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(54) **POWER GENERATION SYSTEM DRIVEN BY HEAT PUMP**

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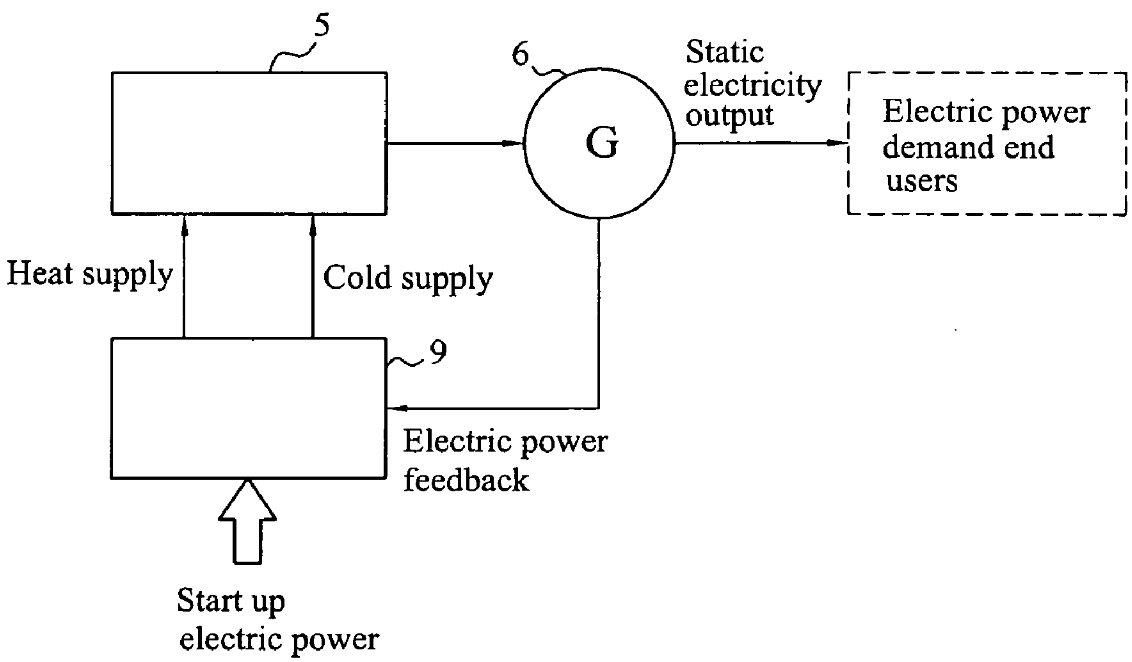
(57) **ABSTRACT**

A power generation system driven by heat pump which produces a heat source by heating and a cold source by cooling for the driving of a heat engine to produce mechanical energy to drive a generator generating electrical power. Part of the power generated by the generator is fed back to the heat pump continuously, and the remaining power is provided to end users in need of electrical power. The heat engine of the power generation system can be Stirling engine or a steam turbine, wherein the heat efficiency of the Stirling engine can reach 25%, and the heat efficiency of the steam turbine can reach above 30%. The heat pump used in the power generation system can be a vapor-compression heat pump. Under operating conditions where temperature difference between the generated heat and cold sources is over 25 degree celcius, the coefficient of performance can reach above 7.



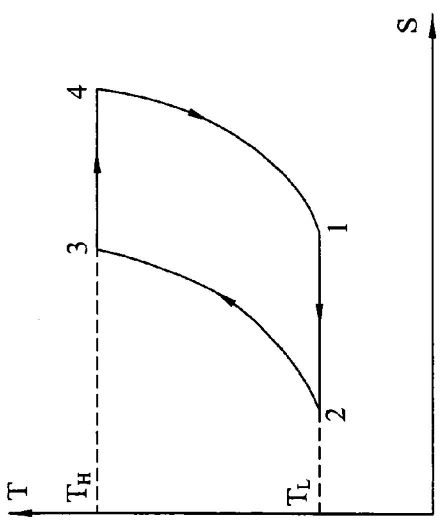


FIG. 1

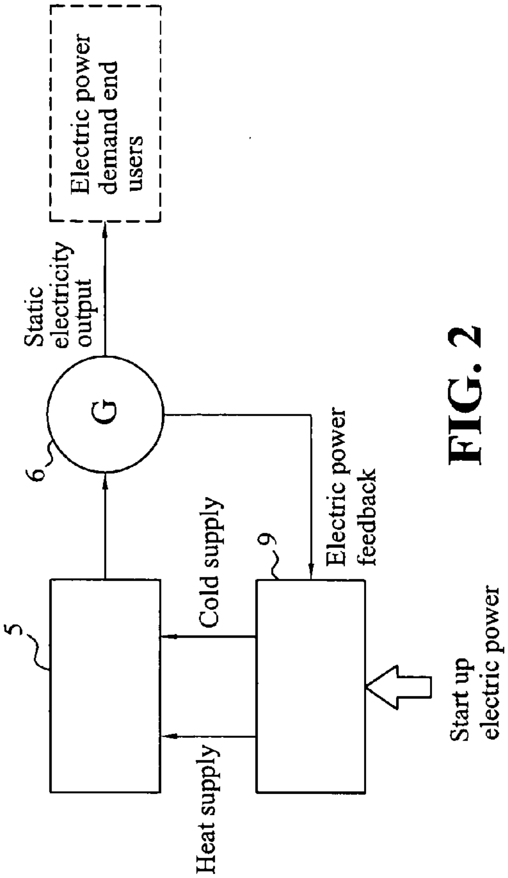


FIG. 2

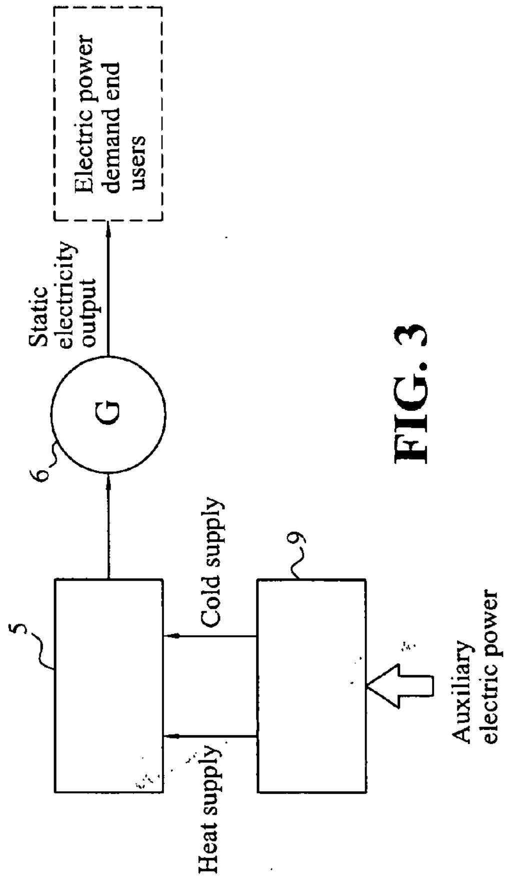


FIG. 3

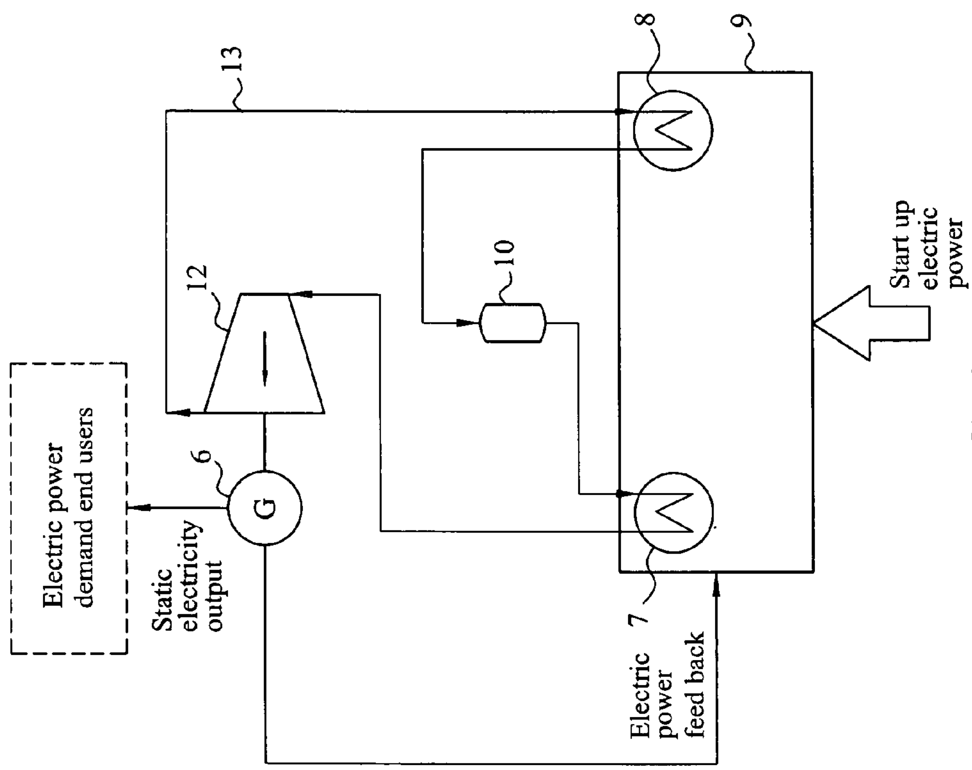
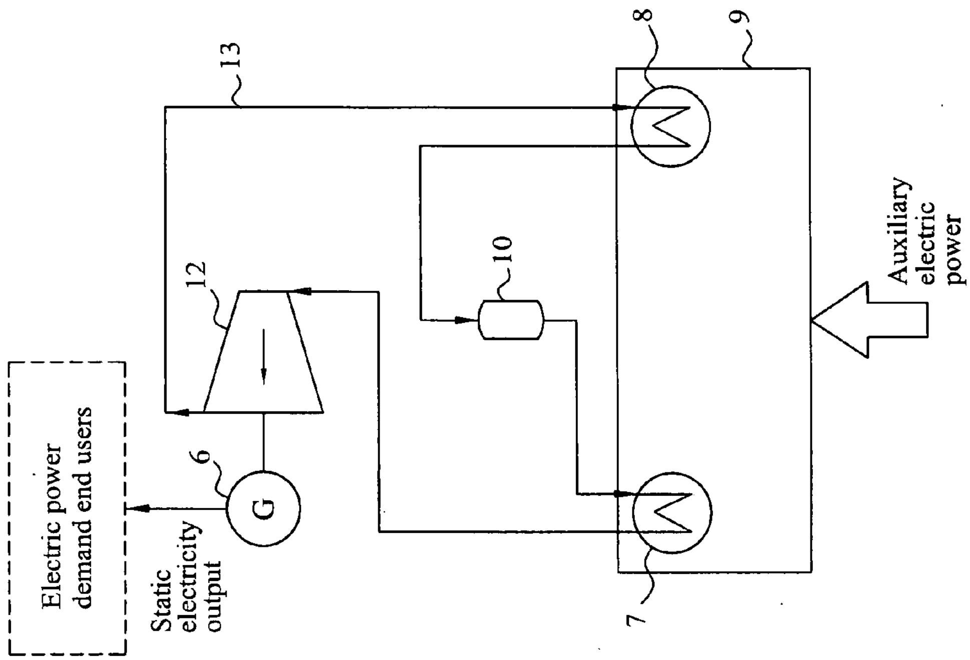

Electric power demand end users
Static electricity output
6
G
12
13
10
8
9
7
Start up electric power
Electric power feed back

FIG. 4


Electric power demand end users
Static electricity output
6
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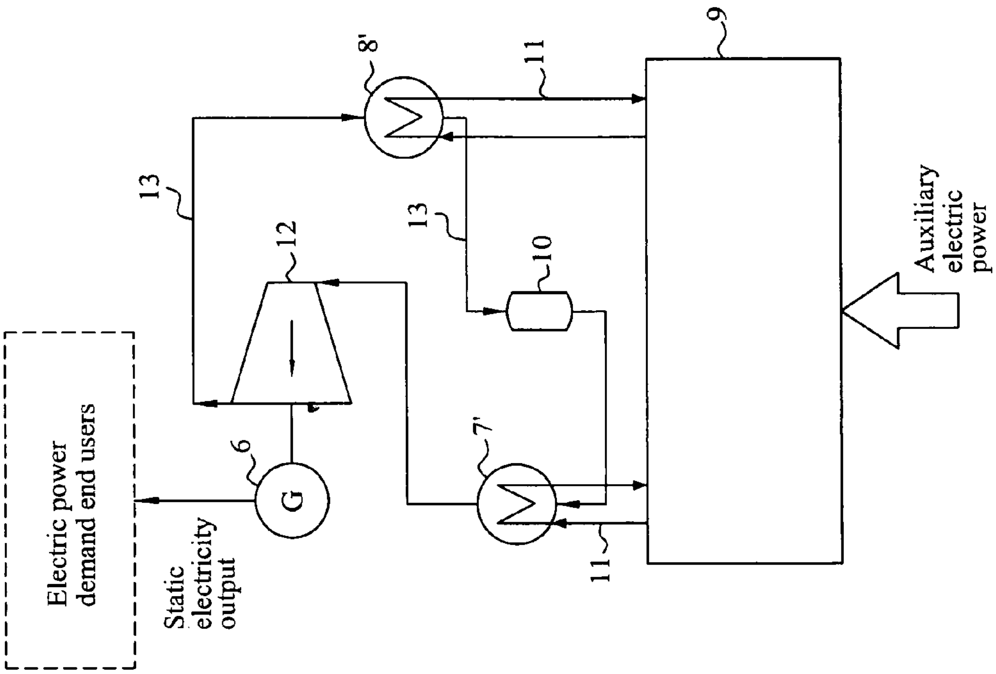
7
Auxiliary electric power

FIG. 5


Electric power demand end users
Static electricity output
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Auxiliary electric power

FIG. 7

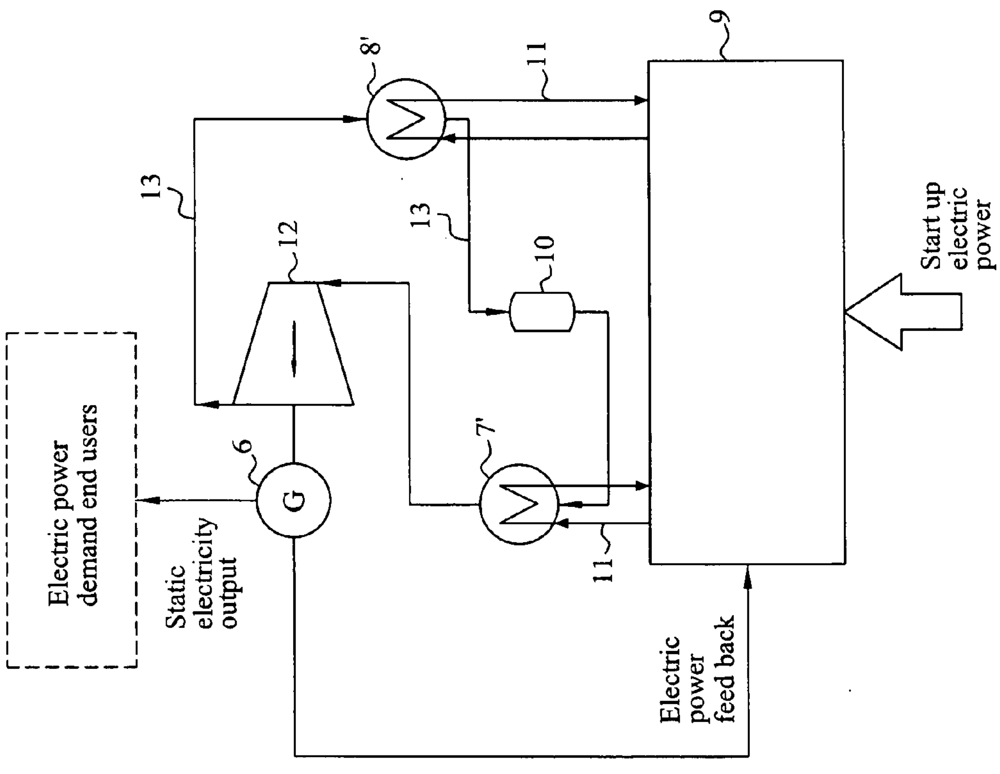
Electric power demand end users
Static electricity output
G
6
12
13
13
8'
11
11
9
10
7'
Start up electric power
Electric power feed back

FIG. 6

POWER GENERATION SYSTEM DRIVEN BY HEAT PUMP

DESCRIPTION OF INVENTION

[0001] The present invention relates to a type of power generation system, especially to a power generation system which utilizes heat pump driven heat engine so as to generate electrical energy, in which heat engine could be Stirling's engine or steam turbine.

BACKGROUND OF THE INVENTION

[0002] Introduction of Stirling Cycle:

[0003] Stirling Cycle is the process of isothermal heat transfer and isochoric expansion and compression, an ideal Stirling cycle possesses similar heat efficiency as that of Carnot cycle, FIG. **1** is the curve showing the relationship between temperature and entropy of Stirling cycle, in which T is Temperature, S is Entropy, 1~4 are four work state points, which is described one by one below.

[0004] 1-2 Isothermal Compression Process (Heat Quantity is Transferred from Working Fluid to Cold Source):

[0005] The displacement piston, after pushing the working fluid into the cold source, retains in the top dead center position, and the working fluid is cooled down and preserved at cold source temperature T_L; fly wheel drives the work piston to compress the working fluid. When work piston moves from the bottom dead center position to the top dead center, then the compression process is finished. The cold source enables compression process to be carried out under isothermal conditions.

[0006] 2-3 Isochoric Heating Process (Heat Quantity is Transferred from Heat Regenerator to the Working Fluid):

[0007] The displacement piston moves from top dead center to bottom dead center, thereupon pushing the working fluid from cold source into heat source, at this point work piston is stationary at its top dead center. During the process when the working fluid is pushed from cold source into heat source, it gain its stored heat quantity from the heat regenerator, working fluid temperature is raised to heat source temperature TH, at the same time pressure is raised.

[0008] 3-4 Isothermal Expansion Process (Working Fluid Gains Heat Quantity of High Temperature Heat Source):

[0009] The displacement piston, after pushing the working fluid into the heat source, retains in the bottom dead center position, correspondingly the working fluid pressure is raised to its highest value. Afterwards, the working fluid absorbs heat from high temperature heat source and expands isothermally, pushing the work piston to move from top dead center to bottom dead center. In this process the work piston drives the fly wheel into rotation, storing mechanical energy for back up use.

[0010] 4-1 Isochoric Cooling Process (Heat Quantity is Transferred from Working Fluid to Heat Regenerator):

[0011] Work piston moves to bottom dead center and remains stationary, displacement piston moves from its bottom dead center to top dead center thereupon pushing the whole working fluid into the cold source. Working fluid heats up the heat regenerator when entering from heat source to cold source, its temperature drops down to temperature of cold source T_L and its pressure is lowered; heat regenerator stores heat quantity of working fluid brought out from heat source.

[0012] Theoretical heat efficiency of Stirling cycle is quite near to highest theoretical heat efficiency of heat engine, which is the heat efficiency of Carnot cycle. Due to problems like temperature difference heat conduction and heat leakages between heat end and cold end of Stirling engine, so far, even though the actual heat efficiency of Stirling heat engine is too low from its theoretical value, it can still reach 20-25%.

[0013] Introduction of Steam Turbine:

[0014] Steam turbine can be driven by utilizing working fluid with low evaporating temperatures, for example working fluids like ammonias or alkanes. Properties of working fluid are evaporating temperatures lies in the 35 degrees celcius to 60 degrees celcius range, and condensing temperatures lies in the 0 degrees celcius to 30 degrees celcius range. The way in which steam turbine performs work is after the working fluid heats up through heat source, evaporates and vaporized, it passes through steam turbine, the steam turbine extracts energy of working fluid vaporized by heat to perform work so as to provide it for use in power generation. The working fluid after extraction of energy by steam turbine lowers its pressure and temperature and condenses through cold source, then passes though flow controller and returns to heat source. Steam turbine roughly uses this method to perform work and its heat efficiency can reach above 30%.

[0015] Introduction of Heat Pump System:

[0016] According to the second law of thermodynamics, heat cannot itself pass from a cold source to a heat source. Extra energy must be input to shift heat quantity from cold source to heat source, and heat pump is the machine used to shift heat quantity. Inputting energy to heat pump can enable it to generate heat source and cold source at the same time, so as to provide cold and heat requirements, enabling adequate utilization of energy inputted at heat pump and accomplishing the most optimum energy utilizing efficiency.

[0017] Problems Faced:

[0018] Stirling Engine because of heat transfer problem in itself, for example heat transfer between heat end and cold end temperature difference, heat leakages during system operation, and irreversible heat regeneration process inevitably generates irreversible loss, thus causing efficiency of Stirling heat engine to be lower than heat efficiency of Carnot heat engine by 50%. Hence how to effectively raise the efficiency of Stirling cycle is an urgent matter. According to principles of thermodynamics, raising temperature of heat source, lowering temperature of cold source can effectively raise efficiency of heat engine, making it more economized.

[0019] In earlier known skills, as for example already proclaimed US patent US2004/0093864A1 and Europe patent EP167470A2 power generation system comprising of Stirling heat engine and already proclaimed in US patent US2006/0225428A1 power generation system comprising of Steam turbine, these known technology all needed fuel combustion to generate heat source for driving Stirling heat engine or generate steam for driving Steam turbine, so as to enable generator to operate. Combustion of fossilized fuels not only causes air pollution moreover aggravates green house effect. Besides, with the present rate of fossilized fuel consumption, it can be foreseen with storage quantity of fossilized fuel gradually decreasing, expenses in mining fossilized fuel and cost in purchasing fossilized fuel will become more expensive. Power generation system using combustion of fossilized fuel will become a problem.

SUMMARY OF THE INVENTION

[0020] With regard to fore described problems, the present invention brings up a novel power generation system, besides from being able to provide work conditions favorable to heat engine operations but also able to lower requirements of fossilized fuel, reducing release of green house gases.

[0021] Besides, to accomplish objective of effective raising of heat source temperature and lowering of cold source temperature and then raising work efficiency of heat engine, the power generation system of the present invention utilizes heat pump to shift the heat quantity already existing in the environment. Using this method can at the same time effectively raise heat source temperature and lower cold source temperature, enabling heat engine to operate in a more favorable operating condition and most optimum utilization of energy inputted to heat pump is then performed.

[0022] The disclosure of the present invention is a type of power generation system driven by heat pump, it comprises at least: heat pump used in the generation of heat source and cold source; heat engine driven by heat source and cold source generated by heat pump; and generator coupled with the heat engine used for power generation; wherein through heat supply and cold supply by the heat source and the cold source to the working fluid of the heat engine, the heat engine is driven into operation thereby generating mechanical energy, moreover through generator mechanical energy is transformed into electrical energy.

[0023] According to another aspect of the present invention, heat pump can be vapor-compression heat pump. Compressor types of vapor-compression heat pump that can be adopted are centrifugal type, screw type, scroll type, reciprocal type, rotatory type etc., but compressor types and kind are not the limiting conditions of the present invention. At present it is known that dual effect type heat pump of high efficiency under operating conditions of cold and heat source temperature difference of over 25 degree celcius, its energy efficiency COP (coefficient of performance) can reach above 7.

[0024] According to another aspect of the present invention, heat engine can be Stirling heat engine

[0025] According to another aspect of the present invention, heat engine can be Steam turbine, especially steam turbine utilizing working fluid that possesses low evaporating temperatures to operate. The working fluid used, by this turbine can be ammonias, alkanes or fluids possessing low evaporating temperature or combinations thereof.

[0026] According to another aspect of the present invention, the heat pump is initially actuated for operation by start up electric power. Until the generator generates enough electric power for both continuous supply to the heat pump for operation and feed back to the heat pump, and then input of start up electric power is stopped or gradually reduced and a remaining electric power (net electricity output) of the generator is then supplied to end user in need of electric power, for example in general industries or household. Or heat pump is continuously actuated by an auxiliary power and the electric power generated by the generator is completely supplied to end users in need of electric power. Since generated electric power is not fed back to heat pump, hence largest net electricity output can be obtained. Startup electric power and auxiliary electric power of heat pump can be chosen from electricity provided by electric power company, fuel batteries, storage batteries, solar energy battery modules, wind power generating modules or combinations thereof.

[0027] Through effective raise of heat source temperature required by Stirling engine or Steam turbine by heat pump and lowering its required cold source temperature, the heat efficiency of heat engine can be effectively raised. As heat pump utilizes energy inputted to it to shift the heat quantity already existing in the environment, thereupon generating heat source and cold source required for heat engine operation, hence comparing to traditional methods of power generation by combustion of fossilized fuel, coal and natural gases etc., the power generation system of the present invention can reduce the requirements of fossilized fuel, preventing the generation of green house gases, lessening the impact of green house effect on the environment. Yet again, the power generation system of the present invention indeed contributed extremely towards environmental issues such as energy utilization and release of green house gases.

BRIEF DESCRIPTION OF THE DRAWING

[0028] FIG. **1** is the thermodynamic cycle temperature-entropy diagram of Stirling cycle;

[0029] FIG. **2** is the schematic view of the first implementation of the present invention's power generation system, wherein Stirling heat engine is used;

[0030] FIG. **3** is the schematic view of the second implementation of the present invention's power generation system;

[0031] FIG. **4** is the schematic view of the third implementation of the present invention's power generation system, wherein Steam turbine is used;

[0032] FIG. **5** is the schematic view of the fourth implementation of the present invention's power generation system;

[0033] FIG. **6** is the schematic view of the fifth implementation of the present invention's power generation system; and

[0034] FIG. **7** is the schematic view of the sixth implementation of the present invention's power generation system.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS OF THE INVENTION

[0035] Below, further description on the technical features of the present invention will be made by the embodiments in reference to the attached drawings in which the embodiments are only preferred examples and are not used to limit the ranges of the present invention.

[0036] As shown in FIG. **2**, the first implementation of the present invention of power generation system includes at least heat pump **9**, Stirling heat engine **5** and generator **6**.

[0037] In the first implementation, after heat pump **9** is initially actuated for operation by start up electric power, it immediately starts to shift the heat quantity that already exists in the environment, hence generating heat source and cold source. The start up electric power of heat pump can be chosen from electricity provided by electric power company, fuel batteries, storage batteries, solar energy battery modules, wind power generating modules or combinations thereof. Through heat supply and cold supply by the heat source and the cold source to the working fluid of Stirling heat engine **5**, so as to enable Stirling heat engine **9** to operate. Following, Stirling engine **5** drives the generator **6** coupled with it, used for generation of electric power. Until generator **6** generates enough electric power for both continuous supply to the heat pump **9** for operation and feed back to the heat pump, then input of start up electric power is stopped or gradually reduced and a remaining electric power (net electricity output) of generator **6** is then supplied to end users in need of electric power.

[0038] FIG. **3** represents the present invention's second implementation, its difference with the first implementation is that the generator **6** in this implementation does not feed back the electric power to heat pump **9**. In this way, largest net electric output can be obtained. While heat pump **9** is continuously actuated by an auxiliary power, auxiliary electric power can be chosen from electricity provided by electric power company, fuel batteries, storage batteries, solar energy battery modules, wind power generating modules or combinations thereof.

[0039] Differentiating from the fore described first and second implementations using Stirling heat engine, in the third implementation of the present invention, Steam turbine **12** is used as heat engine in the power generation system. As shown in FIG. **4**, the power generation system of the third implementation includes at least heat pump **9**, Steam turbine **12** and generator **6**. Working fluid **13** of steam turbine performs heat exchange with heat source **7** and cold source **8** or heat pump **9** in a closed cycle. Working fluid **13** of steam turbine is better composed of fluids with low evaporating temperature, for example ammonias, alkanes, fluid possessing low evaporating temperature or combinations thereof. The temperature of heat pump's heat source is approximately between 35 degree celcius to 60 degree celcius, cold source is approximately between 0 degree celcius to 35 degree celcius. As the working fluid **13** of steam turbine possesses properties of low evaporating temperatures, the steam turbine working fluid **13** evaporates and vaporizes through heating by heat source **7**. In turn, the vaporized steam turbine working fluid **13** passes through steam turbine **12**, and through steam turbine **12** the energy brought about by steam turbine working fluid **13** is extracted. After passing through steam turbine **12**, the temperature and pressure of steam turbine working fluid **13** further decreases, then it flows through cold source **8** and condenses here. The liquid steam turbine working fluid **13** formed is further transferred to heat source **7**.

[0040] Preferably, flow controller **10** is installed on the path of steam turbine working fluid **13** from cold source **8** to heat source **7** to prevent the vaporized steam turbine working fluid **13** in heat source **7** from flowing reversely towards cold source **8** due to increased pressure, moreover it helps in the transfer of steam turbine working fluid **13** from cold source **8** to heat source **7**. Flow controller **10** can also be fluid providing pump.

[0041] Steam turbine **12** roughly operates according to the method described above. As in the first implementation, after the heat pump **9** is initially actuated for operation by start up electric power, it immediately starts to shift the heat quantity that already exists in the environment, as in air, water or soil et cetera, hence generating heat source **7** and cold source **8**. Start up electric power of heat pump **9** can be chosen from electricity provided by electric power company, fuel batteries, storage batteries, solar energy battery modules, wind power generating modules or combinations thereof. Steam turbine **12** drives generator **6** coupled with it, which is used for generation of electric power. Until generator **6** generates enough electric power for both continuous supply to the heat pump for operation and fed back to the heat pump, then input of start up electric power is stopped or gradually reduced and a remaining electric power (net electricity output) of generator **6** is supplied to end users in need of electric power.

[0042] As shown in FIG. **5**, the fourth implementation of the present invention is another modified implementation based on the third implementation. As in the second implementation, generator **6** does not feed back the electric power to heat pump **9**. In this way, largest net electric output can be obtained. While heat pump **9** is continuously actuated by auxiliary electric power, auxiliary electric power can be chosen from electricity provided by electric power company, fuel batteries, storage batteries, solar energy battery modules, wind power generating modules or combinations thereof.

[0043] In the third implementation, the path of steam turbine working fluid **13** directly passes through heat pump **9**, and through working fluid of heat pump **9**, steam turbine working fluid **13** is directly heated and cooled. In other words, heat pump uses directly through method of heat transfer to supply cold and heat to working fluid of heat engine. Due to the steam turbine working fluid **13** directly performing heat exchanges with working fluid of heat pump **9**, the benefit is low heat transfer loss and high heat transfer efficiency, whereas this kind of set up may have inconvenient repair and maintenance disadvantages.

[0044] Hence, the fifth implementation of the present invention is proclaimed here, it is another modified implementation based on the third implementation, as shown in FIG. **6**. In the fifth implementation, through direct heat exchange between heat transfer device **11** and working fluid of heat pump **9**, external heat source **7'** and external cold source **8'** is formed on the outside of heat pump **9**. Steam turbine working fluid **13** supplies heat and cold by way of external heat source **7'** and external cold source **8'**. Heat transfer device **11** can be heat pipe or anisotropic heat materials et cetera. Heat transfer device **11** can also be formed from already known heat exchanging device or heat transfer fluid loop. In other words, heat pump uses indirectly through method of heat transfer to supply cold and heat to working fluid of heat engine. The benefit is having easier installation, repair and maintenance of equipments. Secondly, through the intermediate heat conducting device, the set up of steam turbine and heat pump is not easily limited. Whereas, in this way the heat transfer loss is higher.

[0045] The method of operation of the fifth implementation is roughly similar to that of the third implementation. Heat pump **9** is initially actuated for operation by start up electric power and it immediately start to shift the heat quantity that already exists in the environment. Through heat transfer device **11**, external heat source **7'** and external cold source **8'** is generated on the outside of heat pump **9**. Start up electric power of heat pump **9** can be chosen from electricity provided by electric power company, fuel batteries, storage batteries, solar energy battery modules, wind power generating modules or combinations thereof. Through external heat source **7'** and external cold source **8'**, heat and cold is supplied to steam turbine working fluid **13** so as to drive steam turbine **12**, and the steam turbine **12** drives generator **6** coupled with it, which used for generation of electric power. Until generator **6** generates enough electric power for both continuous supply to the heat pump **9** for operation and feed back to the heat pump, then input of start up electric power is stopped or gradually reduced and a remaining electric power (net electricity output) of generator **6** is supplied to end users in need of electric power.

As shown in FIG. **7**, the sixth implementation of the present invention is another modified implementation based on the fifth implementation. Generator **6** does not feed back the electric power to heat pump **9**. In this way, largest net electric output can be obtained. While heat pump **9** is continuously actuated by an auxiliary power, auxiliary electric power can be chosen from electricity provided by electric power company, fuel batteries, storage batteries, solar energy battery modules, wind power generating modules or combinations thereof.

[0046] Even though in the above described implementations, generator and heat engine are each separated devices, but generator and heat engine can be integrated into a single module.

[0047] Comparing to heat engines of other types, Stirling heat engine and Steam turbine, suitable for use in the present invention, possesses better heat efficiency. Due to direct generation of rotatory motion by steam turbine, connecting rod to transform reciprocatory motion into rotatory motion is not required. Hence steam turbine possesses extremely good heat efficiency, which in general can reach above 30%. Actual heat efficiency of Stirling heat engine can reach upto 25%.

[0048] Stirling heat engine is a type with can operate in any form of heat source and cold source, which means even mere temperature differences enables Stirling heat engine to operate. Hence, Stirling heat engine is uniquely suitable for integration with heat pump in the generation of electricity. Use of working fluid possessing low evaporating temperatures in steam turbine, enables heat pump to be able to drive the steam turbine.

[0049] Based on the power generation system of the present invention, through integration of heat pump and heat engine, heat efficiency of Stirling heat engine and Steam turbine can be effectively raised. Based on the power generation system of the present invention, during the course of power generation fossilized fuels is not combusted, hence release of green house gases is reduced, the impact of green house effect on the environment is lessened.

[0050] Above are only preferred implementations of the present invention and does not limit the scope of the present invention. Hence, equivalent variations and modifications without departing from the spirit and scope of the appended claims should be considered to be within the scope of the present invention.

DESCRIPTION OF MAIN COMPONENT SYMBOLS

[0051]

1-4	Work state points
T	Temperature
S	Entropy
T_H	Temperature of heat source
T_L	Temperature of cold source
5	Stirling heat engine
6	Generator
7	Heat source
8	Cold source
7'	External heat source
8'	External cold source
9	Heat pump
10	Flow controller
11	Heat conducting device
12	Steam turbine
13	Steam turbine working fluid

1: A Power generation system driven by a heat pump at least comprising:

a heat pump for producing a heat source and a cold source;

a heat engine driven by the heat source and the cold source generated by the heat pump; and

a generator coupled with the heat engine for power generation;

wherein, working fluid of the heat engine is heated and cooled by the heat source and the cold source such that the heat engine is powered for generating mechanical energy, and the mechanical energy is converted into electrical power by the generator.

2: The power generation system according to claim **1**, wherein the heat engine is a Stirling heat engine.

3: The power generation system according to claim **1**, wherein the heat engine is a steam turbine.

4: The power generation system according to claim **3**, further including a flow controller arranged in a path of the working fluid of the steam turbine from the cold source towards the heat source for preventing the working fluid vaporized by the heat source from flowing reversely towards the cold source.

5: The power generation system according to claim **3**, wherein the working fluid used in the steam turbine is selected from ammonias, alkanes, fluids possessing low evaporating temperatures or combinations thereof.

6: The power generation system according to claim **5**, further including a flow controller arranged in a path of the working fluid of the steam turbine from the cold source towards the heat source for preventing the working fluid vaporized by the heat source from flowing reversely towards the cold source.

7: The power generation system according to claim **1**, wherein heat is exchanged directly between the working fluid of the heat engine and the heat pump.

8: The power generation system according to claim **7**, wherein the heat pump is a vapor-compression heat pump.

9: The power generation system according to claim **1**, wherein the heat is exchanged indirectly between the working fluid of the heat engine and the heat pump through a heat transfer device.

10: The power generation system according to claim **9**, wherein the heat pump is a vapor-compression heat pump.

11: The power generation system according to claim **1**, wherein the heat pump is initially actuated for operation by start up electric power, which can be chosen from electricity provided by electric power company, fuel batteries, storage batteries, solar energy battery modules, wind power generating modules or combinations thereof, until the generator generates enough electric power for both continuous supply to the heat pump for operation and feed back to the heat pump, then input of start up electric power is stopped or gradually reduced and a remaining electric power of the generator is supplied to end users in need of electric power.

12: The power generation system according to claim **11**, wherein the heat pump is a vapor-compression heat pump.

13: The power generation system according to claim **1**, wherein the heat pump is continuously actuated by an auxiliary power, which can be chosen from electricity provided by electric power company, fuel batteries, storage batteries, solar energy battery modules, wind power generating modules or combinations thereof, and the electric power generated by the generator is completely supplied to end users in need of electric power.

14: The power system according to claim **13**, wherein the heat pump is a vapor-compression heat pump.

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