rankine Cycle condenser and a Rankine Cycle pump are further provided in the Organic Rankine Cycle loop, wherein the organic working medium stream is heated and vaporized by the electrolyte circulating stream in the electrolyte heat exchanger, forming a gaseous working medium stream which does work by expanding in the Rankine expander and is then cooled by a condensed working medium stream in the Rankine Cycle economizer, and is then condensed by cooling water in the Rankine Cycle condenser to obtain the condensed working medium stream, which is conveyed by the Rankine Cycle pump into the Rankine Cycle economizer in which it is heated by the gaseous working medium stream before being conveyed into the electrolyte heat exchanger again, thus forming a cycle; and the generator coupled to the expander converts the work of expansion to electrical energy.