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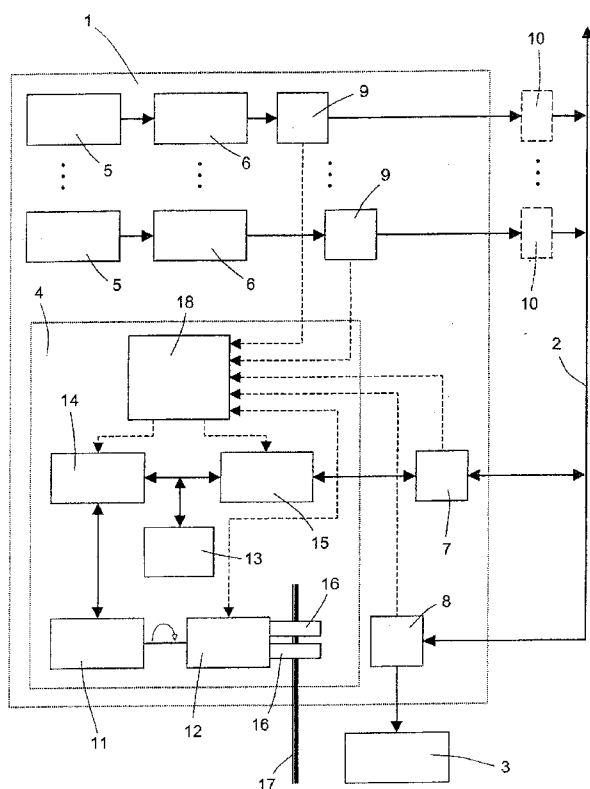


Fig. 1

(57) Abstract: A system for producing electric and thermal energy, and connected to a grid (2) supplying alternating electric energy, the system (1) having a cogeneration unit (4) for supplying alternating electric energy to an electric load (3); at least one discontinuous source (5) of electric energy; an inverter (6) for converting the electric energy produced by the discontinuous source (5) to alternating electric energy for supply to the load (3); and a plurality of alternating electric power measuring units (7, 8, 9) for measuring a first electric power (PG) supplied by the cogeneration unit (4), a second electric power (PL) drawn by the load (3), and a third electric power (PS) supplied by the discontinuous source (5); and wherein the cogeneration unit (4) is designed to regulate the first electric power (PG) so that the sum of the first electric power (PG) and the third electric power (PS) tracks the sum of the second electric power (PL) and a fourth electric power (PN_in) to be fed into the grid (2).

SYSTEM FOR SIMULTANEOUSLY PRODUCING ELECTRIC AND THERMAL
ENERGY

TECHNICAL FIELD

5 The present invention relates to a system for
simultaneously producing electric and thermal energy.

More specifically, the present invention relates to
a system comprising a cogeneration unit for
simultaneously producing alternating-electric and
10 thermal energy, and may be used to advantage, though not
exclusively, for producing electric and thermal energy
in isolated areas with discontinuous electric energy
sources, to which application the following description
refers purely by way of example.

15

BACKGROUND ART

As is known, in recent years, there has been a big
increase in demand for low- and medium-power
cogeneration units for supplying electric energy in
20 rural areas not covered by a conventional grid. It is
very often cheaper, in fact, to produce electric energy
on site using conventional fuel than to install
extensive power lines connecting large electric power
plants to isolated residential areas.

25 A cogeneration unit typically comprises an electric
generator; an endothermic or internal-combustion
(normally diesel) engine to start and run the electric
generator; a heat exchanger for recovering the heat

produced by the internal-combustion engine, and possibly also the electric generator, to produce high-temperature water for various uses; and a control unit for starting the internal-combustion engine when necessary, and
5 controlling it to keep the electric generator running at a predetermined constant speed which depends on the frequency of the alternating electric power distributed by the grid being substituted for.

One known system for producing and supplying
10 electric energy in isolated areas is connected to the grid, and comprises a plurality of discontinuous electric energy sources, and a generator for supplying alternating electric energy to the user load when the discontinuous sources and the grid are unable to do so.
15 "Discontinuous sources" is intended to mean systems for producing electric energy from renewable energy sources, such as photovoltaic panels or aerogenerators, which are typically intermittent or at any rate highly variable energy sources. The system comprises a direct electric
20 energy accumulator; and a two-way electric energy converter connecting the accumulator to the generator and grid to permit electric energy flow between the generator, grid and accumulator. The discontinuous sources are connected directly to the accumulator, so
25 the electric energy produced by the discontinuous sources is supplied to the electric load in addition to the electric energy produced by the generator.

When electric energy cannot be supplied by the

grid, the above system provides for minimizing fuel consumption, depending on how much electric energy is actually produced by the discontinuous sources, but fails to make the best use of discontinuous sources as prescribed by current electric energy supply regulations. That is, according to current regulations, any surplus electric energy produced may be sold by the user to the grid provider, on condition that it is produced by renewable sources and can be measured directly by the provider from the grid.

DISCLOSURE OF INVENTION

It is an object of the present invention to provide a system for producing electric energy, which is designed to eliminate the above drawback, also provides for simultaneously producing thermal energy, and at the same time is cheap and easy to implement.

According to the present invention, there is provided a system for simultaneously producing electric and thermal energy, as claimed in the accompanying Claims.

BRIEF DESCRIPTION OF THE DRAWING

The present invention will be described with reference to the attached drawing, which shows, schematically, a system for simultaneously producing electric and thermal energy in accordance with the present invention and indicated as a whole by 1. System

1 is shown connected to a grid 2 supplying three-phase alternating electric energy at a given power frequency F, and to a three-phase electric user indicated by a generic electric load 3 comprising one or more electric users (not shown) drawing three-phase electric energy at power frequency F.

BEST MODE FOR CARRYING OUT THE INVENTION

With reference to the attached drawing, system 1 comprises a cogeneration unit 4 for simultaneously producing three-phase alternating electric energy and thermal energy, and which is parallel-connected electrically to grid 2 and electric load 3 to supply electric load 3 with alternating electric energy when grid 2 is out of order; a number of discontinuous, i.e. alternative, electric energy sources 5, such as photovoltaic panels, aerogenerators, small hydraulic turbines, etc.; and an equal number of inverters 6, each connected between a respective discontinuous source 5 and grid 2 to convert the alternating or direct electric energy produced by discontinuous source 5 to alternating electric energy at power frequency F. Obviously, the characteristics of each inverter 6 depend on the type of electric energy produced by respective discontinuous source 5.

System 1 also comprises a plurality of alternating electric power measuring units, of which a first, indicated 7, is connected between cogeneration unit 4

and grid 2 to measure the electric power PG supplied or drawn by cogeneration unit 4; a second unit, indicated 8, is connected to electric load 3 to measure the electric power PL drawn by electric load 3; and third 5 units, indicated 9, are connected to the outputs of respective inverters 6 to measure the alternating electric power PS supplied as a whole by discontinuous sources 5.

System 1 as described above enables installation by 10 the grid 2 provider of an alternating electric power supply meter 10 - shown by a dash line in the drawing - at the output of each renewable source alternating electric energy supply line, i.e. at the output of each electric power measuring unit 9, to measure the amount 15 of alternating electric energy produced by the user's discontinuous sources 5.

Cogeneration unit 4 comprises a known rotary electric generator 11, in particular a three- or single-phase electric motor-generator, e.g. a three-phase 20 asynchronous motor-generator, for producing alternating electric energy at a frequency L varying as a function of rotation speed; and a known endothermic engine 12, e.g. a diesel, petrol, methane, or liquid propane gas (LPG) fuelled internal-combustion engine, for keeping 25 the shaft of electric generator 11 rotating at however variable a speed to produce electric energy.

Cogeneration unit 4 also comprises a known electric energy accumulator 13, e.g. a number of lead batteries,

for storing direct-voltage electric energy; and two
inverters, of which a first, indicated 14, connects
accumulator 13 to electric generator 11 to permit
electric energy flow to and from electric generator 11,
5 and a second, indicated 15, is connected between
accumulator 13 and grid 2 to permit electric energy flow
to and from grid 2.

More specifically, inverter 14 converts alternating
electric energy at frequency L to direct electric
10 energy, to permit electric energy flow from electric
generator 11 to accumulator 13, or converts direct
electric energy to alternating electric energy at
frequency L, to permit electric energy flow from
accumulator 13 to electric generator 11. Similarly,
15 inverter 15 converts direct electric energy to
alternating electric energy at power frequency F, to
permit electric energy flow from accumulator 13 and/or
inverter 14 to grid 2, or converts electric energy at
power frequency F from grid 2 to direct electric energy,
20 to permit electric energy flow from grid 2 to
accumulator 13.

As shown in the drawing, cogeneration unit 4 has
one or more heat exchangers 16 for producing thermal
energy. More specifically, heat exchangers 16 recover
25 the thermal energy produced by endothermic engine 12 -
e.g. by absorbing it from the exhaust gases and/or
engine block coolant - and possibly by electric
generator 11, to heat a heat-carrying fluid circulating

in a hydraulic circuit 17 through heat exchangers 16.

Finally, cogeneration unit 4 also comprises a control unit 18 for continually acquiring electric power PG, PL, PS measurements from power measuring units 7, 8, 5 9, and controlling endothermic engine 12 and inverters 14 and 15, which preferably, though not necessarily, are pulse width modulation (PWM) operated, as a function of said measurements.

More specifically, control unit 18 has a 10 microprocessor (not shown) programmed to process the electric powers PS, PG, PL measurements, and accordingly real-time control endothermic engine 12 and inverters 14 and 15 to regulate the electric power PG supplied by cogeneration unit 4 so that the sum of electric power PG 15 and electric power PS supplied by discontinuous sources 5 tracks the sum of the electric power PL drawn by the load and a further predetermined net alternating electric power PN_{in} to be fed into grid 2.

In other words, control unit 18 is configured to 20 ensure the electric power produced by cogeneration unit 4 and discontinuous sources 5 as a whole always meets the electric power demand by electric load 3 and by grid 2, seen as a further electric load, by privileging use of discontinuous sources 5, i.e. by only increasing 25 electric power PG in the event of electric power PS falling off to the point of being unable to meet demand by the electric loads.

The control logic with which the microprocessor is

programmed is based on the following alternating electric power balance equation :

$$PS + PG + PN_{out} = PL + PN_{in} \quad (1)$$

where PN_{out} is the net alternating electric power
5 supplied by grid 2 and which is normally zero, since the aim of system 1, in addition to meeting demand by electric load 3, is to feed power into, as opposed to drawing power from, grid 2.

As long as electric power PS supplied by
10 discontinuous sources 5 is sufficient to meet electric power demand, i.e.

$$PS \geq PL + PN_{in}$$

cogeneration unit 4 remains off.

Conversely, when electric power PS is no longer
15 sufficient, control unit 18 commands inverter 14 to draw electric energy from accumulator 13 to power electric generator 11, which acts as a starting motor to immediately start up endothermic engine 12, and commands inverter 15 to draw electric energy from accumulator 13
20 to immediately supply enough electric power PG to meet electric power demand given by $PL + PN_{in}$. As soon as endothermic engine 12 reaches a minimum steady operating speed, control unit 18 commands inverter 14 to produce an opposite electric energy flow to before and produce
25 direct electric energy which is normally used by inverter 15 to supply electric power PG .

In the presence of gradual variations in electric power PL and PS , tracking of the electric power demand

given by $PL + PN_{in}$ is met by acting on fuel supply and so adjusting the speed of the endothermic engine 12. Conversely, in the presence of variations in electric power PL and PS resulting in relatively sharp, high electric power demand peaks, inverter 15 also draws electric energy from accumulator 13.

Accumulator 13 can be recharged by electric generator 11 by means of inverter 14, or, when endothermic engine 12 is off, by grid 2 by means of inverter 15.

The above operating mode enables regulation of electric power PG independently of the response times of endothermic engine 12, which would not be able to track fast variations in electric power PS supplied by discontinuous sources 5. More specifically, using a microprocessor to continually monitor alternating electric powers PS , PG and PL by means of power measuring units 7, 8 and 9, and to real-time control the two inverters 14 and 15, cogeneration unit 4 is capable of regulating electric power PG within its operating dynamics in the space of thousandths of a second.

If even electric power PG supplied by cogeneration unit 4 fails to meet electric power demand, i.e. when electric power PG reaches a predetermined maximum value PG_{max} , no electric energy can be fed into grid 2 ($PN_{in} = 0$), and system 1 is forced to draw alternating electric power from grid 2 (PN_{out}), the amount of which is defined by equation (1) rewritten as follows:

$$PS + PG_{\max} + PN_{\text{out}} = PL$$

The control logic of control unit 18 and relative operation of system 1 have so far been described assuming grid 2 is operating properly, i.e. is capable
5 of supplying alternating electric energy to system 1, or drawing alternating electric energy produced by system 1.

If grid 2 is not operating properly, or does not actually exist, PN_{out} and PN_{in} are always zero, and
10 the alternating electric power balance equation (1) is simplified as follows:

$$PS + PG = PL \quad (2)$$

Operation of control unit 18 and system 1 in the absence of grid 2 is easily inferable from the above
15 description relative to the presence of grid 2, and therefore needs no further explanation, except to state that accumulator 13 is rechargeable by electric generator 11 by means of inverter 14, even in the absence of grid 2.

20 The main advantage of electric energy producing system 1 as described above is that of supplying alternating electric energy in remote areas not adequately catered to by grid 2, and at the same time feeding directly into grid 2 alternating electric energy
25 produced by privileging use of renewable energy sources present in the area.

This therefore enables users to benefit from recent regulations governing electric energy supply, i.e. the

possibility of selling surplus electric energy to the grid 2 provider, on condition that it is produced by renewable energy sources and can be measured by the provider directly from the grid. The grid 2 provider, in fact, is able to meter the amount of alternating electric energy produced by users' discontinuous sources 5 by means of meters 10, and, given the amount of alternating electric energy fed into grid 2 by the user (PN_out), is able to determine how much of this was 10 produced by renewable sources.

System 1 also provides for stable, continuous alternating electric energy supply by employing cogeneration unit 4 described above, which provides for covering non-producing periods of discontinuous sources 15 5 by operating electric generator 11, and for real-time tracking sharp variations in alternating electric power supply PS by discontinuous sources 5 by continuously monitoring alternating electric powers PS, PG, PL by means of power measuring units 7, 8, 9, and accordingly 20 controlling the two inverters 14 and 15.

CLAIMS

1) A system for simultaneously producing electric and thermal energy, and connectable to a grid (2) supplying alternating electric energy; the system (1) comprising a cogeneration unit (4) for generating electric and thermal energy, and for supplying alternating electric energy to an electric load (3); and the system being characterized by comprising at least one discontinuous source (5) of electric energy; first electric energy converting means (6) connected between the discontinuous source (5) and the grid (2) to convert the electric energy produced by the discontinuous source (5) to alternating electric energy for supply to the electric load (3); and alternating electric power measuring means (7, 8, 9) for measuring a first electric power (PG) supplied by the cogeneration unit (4), a second electric power (PL) drawn by the electric load (3), and a third electric power (PS) supplied by the discontinuous source (5); and in that said cogeneration unit (4) comprises processing and control means (18) configured to regulate said first electric power (PG) so that the sum of the first electric power (PG) and third electric power (PS) tracks the sum of the second electric power (PL) and a predetermined alternating fourth electric power (PN_{in}) to be fed into the grid (2).

2) A system as claimed in Claim 1, wherein said

processing and control means (18) regulate said first electric power (PG) to a zero value when said third electric power (PS) at least equals said sum of the second electric power (PL) and fourth electric power
5 (PN_{in}).

3) A system as claimed in Claim 1 or 2, wherein said grid (2) and said electric load (3) respectively carry and draw alternating electric energy at a given power frequency (F); said cogeneration unit (4)
10 comprising a rotary electric generator (11) for producing alternating electric energy at variable frequency (L), and an endothermic engine (12) for keeping the electric generator (11) running.

4) A system as claimed in Claim 3, wherein said
15 processing and control means (18) regulate said first electric power (PG) by varying the speed of said endothermic engine (12).

5) A system as claimed in Claim 3 or 4, wherein said cogeneration unit (4) comprises storage means (13)
20 for storing direct electric energy; second electric energy converting means (14) connecting the storage means (13) to said electric generator (11) to permit energy flow to and from the electric generator (11); and third electric energy converting means (15) connected
25 between the storage means (13) and said grid (2) to permit electric energy flow to and from the grid (2).

6) A system as claimed in Claim 5, wherein said processing and control means (18) control said second

converting means (14) to convert said alternating electric energy at variable frequency (L) to said direct electric energy to recharge said storage means (13) when said grid (2) is unable to supply electric energy.

5 7) A system as claimed in Claim 5 or 6, wherein said processing and control means (18) control said second converting means (14) to convert said alternating electric energy at variable frequency (L) to said direct electric energy, and control said third converting means
10 (15) to convert the direct electric energy supplied directly by the second converting means (14) and/or stored by the storage means (13) to said alternating electric energy at power frequency (F), so that said first electric power (PG) is regulated independently of
15 the response time of said endothermic engine (12).

8) A system as claimed in one of Claims 5 to 7, wherein said electric generator (11) is an electric motor-generator.

9) A system as claimed in Claim 8, wherein said
20 processing and control means (18) control said second converting means (14) to convert the direct electric energy stored by the storage means (13) to said alternating electric energy at variable frequency (L), so as to power said electric motor-generator to start
25 said endothermic engine (12).

10) A system as claimed in one of Claims 5 to 9, wherein said processing and control means (18) control said third converting means (15) to convert said

alternating electric energy at power frequency (F) to said direct electric energy to recharge said storage means (13) when the endothermic engine (12) is off.

11) A system as claimed in one of the foregoing
5 Claims, wherein said cogeneration unit (4) comprises a rotary electric generator (11) for producing alternating electric energy; an endothermic engine (12) for keeping the electric generator (11) running; a hydraulic circuit (17) in which a heat-carrying fluid circulates; and heat
10 exchange means (16) connected to the hydraulic circuit (17) and for recovering thermal energy, produced by the endothermic engine (12), to heat the heat-carrying fluid.

12) A system as claimed in one of the foregoing
15 Claims, wherein said first electric energy converting means comprise at least a first inverter (6).

13) A system as claimed in one of Claims 5 to 12, wherein said second electric energy converting means comprise a second inverter (14), and said third electric
20 energy converting means comprise a third inverter (15).

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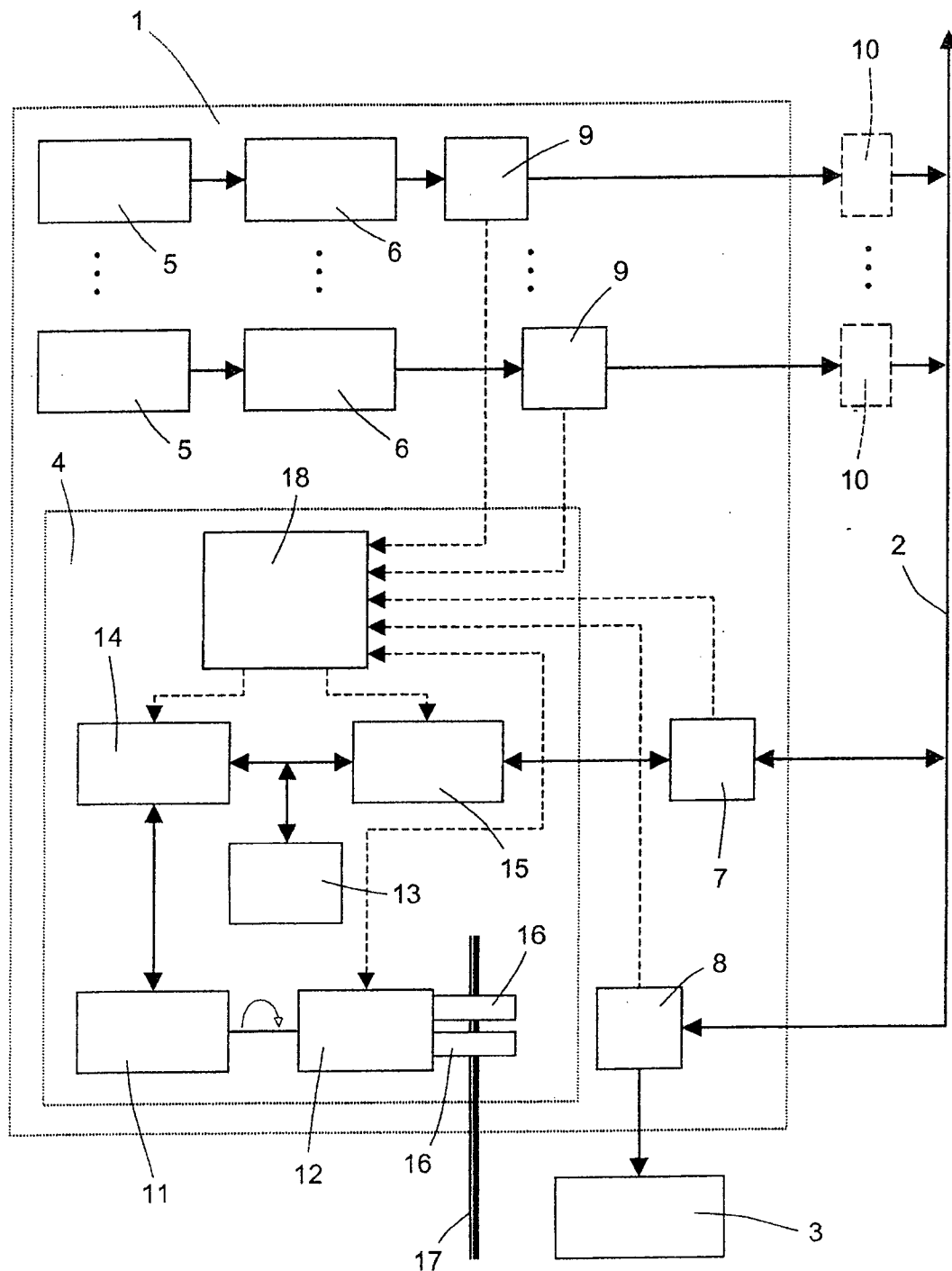


Fig. 1