



(51) International Patent Classification:

H01M 16/00 (2006.01) H02J 3/38 (2006.01)  
F24D 11/00 (2006.01) H01M 8/124 (2016.01)  
F28D 20/02 (2006.01)

(21) International Application Number:

PCT/EP2017/025013

(22) International Filing Date:

23 January 2017 (23.01.2017)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

102016000007103 25 January 2016 (25.01.2016) IT

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(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:

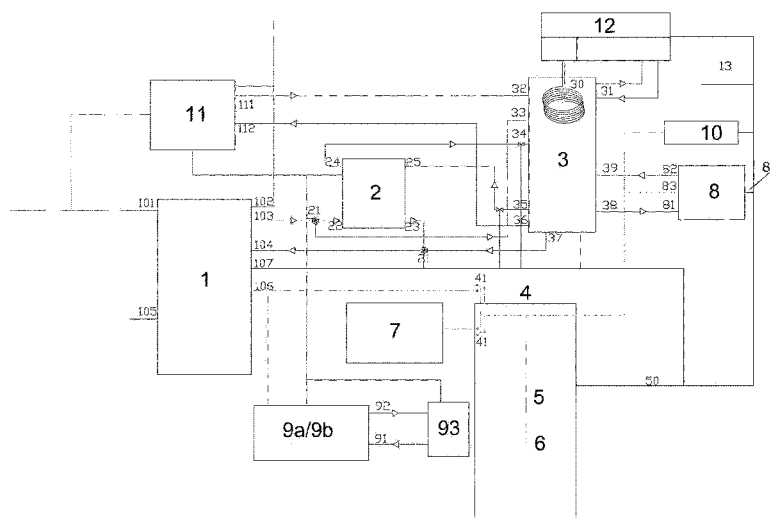
— as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))

Published:

— with international search report (Art. 21(3))

(54) Title: ISLAND SYSTEM FOR THE PRODUCTION OF ELECTRIC AND THERMAL ENERGY

FIG. 1



(57) Abstract: The present invention relates to the field of power generation in the residential, commercial, industrial and public administration spheres both for conventional and stand-alone buildings and specifically relates to an island energy system for the production of electric and thermal energy comprising an SOFC CHP generator which simultaneously produces both heat energy, directed to a latent heat storage comprising a heat exchanger with phase change materials and a sensible heat storage, and electricity directly to an electric storage, a management system and control logic, lithium batteries, a main heat pump, an auxiliary heat pump or an electrolyser in the case of emergency and to the electrical loads of the building.



**Island system for the production of electric and thermal energy.****Description****5** *Field of the invention*

The present invention relates to the field of power generation in the residential, commercial, industrial and public administration spheres both for conventional and stand-alone buildings and specifically relates to an island energy system for the production of electric and thermal energy comprising  
**10** an SOFC CHP generator which simultaneously produces both heat energy, directed to a latent heat storage comprising a heat exchanger with phase change materials and a sensible heat storage, and electricity directly to an electric storage, a management system and control logic, lithium batteries, a main heat pump, an auxiliary heat pump or an electrolyser in the case of  
**15** emergency and to the electrical loads of the building.

*Background of the invention*

Systems are known in the prior art relating to the production of energy at a domestic level where an SOFC cogenerator is integrated for household use, which has a thermal storage of water and is connected to the public power  
**20** grid.

For these systems connection to the public power grid is mandatory since the SOFC cannot be switched on and off instantaneously, so the amount of energy produced and not self-consumed is fed into the public network without any economic advantage.

**25** Additionally, it is known that on the one hand a household CHP generator produces electricity and heat at the same time, while on the other a demand exists characterised by instantaneous variations and otherwise, both as regards the thermal and electrical load. Despite a CHP generator being able to instantaneously modulate its electricity production according to the load

required, it is impossible for it to also provide the heat required in that precise moment given the close correlation between the power and heat production of the CHP generator, all the more because instant thermal and electrical spikes are very often independent of one another.

- 5 Additionally it is known that daily heat consumption for heating and domestic hot water production varies continuously depending on the external conditions, the end-terminals for heating, the building concerned, the time of year and on the presence or absence of people in the building, which is the most unpredictable unknown.
- 10 It is therefore clear that no single configuration of the system can adapt to all the needs and characteristics of the end users.

It follows from the above that in the state of the art a system is not known of equipped simultaneously with a CHP generator with fuel cell technology, a thermal storage and electric storage able to meet the energy needs of the end

- 15 utility.

*Disclosure of the invention*

The purpose of the present invention is to provide the user with the portion of missing energy when the generator fails to adapt instantly to a very high electrical load.

- 20 Another purpose of the present invention is to meet the instantaneous electricity demand of a load in the case in which consumption is greater than the electrical power produced.

Another purpose of the present invention is to ensure a cost saving for the household energy bill resulting from savings in primary energy use for the

25 electrical and thermal requirements of the building.

Another purpose of the present invention is to reduce greenhouse gas emissions and eliminate NO<sub>x</sub>, SO<sub>x</sub> emissions, smog particulate and all the residues resulting from the combustion of a gas.

- Another purpose of the present invention is to ensure energy supplies for
- 30 heating and domestic hot water to buildings in stand-alone mode.

A further, no less important, purpose of the present invention is to adjust the energy flows produced according to demand.

Further characteristics and advantages will be more clearly comprehensible from the description of a preferred but non-limiting embodiment of the island system for the production of electric and thermal energy of the present patent application, illustrated by way of a non-limiting example in the appended drawing wherein:

- Fig. 1 shows a block diagram of the island system for the production of electric and thermal energy, the main components of which are listed below while the others are described in the main text of the detailed description:
- an SOFC CHP generator (1);
  - a latent heat storage comprising a heat exchanger (2) with phase change materials;
  - a sensible heat storage (3);
  - an electric storage (4);
  - a management system and control logic (5);
  - lithium batteries (6);
  - an emergency system (7);
  - a main heat pump (8);
  - an auxiliary heat pump (9a) or an electrolyser (9b);
  - electrical loads (10) of the building;
  - an auxiliary burner (11);
  - heat loads (12);
  - an auxiliary tank (93) for refrigerated water.

**25** *Detailed description of the invention:*

According to a preferred but non-limiting embodiment, the present invention relates to an island system for the production of electric and thermal energy comprising an SOFC (1) CHP generator which simultaneously produces both heat energy, directed at a latent heat storage comprising a heat exchanger (2)

with phase change materials and a sensible heat storage (3), and electricity directly to the electric storage (4), a management system and control logic (5), lithium batteries (6), a main heat pump (8), an auxiliary heat pump (9a) or an electrolyser (9b) in case of emergency and to the electrical loads (10) of the  
**5** building.

In order to self-consume and/or store all the portion of electricity and thermal energy generated by the SOFC (1), the system is equipped with a management system and control logic (5) able to manage and optimise the electric or thermal requirements, the production and the energy flows in play.  
**10** It must also be able to anticipate the hourly consumption of heat and electricity as much as possible and adapt the operation of the system to all the external and internal variables characterising each individual building throughout the year.

The thermal energy directed to the sensible heat storage (3) is produced by the  
**15** auxiliary burner (11).

The system which the present patent application relates to, is provided with an emergency system (7) which supplies the electrical load (10) in case of standard maintenance or possible malfunction of the SOFC (1).

The sensible heat storage (3) has the purpose of separating the supply and  
**20** demand for heat and the electric storage (4) is designed to stabilise stand-alone operation. Another substantial feature of the electric storage (4) is to be able to work in parallel with the CHP generator (1) and thus meet the instantaneous electricity demand of the electrical load (10) in the case of consumption being higher than the electric power produced.

**25** From this it follows that even in the case of the CHP generator (1) being unable to adapt instantly to a very high electrical load (10), the electric storage (4) will provide the missing part of energy and when this load is finished then the CHP generator (1) will recharge the amount of electricity taken from the storage. (4).

However, given that the production of electricity and heat by the CHP generator (1) are related to each other, it will not be possible to follow the instantaneous electrical load (10) without producing heat energy. Storage (4) thus becomes essential since the thermal loads (12) may not be proportional to electrical loads (10) throughout the year. This is accentuated by the fact that the heat demanded during the heating season is much higher than that demanded for the production of domestic hot water which is more or less constant throughout the year. For a correct sizing of the power plant, electric storage (4) and sensible heat storage (3), attention must be paid to both these daily loads as the time of year varies.

In the case of buildings in standalone mode, the electrical and thermal power of most CHP generators on the market is too powerful for the respective loads demanded by small-medium sized buildings, but is well suited to large buildings or building complexes since they work on a "baseload" or base minimum load of the consumption of buildings covering up to a maximum of 20% of electricity requirements. However, it could be worthwhile to adopt a CHP generator that has both these two powers with the same order of magnitude as those demanded by small-medium sized buildings, since it would then be sufficient to merely increase the number of these smaller CHP generators to supply more energy-consuming buildings.

In general the CHP generator (1) is sized based on the minimum thermal power demand during the year, i.e. the summer case if one does not wish to disperse heat at this time of year and thereby lower the overall efficiency and lengthen the economic payback time of the system. This is partly possible in the case of stand-alone buildings since while on the one hand it is essential not to produce more heat than is necessary on a daily basis, on the other it may be necessary to dispel a part so as to supply the electrical load demanded by the building. This could occur if the building has much lower loads than usual and has the sensible heat stores (3) already heavily loaded. A shutdown of the CHP generator (1) could be useful in the case in which the

electric storage (4) is able to supply power for several days, but in other cases (with the thermal storage always heavily loaded) it becomes mandatory to disperse part of this thermal energy outwards. One might think of providing the system according to this patent application with an electrolyser (9b) that  
5 converts the extra electricity produced during these critical moments into hydrogen. Otherwise one might think of having an auxiliary heat pump (9a) which produces cold water to put in a tank (93) to be used for any refrigerant loads or to cool the CHP generator (1).

#### SOFC (1)

10 Given its considerable electrical efficiency, the system covered by this patent application consists of a CHP generator (1) of the solid oxide fuel cell, SOFC, type which due to the presence of solid oxide membranes produces electricity and heat without the combustion of fuel. It is therefore an electrochemical device that needs hydrogen to work but which can potentially use any  
15 hydrocarbon containing hydrogen.

This type of fuel cell, thanks to the reactions occurring at high temperature (above 600° C), via an internal reforming, breaks down the hydrocarbon in input into hydrogen and carbon dioxide which is dissociated into hydrogen ions and electrons by the solid oxide membrane; this type produces electricity  
20 as well as heat by means of an overall exothermic reaction.

All the reactions require: fuel, water vapour, oxygen and thermal energy, while they provide water, carbon dioxide, heat and electricity. And more heat is generated than that required to supply itself. This heat must be removed as soon as possible to avoid overheating and decreases in the overall efficiency  
25 of the electrochemical device.

CHP generation efficiency may exceed 90%. Electrical efficiency generally remains at around 50%, while the remaining percentage is thermal efficiency. The SOFC (1) has such high electrical efficiency despite the low electric power that can be generated since it works at high temperatures and provides  
30 for only chemical reactions and no combustion.

With this information to hand, it is easy to see why at least one main heat pump (8) is needed. This is due to the fact that the heat energy annually produced is much less than the electric energy. As a result of this, one would have much more electrical power than that required during the year and little  
5 thermal energy produced, if one had only the CHP generator (1). The heat pump (8) in addition to making the stand-alone system more stable, makes it possible to convert with great efficiency part of the surplus of electricity produced, into heat energy.

Since the SOFC (1) must generate a quantity of electricity and thermal energy  
10 at least equal to the daily amount, storage systems are needed to meet the peaks in energy demand. As regards its operation, the SOFC (1) will tend to follow the electrical load (10), to depart from it in case of low-charged batteries (6) or withdrawals from the main heat pump (8). It is preferable that the heat generated during operation does not exceed that required during the  
15 day. This is to prevent the sensible heat storage (3) and the latent heat storage, both consisting of tanks, from overloading and requiring the system to dissipate the excess heat produced. The management system and control logic (5) is intended to prevent this as far as possible.

Said management system and control logic (5) is connected to the CHP  
20 generator (1), the electric storage (4) and the electrical loads (10) of the utilities to receive electricity produced by the CHP generator (1) and use said power to charge the electric storage (4) and/or electrical loads (10) of the utilities. Said management system and control logic (5) is further connected to the three-way diverter valve (21) of the hydraulic circuit, to the heat pump (8)  
25 to control the flow of heat energy towards said sensible heat storage (3).

However throughout the year the thermal energy demand for heating and domestic hot water production varies greatly, making the main heat pump (8) work in parallel with the SOFC (1) during the cold months or just the SOFC (1) with partial loads in summer. The CHP generator (1) can adjust its electric  
30 power up to 30% and heat power up to about 50%. So, besides having a daily

heat load (12) to produce, the SOFC (1) must also take into account the portion of electricity continuously absorbed by the main heat pump (8) during the cold months. The management system and control logic (5) housed in the electric storage (4) makes it possible to find this ideal operation point. In the event that the end terminals of the building are capable of providing refrigerant energy, a reversible heat pump capable of producing even temperate cold water could be fitted as the main heat pump (8).

Instead, the auxiliary heat pump (9a) or the electrolyser (9b) are designed to protect the operation of the SOFC (1) during malfunctions or critical moments of the year.

For example, in the case of the electrical load (10) demand being lower than that produced by the CHP generator (1) it may be necessary to isolate the SOFC (1) from the electric storage (4). The CHP generator (1) will then decrease the electric power supplied to satisfy only the electrical load (10) demand of the auxiliary heat pump (9a) or the electrolyser (9b). This is because even in the case of critical moments of low energy requirements the CHP generator (1) must not be turned off but must continue to supply electricity and heat.

Conversely, in the case of the electrical load (10) demand being too low, the management system and the control logic (5) makes a calculation to see the actual thermal energy demand of the building. In the event of there being a demand for heat energy, the management system and control logic (5) makes the main heat pump (8) work. Failure to do so causes the auxiliary heat pump (9a) or the electrolyser (9b) to switch on, producing cold water or hydrogen, respectively. From this the importance of the presence of at least one of these two devices can be seen, to be chosen according to climatic characteristics, the building and type of utility.

The SOFC (1) provides a gas side connection (101) and a flue (102). The hydraulic systems provided are a water supply side (103), a water return side (104) and a drain (105). Lastly there are two last outputs: an electric

connection (106) and the last connection (107) to the management system and control logic (5).

The SOFC (1) according to this patent application is a solid oxide fuel cell CHP generator which uses LPG and oxygen from the air as incoming fuel but  
5 in alternative embodiments, it could be powered by natural mains gas at normal operating pressure or hydrogen. Instead, the water to be heated is made to circulate in a closed hydraulic circuit in communication with said  
10 CHP generator (1), with the latent heat storage comprising a heat exchanger with PCMs (2) and/or with the sensible heat storage (3) via a three-way  
15 diverter valve (21) managed by the management system and control logic (5).

The diverter valve (21) is responsible for making the correct rate of hot water flow according to the needs of the building. For example, during the summer the possibility of not making water circulate in the heat exchanger (2) may be provided for if the demand for domestic hot water is too low for the potential  
15 of the PCMs and to increase their useful life.

The electrical connection (106) of the SOFC (1) reaches one of two interlocked relays (41). If this is on, the transit of current is blocked and the only electrical load (10) that the SOFC (1) can supply is the auxiliary heat pump (9a) or the electrolyser (9b). Instead, if the interlocked relay (41) is off,  
20 the electricity produced reaches as far as the electric storage (4) to then flow to or from electrical loads (10), or to the main heat pump (8) or lastly to the lithium batteries (6).

For the SOFC (1) a connection to the drain (105) for the collection of condensed water and remote monitoring is provided for, GPRS coverage  
25 2G/3G is therefore recommended.

In compliance with technical regulations, the installation room must be provided with appropriate safety equipment, such as gas detector, safety NC solenoid valve located on the fuel supply line and accessible shut-off valve with manual override installed upstream of the system.

Said CHP generator (1) has on and off times to the order of 6-8 hours each and it is not advisable to have more than ten of these on-off cycles per year. For the patent application in question, which has as its scope of application both traditional and new buildings of all types, such as residential, 5 commercial, industrial and government buildings, these aspects are beneficial and necessary for the continuous operation of the energy system for the supply of electrical (10) and heat loads (12) required moment by moment, day by day.

Even if the CHP generator (1) were able to work continuously throughout the 10 year, routine maintenance should always be scheduled. In this case, the electrical load (10) must necessarily be provided by an emergency system (7) capable of delivering the electricity needed, isolating the SOFC (1) from the utility system. Said emergency system (7), subject to availability, may connect directly to the national grid, or be a generator.

15 Two interlocked relays (41) are provided which isolate the SOFC (1) when the electrical load (10) is connected to the emergency system (7) or isolate the latter when the SOFC (1) is connected to the internal network of the building. The building may have to be connected to the emergency system (7) in the event of malfunction of a component other than the CHP generator (1), 20 in these cases the emergency system (7) would supply the electrical load (10) while the SOFC (1) would continue to produce both thermal energy and refrigerant energy or hydrogen respectively by means of an auxiliary heat pump (9a) or an electrolyser (9b).

To avoid having an overly cumbersome sensible heat storage (3), the system 25 is fitted with a main heat pump (8) in parallel with the CHP generator (1) which works above all during the heating season and which as well as making the stand-alone system more stable, makes it possible to convert with great efficiency part of the surplus electricity produced into heat energy. This would allow a medium-small sensible heat storage (3) but able to handle 30 larger fluctuations such as prolonged decreases in electrical or thermal loads.

This electricity-heat energy binomial allows greater flexibility in the system and thus significant energy security of the building. However, during the year serious problems can arise especially if the building is situated in a very severe climate. This is because the case could arise in which the electrical load (10) demand of the building added to that needed for the main heat pump (8) for the production of thermal energy is greater than the electrical output of the CHP generator (1) for too long a period of time. Therefore in these cases, the system is equipped with an auxiliary burner (11) for the coldest peaks of the year and to reduce the power consumption of the heat pump (8).

#### 10 HEAT PUMP (8)

The main heat pump (8) will depend on the type of end terminals present in the building. In the case of radiators in fact, heat pumps (8) at medium temperature will be provided, in the case of convector fans and radiant panels, heat pumps (8) at low temperature. The latter case may result in the presence of a reversible main heat pump (8) i.e. able to generate heat or refrigerant energy depending on the season.

Since the performance of air-water heat pumps falls as the outside temperature decreases, preheating systems of the air entering the heat pump (8) may be provided and/or it may be made to work in the hottest moments of the day and store the heat produced in the sensible heat storage (3).

As explained earlier, the heat pump (8) makes it possible to transform the extra electricity produced by the SOFC (1) and not self-consumed by electrical loads (10) into heat energy. And being in a stand-alone configuration, the main heat pump (8) would provide more stability and significant versatility by being able to convert electrical energy into thermal energy with excellent efficiency coefficients. This feature also allows savings in fuel for the same thermal energy dispensed. If there were only the SOFC (1), the production of electricity would be vastly greater than that consumed with a large input of electricity into the network and thus an increase in fuel

consumption. This case is therefore not possible because it would disperse the excess heat produced or the surplus electricity into the atmosphere .

The main heat pump (8) in addition to the external supply and return connection with the air or earth, is connected to the sensible heat storage (3) through a supply and return hydraulic circuit (82, 81). In addition there is an electrical connection (83) to meet the power consumption and a connection (84) for the management system and control logic (5) which manages the switching on and off of the main heat pump (8) as internal and external conditions change.

10 The management system and control logic (5) will take into consideration the type of heat pump installed, the end terminals present in the building as well as all the external and internal conditions.

#### HEAT EXCHANGER (2) WITH PHASE CHANGE MATERIALS (PCM).

The latent heat storage comprises a heat exchanger (2) with phase change materials such as organic materials but there is nothing to prevent the use of other types of phase change materials in alternative embodiments. The heat exchanger (2) is hydraulically connected to the CHP generator (1) to accumulate the heat energy produced by it. To increase the stored energy-occupied volume ratio as much as possible, the storage system is equipped with a heat exchanger (2) containing phase change materials (PCMs). PCMs are able to amass a significant amount of thermal energy, with a high energy/volume ratio during their phase change although they have a characteristic time of charging and discharging which is not comparable to other fluids such as water. This is due to their very low thermal conductivity, which considerably extends the characteristic storage times.

This defect may however be solved by resorting to the presence of both traditional heat storage, such as conventional water tanks, and a heat exchanger (2) which reduces the characteristic charging and discharging time of these PCMs.

The main feature of the use of PCMs in this system is that they work in parallel with other heat generators, i.e. the SOFC (1) and/or the main heat pump (8). Thus the sum of the three heat outputs generated-in the case of the main heat pump (8) also being on-will amount to the demand, with a consequent saving in power consumption of the main heat pump (8) which will need to supply less power than that without the PCMs.

By making water to be cooled or to be heated flow in the heat exchanger (2) with PCMs and having respectively reached the melting or freezing temperature of said phase change materials, there is an increase or decrease of the thermal energy accumulated in said PCMs despite the temperature in the PCMs remaining constant (some PCMs have a range of melting and freezing temperatures and not a unique value). When the phase change material has become completely molten or solid, then the temperature of these materials will once again increase or decrease.

The melting or freezing temperature is a key feature which influences the choice of the phase change material. Other important variables are for example the high latent melting heat per unit of volume, chemical stability and low costs or widespread availability on the market. However, a predominant role is played by the ability of the heat exchanger (2) to exchange thermal energy with the heat transfer fluid such as water. In fact almost all the PCMs have low thermal conductivity which must be increased through the use of finned tubes, metallic matrices or grids, cascade exchangers or metal foams.

In addition to this, the PCMs degrade as the number of thermal charge and discharge cycles increases. This has increasingly less influence as the chemical stability of these phase change materials increases. At the end of their useful life in fact, the PCMs will be replaced either because of the excessive chemical instability which they have reached, or because their melting (or freezing) heat has become extremely reduced. Given the cost and the deterioration of some of these PCMs for a large number of charging/

discharging cycles it may be advantageous, depending on the needs of the building, to suspend operation of the PCMs in summer. Thus in summer, the SOFC (1) goes to directly heat the sensible heat storage (3) thanks to the three-way diverter valve (21) which is instead totally closed towards the heat exchanger (2) with PCMs.

The heat exchanger (2) with PCMs is composed of three sectors sealed from each other. In the lowest, water (22) coming from the three-way diverter valve (21) or water (23) directed to the second three-way diverter valve (21) enters and exits respectively. In the central sector the PCMs warming or transferring heat to finned heat pipes which are the preferential route of this heat exchange, are housed. The highest sector has an inlet (25) and an outlet (24). The first comes from the sensible heat storage (3) and the second flows towards it.

Sensors (13) may be provided which monitor the temperature and estimate the amount of heat energy stored in the PCMs, for this reason a connection to the management system and control logic (5) is present which is provided with an adaptive algorithm that checks the external environmental conditions to forecast the daily heat load of the building.

#### SENSIBLE HEAT STORAGE (3)

The sensible heat storage (3) aims to satisfy the thermal load (12) demand of the building, divided into the load for domestic hot water DHW and the load for heating. The management and optimisation of all these energy flows is performed by a software (50) implemented in the management system and control logic (5) installed in the electric storage (4) partly thanks to the presence of sensors (13) both in the other components of the system and in the environments to be conditioned.

The sensible heat storage (3) is hydraulically connected to the CHP generator (1) and to the latent heat storage to store thermal energy from the CHP generator (1) or from the latent heat storage. The sensible heat storage (3) is nothing more than a hot water tank.

The number and size of the sensible heat storage units (3) will be determined according to the type of end-terminals in the building such as radiators, convector fans, radiant panels or otherwise. Each type has its own maximum and minimum operating temperature which must be taken into account in the

**5** sizing of the sensitive heat storage (3).

The circuit used for heating is a closed circuit. In other words, no heat exchange coils are provided in the sensible heat storage (3) except for the coil (30) used for domestic hot water DHW.

All the other circuits i.e. those coming from or going to the heat exchanger (2)

**10** with the PCMs, to the three-way diverter valve (21), to the main heat pump (8) and to the heating system, have the same heat transfer fluid which will thus not need to be continuously filtered as instead is necessary for the water network. This installation choice would take advantage of the ability of water to stratify the heat.

**15** The sensible heat storage (3) is thus provided with:

- a heat exchange coil (30) used for the domestic hot water;
- an inlet (33) coming from the three-way diverter valve (21) coming in turn from the SOFC (1);
- an outlet (37) directed to the three-way diverter valve (21) directed in turn

**20** from the SOFC (1);

- an inlet (34) coming from the heat exchanger with PCMs (2);
- an outlet (35) directed to the heat exchanger with PCMs(2);
- an inlet (32) coming from the auxiliary burner (11);
- an outlet (36) directed to the auxiliary burner (11);

**25** -an inlet (39) coming from the main heat pump (8);

- an outlet (38) directed to the main heat pump (8);
- an inlet coming from the end-terminals of the utility (31);
- an outlet towards the end-terminals of the utility (31).

If the end-terminals of the utility (31) are not able to deliver refrigerant

**30** energy, at the end of the heating period, the outlets for the end terminals will

be closed and the hot water will be used only to heat the coil (30) of the domestic hot water. Sensors (13) may be provided which monitor the temperature and estimate the amount of heat energy stored in the sensible heat storage (3), for this reason a connection to the management system and  
5 control logic (5) is present which is provided with an adaptive algorithm that checks the external environmental conditions to forecast the daily heat load of the building.

#### ELECTRIC STORAGE (4)

The electric storage (4), like the main heat pump (8) and the sensible heat  
10 storage (3), concurs to keeping the stand-alone system in a condition to be able to operate throughout the year. In fact, thanks to the electric storage (4) it is possible to supply the instant electrical power peaks which the CHP generator (1) cannot supply quickly. When the electrical load (10) is disconnected, then the CHP generator (1), which continues to produce the  
15 same amount of electricity as before the peak consumption, will recharge the lithium batteries (6).

The second of the two interlocked relays (41) which is designed to isolate the SOFC (1) from the emergency system (7) is in the electric storage (4). The emergency system (7) could come into operation in case of malfunctions and  
20 maintenance of the CHP generator (1). Having available a possible connection to the mains or the presence of a generator, in the first case it would be possible to supply the energy demand of the building while performing maintenance on the CHP generator (1).

The electric storage (4) is equipped with one or more packs of lithium  
25 batteries (6) monitored and managed by its own management system and control logic (5).

Said lithium batteries (6) have a structure with new elements which lengthen the number of life cycles thereof. The BMS (battery management system) monitors the most important electrical characteristics such as the temperature

and voltage of the cells, this way it is able to diagnose faults or malfunctions to prevent problems (such as the rupture of the cell) of the batteries (6).

The purpose of the electric storage (4) is thus to store the electricity generated by SOFC (1) in the lithium batteries (6) during periods of reduced load and  
5 make it available during times of greatest consumption, such as in the evening and night or to contribute more power to the load, such as the main heat pump (8).

In the case of a fully charged lithium battery (6) the management system and control logic (5) would turn on the main heat pump (8) if further thermal  
10 energy were needed by the building, or would run the auxiliary heat pump (9a) or the electrolyser (9b) and produce either refrigerant energy or hydrogen for the SOFC (1). Meanwhile the CHP generator (1) would reach an operating point as close as possible to the electrical load (10) required.

In the case of a flat lithium battery (6) instead, the SOFC (1) begins to provide  
15 a higher electric power than the electrical load (10) to recharge the electric storage (4). Given the wide range of situations, it is clear that the management system and control logic (5) is the real core of the system and permits the entire functioning of the stand-alone building.

The nominal efficiency of the lithium battery (6) is greater than 90% in C / 3  
20 at 25 ° C. Another predominant property is the high number of cycles both at 90% of the depth of discharge (over 6000 cycles with the end of life at 60% of the initial energy storage), and at 80% of the depth of discharge (about 10000 cycles).

Moreover the operating temperature must not exceed 40° C and natural  
25 convection is sufficient to cool the heat produced during operating hours.

All the connections to the various devices in the system come from the electric storage (4) and all the information in input and output is handled by the software (50) installed on the management system and control logic (5). This decides each time how much power supply must be produced acting on  
30 the input flow to the SOFC (1), how much heat output must be produced by

the heat pump (8), what flow rate must pass through the various circuits and if the CHP generator must be isolated (1) and the emergency system (7) used.

The initial inputs which must be provided to the software (50) of the management system and control logic (5) to adapt with adequate accuracy

**5** are:

- number of apartments or buildings served;
- estimate of the average number of people forecast;
- location and climatic conditions of the place;
- heating requirements;

**10** -nominal and minimum power at partial loads of the main heat pump (8);

- COP or coefficient of performance of the main heat pump (8) shown in the data sheet;

-maximum energy which can be stored by the heat exchanger (2) with PCMs and their charging and discharging times;

**15** -maximum energy which can be stored in the electric storage (4).

For the collection of data from the management system and control logic (5), a database running on a web server may be implemented which may allow remote control by the utilities.

The management system and control logic (5) includes a logical device

**20** connected to the aforesaid two-way relay (41) to manage the electricity generated by the CHP generator (1) according to the energy demand of the electrical loads (10) of the utilities, being configured to check said relay (41) to obtain the following electrical demand management configurations:

**25** - POSITION 1: the electrical loads (10) of the utilities are powered with electricity produced by the CHP generator (1);

- POSITION 2: in which the electric storage (4) is charged by the electricity produced by the CHP generator (1);

**30** - POSITION 3: in which the electric storage (4) is fully charged and the electricity produced by the CHP generator (1) and not consumed by electrical loads (10) is self-consumed by the main heat pump (8);

- POSITION 4: in which all the power supply demand of the utilities is supplied simultaneously via the CHP generator (1) and the electric storage (4);

5 - POSITION 5: in which the electric storage (4) is charged, the CHP generator (1) produces more electricity than the demand of all the electrical loads (10) (including the main heat pump (8)) and the electrical energy is directed towards the auxiliary heat pump (9a) or alternatively to the electrolyser (9b);

10 - POSITION 6: wherein the control relay (41) changes its position and the CHP generator (1) is isolated while the electric storage (4) is connected to an external back-up source (mains or generator). This can happen during maintenance of the CHP generator (1) or in case of breakage or malfunctions. AUXILIARY HEAT PUMP (9a) / ELECTROLYZER (9b) and AUXILIARY BURNER (11).

15 The auxiliary heat pump (9a) or the electrolyser (9b) is designed to solve the possible critical situations which might arise in certain climatic conditions or at certain times of the year.

The function of the auxiliary heat pump (9a) or the electrolyser (9b) is to make the SOFC (1) operate both when the electrical load (10) demand is too  
20 low and when it no longer supplies the electrical loads (10) of the building by means of the two interlocked relays (41). Using the electricity produced by the CHP generator (1) this is prevented from turning off and in the meantime dissipates in resistance, going to produce more thermal energy than that required by the software (50) of the management system and control logic (5).

25 The auxiliary heat pump (9a) or the electrolyser (9b) is connected to a tank (93) which in the first case stores refrigerant energy and in the second hydrogen.

The auxiliary heat pump (9a) or the electrolyser (9b) are therefore electrically connected to the SOFC (1) and to a tank (93) which will be respectively of  
30 cold water or hydrogen. The usefulness of the cold water is the ability to cool

the SOFC to maintain as ideal operating conditions as possible. The usefulness of the hydrogen is instead its direct use as fuel for the SOFC (1). The choice of one or the other device will vary depending on the weather and the type of building and end terminals. In the case of an auxiliary heat pump  
5 (9a), this will produce cold water to be stored in the tank (93) through the supply and return hydraulic circuit (92, 91). In the case of an electrolyser (9b), the hydrogen produced is stored in a cylinder for metal hydrides which is able to store hydrogen and then send it to the SOFC (1).

The auxiliary burner (11) instead has the purpose of balancing electric and  
10 heat production depending on the load demand. It is possible in fact that certain situations during the year show an excessive imbalance of one energy compared to the other. In the event that too much electricity compared to heat is produced, the management system and control logic (5) will make the main heat pump (8) and/or the auxiliary heat pump (9a) or the electrolyser (9b)  
15 produce. Conversely, i.e. if there is too much heat to be generated, and the main heat pump (8) is already in operation, the auxiliary burner (11) must be used to supply thermal energy to the sensible heat storage (3) via a supply and return hydraulic circuit (111, 112). The burner (11) uses the same hydrocarbon consumed by the SOFC (1) with the exception of hydrogen  
20 which will be exclusively for the CHP generator (1).

The materials and the dimensions of the invention as described above, illustrated in the appended drawings and later claimed, may be any as needed. Moreover all the details may be replaced with others technically equivalent, without departing from the scope of protection of the present patent  
25 application.

## Claims

1. Island system for the production of electric and thermal energy characterised in that it comprises:
- 5 - a solid oxide fuel cell CHP generator (1) which uses LPG or natural mains gas at normal pressure or hydrogen and oxygen from the air as incoming fuel;
- a latent heat storage comprising a heat exchanger (2) with phase change materials such as organic materials and hydraulically connected to the CHP generator (1) to accumulate heat energy produced by it;
- 10 - a sensible heat storage (3) which is a hot water tank hydraulically connected to the CHP generator (1) and to the latent heat storage to store thermal energy from the CHP generator (1) or from the latent heat storage;
- 15 - a closed hydraulic circuit which connects the CHP generator (1), the latent heat storage comprising a heat exchanger (2) and the sensible heat storage (3) via a three-way diverter valve (21);
- an electric storage (4) to store electricity;
- a management system and control logic (5):
- 20 • which is housed in the electric storage (4);
- on which a software (50) is implemented;
- which is connected to the CHP generator (1), to the electric storage (4) and to the electrical loads (10) of the utilities to receive electricity produced by the CHP generator (1) and use said power to
- 25 charge the electric storage (4) and/or electrical loads (10) of the utilities;
- which is connected to the three-way diverter valve (21) of the hydraulic circuit, to the heat pump (8) to control the flow of heat energy towards said sensible heat storage (3).

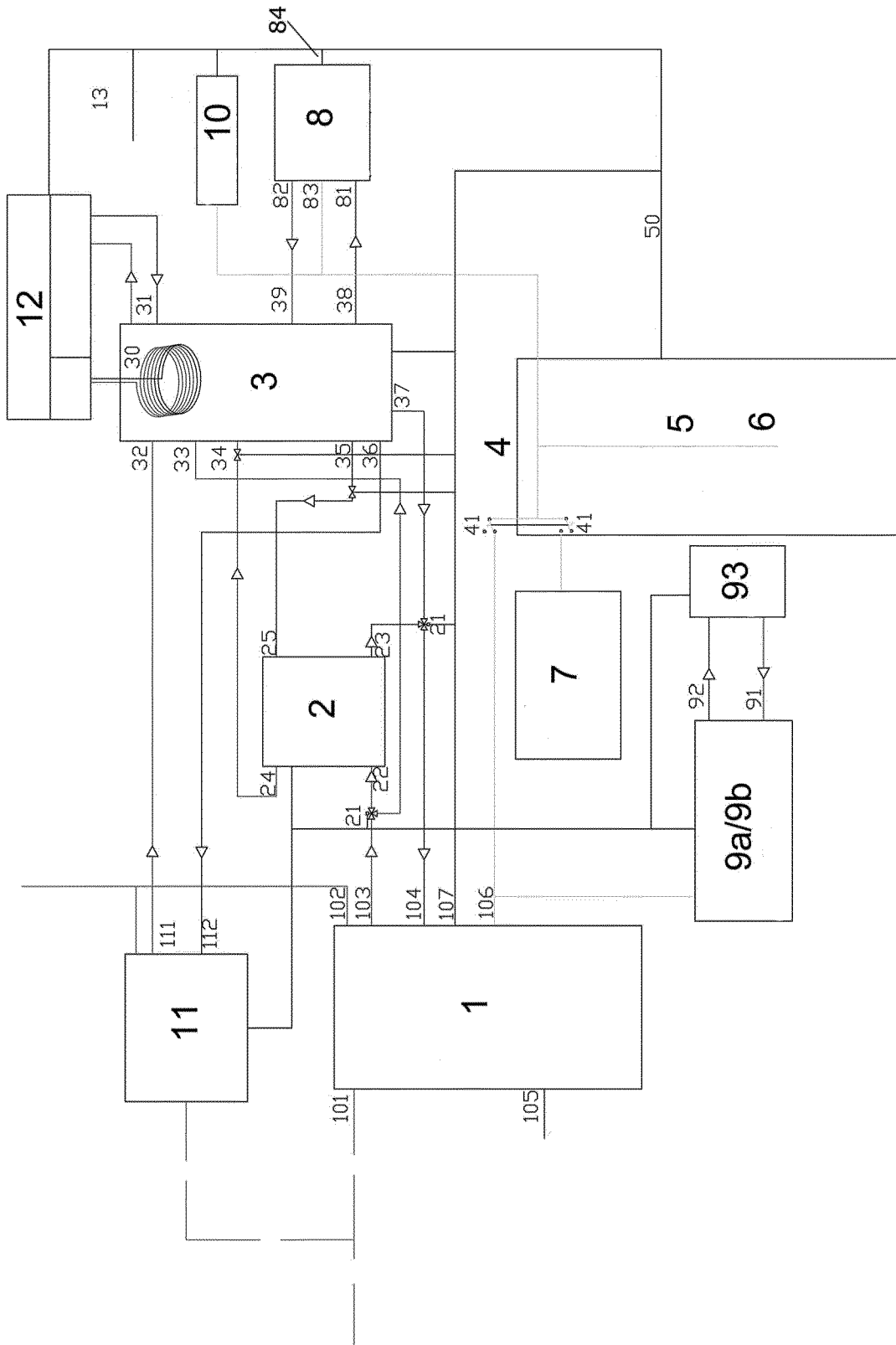
- which is provided with an adaptive algorithm that checks the external environmental conditions to forecast the daily heat load of the building;
  - lithium batteries (6) housed in the electric storage (4);
- 5**
- an emergency system (7) which supplies an electrical load (10) in case of maintenance or malfunction of the SOFC (1)
  - a heat pump (8) which transforms into thermal energy the extra electricity produced by the SOFC (1) and not self-consumed by electrical loads (10) and connected to the sensible heat storage (3) via a
- 10**
- supply and return hydraulic circuit (82, 81);
  - an auxiliary heat pump (9a) which produces cold water to put in a tank (93) to be used for refrigerant loads or to cool the CHP generator (1) or an electrolyser (9b) which converts into hydrogen the excess electricity produced by the CHP generator (1);
- 15**
- electrical loads (10) of the building;
  - an auxiliary burner (11) which provides the thermal energy to the sensible heat storage (3) via a supply and return hydraulic circuit (111, 112);
  - heat loads (12).
- 20**
- 2.** Island system for the production of electric and thermal energy according to claim 1 characterised in that the SOFC (1) provides for:
- a gas side connection (101);
  - a flue (102);
  - a hydraulic circuit comprising a water supply side (103), a water
- 25**
- return side (104) and a drain (105);
  - an electric connection (106);
  - a connection (107) to the management system and control logic (5).

3. Island system for the production of electric and thermal energy according to claim 1 characterised in that the sensible heat storage (3) has:
- a heat exchange coil (30) used for the domestic hot water;
  - 5 - an inlet (33) coming from the three-way diverter valve (21) coming in turn from the SOFC (1);
  - an outlet (37) directed to the three-way diverter valve (21) directed in turn from the SOFC (1);
  - an inlet (34) coming from the heat exchanger with PCMs (2);
  - 10 - an outlet (35) directed to the heat exchanger with PCMs (2);
  - an inlet (32) coming from the auxiliary burner (11);
  - an outlet (36) directed to the auxiliary burner (11);
  - an inlet (39) coming from the main heat pump (8);
  - an outlet (38) directed to the main heat pump (8);
  - 15 - an inlet coming from the end-terminals of the utility (31);
  - an outlet towards the end-terminals of the utility (31).
4. Island system for the production of electric and thermal energy according to claim 1 characterised in that the heat exchanger with the PCMs (2) is composed of three sectors sealed from each other, wherein:
- 20 - water (22) coming from the three-way diverter valve (21) or water (23) directed to the second three-way diverter valve (21) enters the lowest;
  - the PCMs warming or transferring heat to finned heat pipes which are the heat exchange route, are housed in the central sector;
  - the highest sector has an inlet (25) from the sensible heat storage (3)
  - 25 and an outlet (24) towards it.
5. Island system for the production of electric and thermal energy according to claim 1 characterised in that the auxiliary heat pump (9a) produces cold water to store in the tank (93) via a supply and return hydraulic circuit (92, 91).

6. Island system for the production of electric and thermal energy according to claim 1 characterised in that the main heat pump (8) is provided with an electrical connection (83) to meet the power consumption and a connection (84) for the management system and control logic (5) which manages the switching on and off of the main heat pump (8) as internal and external conditions change.
7. Island system for the production of electric and thermal energy according to claim 1 characterised in that two interlocked relays (41) isolate the SOFC (1) when the electrical load (10) is connected to the emergency system (7), of which one is connected to the electrical connection (106) of the SOFC (1) and the other is located inside the electric storage (4).
8. Island system for the production of electric and thermal energy according to claims 1 and 7 characterised in that when the interlocked relay (41) is opened the flow of current is prevented and the electric load (10) supplied by the SOFC (1) is the auxiliary heat pump (9a) or the electrolyser (9b) while when it is closed the electricity produced reaches as far as the electric storage (4) and then flows towards the electrical loads (10) , or towards the main heat pump (8) or lastly towards the lithium batteries (6).
9. Island system for the production of electric and thermal energy according to claim 1 characterised in that the management system and control logic (5) is configured to check the relay (41) to obtain the following management configurations of the electrical demand:
- POSITION 1: the electrical loads (10) of the utilities are powered with electricity produced by the CHP generator (1);
  - POSITION 2: in which the electric storage (4) is charged by the electricity produced by the CHP generator (1);

- POSITION 3: in which the electric storage (4) is fully charged and the electricity produced by the CHP generator (1) and not consumed by electrical loads (10) is self-consumed by the main heat pump (8);
  - POSITION 4: in which all the power supply demanded by the utilities is delivered simultaneously via the CHP generator (1) and the electric storage (4);
  - POSITION 5: in which the electric storage (4) is charged, the CHP generator (1) produces more electricity than the demand of all the electrical loads (10) (including the main heat pump (8)) and the electrical energy is directed towards the auxiliary heat pump (9a) or alternatively to the electrolyzer (9b);
  - POSITION 6: wherein the control relay (41) changes its position and the CHP generator (1) is isolated while the electric storage (4) is connected to an external back-up source (mains or generator).
- 10**    **10.** Island system for the production of electric and thermal energy according to claim 1 characterised in that the heat exchanger (2) with PCMs and the sensible heat storage (3) are connected to sensors (13) which monitor the temperature and estimate the amount of stored thermal energy via a connection to the management system and control logic (5).

FIG. 1



**INTERNATIONAL SEARCH REPORT**

International application No  
PCT/EP2017/025013

**A. CLASSIFICATION OF SUBJECT MATTER**  
 INV. H01M16/00 F24D11/00 F28D20/02 H02J3/38  
 ADD. H01M8/124

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**  
 Minimum documentation searched (classification system followed by classification symbols)  
 H01M F24D F28D H02J

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)  
 EPO-Internal, WPI Data

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP 1 172 874 A2 (SULZER HEXIS AG [CH]) 16 January 2002 (2002-01-16) abstract; figure 1 paragraph [0007] - paragraph [0013] paragraph [0015]	1-10
A	EP 1 798 488 A2 (VAILLANT GMBH [DE]) 20 June 2007 (2007-06-20) figures 1, 2 paragraph [0016] - paragraph [0019]	1-10
A	US 2013/189594 A1 (BREIT JOSEPH SHERMAN [US] ET AL) 25 July 2013 (2013-07-25) abstract; figure 8	1-10
A	WO 2015/046464 A1 (KYOCERA CORP) 2 April 2015 (2015-04-02) abstract; figures 1, 2, 5, 6	1-10
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Further documents are listed in the continuation of Box C.

See patent family annex.

\* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search <b>29 March 2017</b>	Date of mailing of the international search report <b>10/04/2017</b>
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Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Authorized officer  <b>Pipoli, Tiziana</b>
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## INTERNATIONAL SEARCH REPORT

International application No  
PCT/EP2017/025013

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	& EP 3 051 228 A1 (KYOCERA CORP [JP]) 3 August 2016 (2016-08-03) ----- DE 10 2013 204162 A1 (BOSCH GMBH ROBERT [DE]) 11 September 2014 (2014-09-11) paragraph [0009] - paragraph [0022]; figure 1 abstract -----	1-10

# INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No PCT/EP2017/025013
---

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 1172874	A2	16-01-2002	NONE
-----			
EP 1798488	A2	20-06-2007	AT 478309 T 15-09-2010
		AT 502649 A4	15-05-2007
		DK 1798488 T3	29-11-2010
		EP 1798488 A2	20-06-2007
-----			
US 2013189594	A1	25-07-2013	EP 2621010 A1 31-07-2013
		JP 2013191545 A	26-09-2013
		US 2013189594 A1	25-07-2013
		US 2016380279 A1	29-12-2016
-----			
WO 2015046464	A1	02-04-2015	CN 105593613 A 18-05-2016
		EP 3051228 A1	03-08-2016
		JP WO2015046464 A1	09-03-2017
		KR 20160045110 A	26-04-2016
		US 2016211534 A1	21-07-2016
		WO 2015046464 A1	02-04-2015
-----			
DE 102013204162	A1	11-09-2014	CN 105190186 A 23-12-2015
		DE 102013204162 A1	11-09-2014
		EP 2971980 A1	20-01-2016
		JP 2016515190 A	26-05-2016
		WO 2014139712 A1	18-09-2014
-----			