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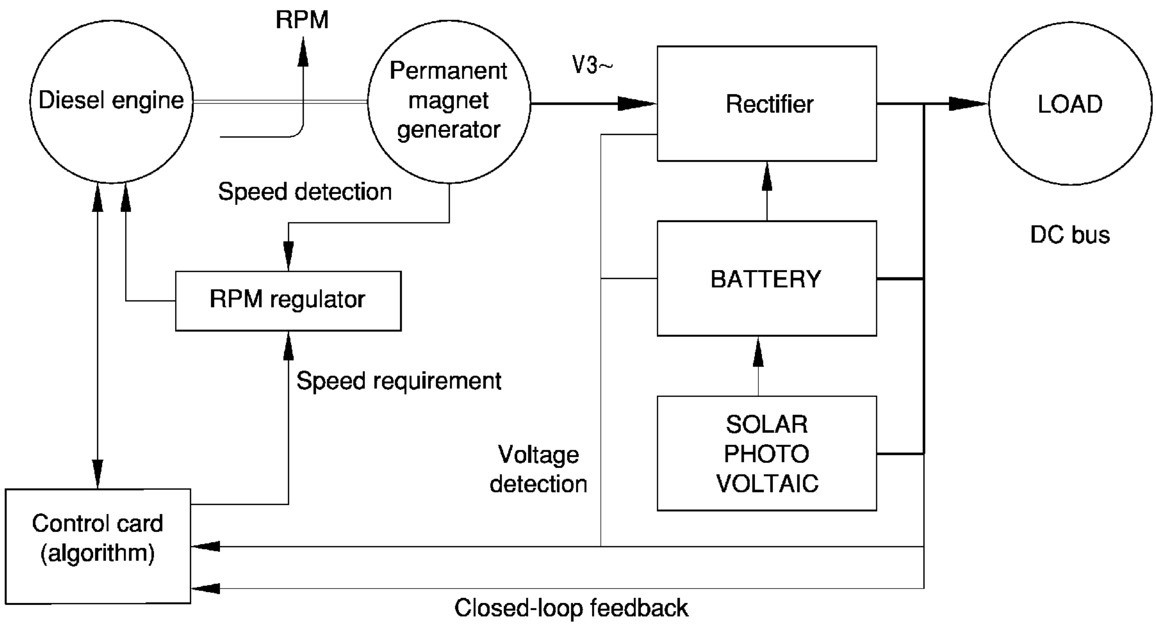

Fig.3

(57) Abstract: Equipment for voltage (V) and current (I) feed of an electric load comprised of a load (LOAD) with substantially fixed current absorption and of a storage battery (Battery BANK) with current absorption variable according to the actual charge volume (Charge Volume) thereof, said equipment comprising a variable RPM engine (Engine) and an alternator (PMG) actuated by means of said engine (Engine), the equipment furthermore comprising regulating means (RPM regulator) for regulating the number of revolutions (RPM) of said engine (Engine) so as to generate an output voltage (VG) from said alternator (PGM) variable according to the number of revolutions (RPM) of said engine (Engine).

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EQUIPMENT FOR VOLTAGE (V) AND CURRENT (I) FEED OF AN ELECTRIC LOAD

DESCRIPTION

The present invention relates to the technical field of charging storage batteries like batteries or battery banks or the like. In particular, the present invention relates to an equipment for voltage and current feed of an electric load comprised of a load with substantially fixed current absorption and of a storage battery with current absorption variable according to the status and/or actual charge volume thereof. In more detail, the present invention relates to an equipment as mentioned above, the equipment comprising a variable RPM engine (for example an endothermic engine) and an alternator actuated by means of the engine, wherein the number of revolutions of the engine is regulated according to a target voltage that can be set by the user.

PRIOR ART

Variable RPM engines are well known in the prior art, used for charging storage batteries and the like. A typical example of use of a variable RPM engine (in the specific case an internal combustion diesel endothermic engine) for charging a battery pack (Battery Pack) is illustrated in Fig. 2.

This Figure illustrates, in particular, a diesel engine (Diesel Engine), an alternator (PGM) actuated (driven into rotation) by means of the engine so as to generate an output voltage variable according to the number of revolutions (RPM) of the engine, a load (LOAD) with substantially fixed current absorption, and a battery pack (Battery Pack) connected to both the load and the alternator by means of a common bus (DC Bus).

In Figure 2 regulating means (RPM regulator) are also illustrated, for regulating the number of revolutions of the engine, as well as rectifying means (regulated AVR Rectifier) for converting alternating three-phase current to direct current with minimized ripples; practically, the rectifying means are usually constituted by an integrated system provided with a plurality of sensors, for measuring parameters of operation and/or use (voltage, current, temperature and/or similar parameters), a rectifier inverter, and control electronics to stabilize and adjust the output current.

In the case of the system illustrated in Figure 2, the typical and/or standard operation provides for the following: when the batteries are charged enough, the current absorbed by the load is supplied by them; contrarily, when the batteries are not enough charged, the engine is actuated for simultaneously feeding both the load and the batteries, i.e. so as to supply both the power required (absorbed) by the load and the power necessary for progressively charging the batteries, wherein as the charge in the batteries increases, the number of revolutions of the engine decreases.

It should be noted that charging a battery (or a battery pack) shall comply with the specifications given by the battery manufacturer; namely, charging a battery according to different specifications may cause even serious damages, such as a reduction in the accumulated charge (and therefore in the current that can be supplied), as well as a reduction in the battery useful life.

Figure 1 shows an example of charge specifications.

As schematized in Figure 1, a full charge cycle comprises various steps, the charge voltage and current varying according to the steps. In fact, as it is well known, while charging a battery, given the same charge voltage, the current absorbed by the battery varies according to the actual charge of the battery. The charge cycle provides therefore for a first step (Time = t), wherein the current increases so as to achieve the saturation value (approximately 25% of the battery pack capacity expressed in Ah) and the voltage gradually increases up to achieve the optimal voltage. In the following step (Time = t/2), voltage remains constant and current decreases; lastly, in the third step (Floating) voltage is kept at the equalization value and current remains at the minimum value to complete battery equalization, equalization being of importance for decreasing the cell self-discharge and increasing the batter useful life.

Obviously, the load curve represented by way of example in Fig. 1 relates to a specific battery, being intended that different load curves correspond to different batteries.

From what above it is clearly apparent that there is the need for charge systems that are as versatile as possible, i.e. that are able to generate voltages and currents compatible with different load curves.

In the prior art system shown in Fig. 2, the output voltages and currents from the alternator are adjusted to the different load curves by means of the above mentioned rectifying means.

However, the use of outer regulators like those represented in Fig. 2 (AVR = automatic voltage regulator) entails various disadvantages and/or drawbacks. A first disadvantage is that a double closed-loop feedback is necessary, as two separate control and regulation loops shall be provided, one for the number of revolutions of the engine ad one for the output voltage. Moreover, the cost of the DC-to-DC converter for high output currents is often too high, the high complexity of the rectifier making difficult to use it in simple and/or cheap systems. The system complexity also results in a high number of failures, as well as in an excessive bulk.

DESCRIPTION OF THE PRESENT INVENTION

An object of the present invention is therefore an equipment for charging accumulators (batteries) allowing to overcome or at least to limit the drawbacks of the prior art equipment.

In particular, a first object of the present invention is an equipment allowing to limit both the manufacturing and managing costs, and/or to limit the overall bulk of the equipment, and/or to limit the complexity of the equipment, by eliminating, where possible, the more complex and critical components of the prior art equipment, and/or to increase the reliability of the equipment by decreasing the risk of failure and therefore limiting, at least indirectly, the maintenance interventions, and/or to increase the conversion efficiency of the equipment.

In view of the objects described above, the present invention is based on the general concept that the drawbacks and/or problems of the prior art equipment can be overcome or at least effectively limited by using only one closed-loop control logics for the whole equipment and/or by eliminating the more expensive and/or more complex components of the prior art equipment and/or by replacing these components with simpler and less expensive components, and/or by eliminating the active regulation components of the prior art equipment, and/or eliminating the components of the prior art equipment that are less reliable, and therefore more subjected to failures, as well as by reducing the intermediate conversion steps.

In view of the drawbacks of the prior art equipment and of the purposes described above, the object of the present invention is an equipment for voltage (V) or current (I) feed of an electric load comprised of a load (LOAD) with substantially fixed current absorption and of a storage battery (Battery BANK) with current absorption variable according to the actual status and/or charge volume (Charge Volume) thereof, the equipment comprising a variable RPM engine (Engine) and an alternator (PMG) actuated by means of the engine (Engine), the equipment furthermore comprising regulating means (RPM regulator) for regulating the number of revolutions (RPM) of the engine (Engine) so as to generate an output voltage (VG) from the alternator (PGM) variable according to the number of revolutions (RPM) of the engine (Engine), the equipment furthermore comprising first measuring means designed to measure voltage (VB) on a bus common to the load (LOAD) and to the storage battery (Battery Bank), the equipment furthermore comprising an electronic controller card (TE controller) connected to both the measuring means and the regulating means (RPM Regulator), and the controller card (TE Controller) being so configured as to control the regulation of the number of revolutions (RPM) of the engine (Engine) by means of the regulating means (RPM regulator) according to the difference between the voltage (VB) on the bus and a target voltage.

Practically, the concept underlying the present invention is that a target voltage and/or current are "pursued", the target voltage and/or current to be pursued being those indicated in the battery charge specifications, the target voltage and/or current being pursued by measuring the difference between the target voltage and/or current and the actually measured (input) voltage and/or current applied to the battery(s).

In detail, according to the general principle underlying the invention, the target voltage and/or current may be set according to the different charge cycles, as well as according to the different steps of each cycle, the difference between each target voltage and/or current and the actually measured voltage and/or current is decreased by adequately adjusting the number of revolutions of the engine.

According to an embodiment, the electronic controller card (TE Controller) is so configured as to control the increase of the number of revolutions (RPM) of the engine (Engine) by means of the regulating means (RPM regulator) when the difference between the voltage (VB) on the bus and the target voltage is greater than a given threshold (ERROR).

According to an embodiment, the electronic controller card (TE Controller) is so configured as to control the increase of the number of revolutions (RPM) of the engine (Engine) by means of the regulating means (RPM regulator) according to pre-set increasing steps.

According to an embodiment, the electronic controller card (TE Controller) is so configured as to allow a user to set and/or to modify the target voltage.

According to an embodiment, the electronic controller card (TE Controller) is so configured as to allow the user to set a plurality of target voltages, and to control the increase of the number of revolutions (RPM) of the engine (Engine) by means of the regulating means (RPM regulator) according to pre-set time intervals when, in each pre-set time interval, the difference between the voltage (VB) on the bus and one of the target voltages is greater than a given threshold (ERROR).

According to an embodiment, the electronic controller card (TE Controller) is so configured as to allow a user to set and/or to modify one or more of the target voltages of the plurality of target voltages.

According to an embodiment, the equipment furthermore comprises second measuring means designed to measure the instant current (IB) actually absorbed by the storage battery

(Battery BANK), wherein the controller card (TE Controller) is so configured as to subordinate the regulation of the number of revolutions (RPM) of the engine (Engine) made by the regulating means (RPM regulator) to the instantaneous current (IB) actually absorbed by the storage battery (Battery BANK).

According to an embodiment, the controller card (TE controller) is so configured as to control the decrease of the number of revolutions (RPM) of the engine (Engine) by means of the regulating means (RPM regulator) according to the instantaneous current (IB) actually absorbed by the storage battery (Battery BANK).

According to an embodiment, the electronic controller card (TE Controller) is so configured as to control the decrease of the number of revolutions (RPM) of the engine (Engine) by means of the regulating means (RPM regulator) according to pre-set decreasing steps.

According to an embodiment, the equipment furthermore comprises third measuring means designed to measure the actual status and/or charge volume of the storage battery (Battery BANK), wherein the controller card (TE Controller) is so configured as to subordinate the regulation of the number of revolutions (RPM) of the engine (Engine) made by the regulating means (RPM regulator) to the actual charge status of the storage battery (Battery BANK).

According to an embodiment, the controller card (TE controller) is so configured as to control the decrease of the number of revolutions (RPM) of the engine (Engine) by means of the regulating means (RPM regulator) according to the actual charge status of the storage battery (Battery Bank).

According to an embodiment, the engine is an endothermic engine.

According to an embodiment, the alternator (PGM) is a three-phase permanent magnet alternator.

According to an embodiment, the equipment furthermore comprises a rectifier (Rectifier) connected to the output of the alternator (PGM) for converting alternating current (AC) from the alternator (PGM) to direct current (DC).

According to an embodiment, the equipment comprises a user interface for managing the controller card (TE Controller).

Any further embodiments of the equipment according to the invention are defined in the claims.

BRIEF DESCRIPTION OF DRAWINGS

The invention will be better explained in the description below of the embodiments illustrated in the drawing. However, the present invention is not limited to the embodiments described below and illustrated in the drawing; contrariwise, all variants of the embodiments described below and represented in the drawing that are clearly apparent to those skilled in the art fall within the scope of the invention.

In the drawing:

Fig. 1 shows an example of battery charge specifications;

Fig. 2 schematically shows a prior art equipment for charging a battery;

Fig. 3 schematically shows an embodiment of the equipment according to the invention for charging a battery;

Fig. 4 shows a diagram of a charge cycle that can be carried out by means of an equipment according to an embodiment of the invention;

Fig. 5 shows a diagram of a charge cycle that can be carried out by means of an equipment according to an embodiment of the invention;

Fig. 6 shows a flow diagram of the method for charging a battery according to an embodiment of the invention;

Fig. 7 shows a diagram of a charge cycle that can be carried out by means of an equipment according to an embodiment of the invention;

Fig. 8 shows the correlation between charge volume and power supplied during a charge cycle according to an embodiment of the invention;

Fig. 9 shows the correlation over time between the number of revolutions of the engine and the power supplied during a charge cycle according to an embodiment of the invention;

Fig. 10 shows the correlation between different voltages during a charge cycle according to an embodiment of the invention.

DETAILED DESCRIPTION OF THE PRESENT INVENTION

Fig. 3 shows an embodiment of an equipment according to the invention. In particular, the equipment comprises a power source (DIESEL ENGINE), in this specific case a diesel endothermic engine of variable power according to the needs and/or circumstances, an alternator PGM, in this specific case a three-phase permanent magnet alternator, being applied to the power source, wherein the activation of the alternator by means of the engine results in the alternator generating a voltage and a current variable according to the number of revolutions of the engine.

The equipment also comprises regulating means (RPM REGULATOR) for regulating the number of revolutions of the engine, comprised for example by a linear actuator, a speed sensor and a microprocessor card, wherein the actual composition of the regulating means according to the present invention may vary according to the specific needs and/or circumstances.

In the equipment of Fig. 3, control means (GENSET CONTROLLER) are also provided for managing and monitoring the engine, for example for managing the engine start and stop and for monitoring the operation thereof, wherein the control means may comprise, for example, according to an embodiment of the invention, a programmable microprocessor card provided with a user interface, measuring means, logic ports and communications ports.

According to the embodiment of the invention schematically shown in Fig. 3, the equipment comprises a control logics (TE Controller ALGORITHM) for taking into account all the system parameters detected by the measuring means connected together (not all shown in the figures), by acting on the adjusting device for regulating the engine speed, thus allowing the right voltage and current, i.e. the voltage and current as indicated in the charge specifications, to be supplied to the batteries.

Lastly, the equipment comprises a rectifier, for example a traditional AC-to-DC converter without control logics and integrated regulation.

Having explained the equipment, the figure also shows an example of use and/or application thereof, the equipment being applied to one or more batteries (BATTERY BANK), or, in general, to an accumulator with different cells connected in series and/or in parallel for supplying the right voltage values (cells in series) and capacity values (cells in parallel), both the equipment and the batteries being connected to a load (LOAD) with substantially fixed current absorption through a common bus (DC Bus).

As in the previous case, also in the case of the equipment illustrated in Figure 3, the typical and/or standard operation provides for the following: when the batteries are charged enough, the current absorbed by the load is supplied by them; contrarily, when the batteries are not enough charged, the engine is actuated for simultaneously feeding both the load and the batteries, i.e. so as to supply both the power required (absorbed) by the load and the power necessary for progressively charging the batteries, wherein as the charge in the batteries increases, the number of revolutions of the engine decreases.

Obviously, in the case of the equipment of Fig. 3, the method for charging batteries is different than that mentioned above with reference to Fig. 2, the method being better explained below with the description of example of charge cycles.

In particular, for the sake of clarity of explanation, the description below will be done assuming that the various charge cycles (described just by way of non-limiting example) are destined for charging a battery pack according to the specifications of Fig. 1, being however intended, obviously, that the equipment of the invention can be managed so as to perform charge cycles according to any type of charge specifications, and not only to those of Fig. 1.

In particular, Fig. 4 refers to a fast charge cycle actuated for charging batteries by keeping the generator operation time as lowest as possible. In the diagram of Fig. 4, the curves relate to:

1. VB: DC bus voltage, in volts
2. VG: generator voltage, in volts
3. IB: battery charge current, in amperes.

The cycle illustrated in Fig. 4 (fast charge) is carried out for charging a 600Ah battery pack, wherein the limit current is 100A.

As shown in the figure, at the beginning of the charge cycle the voltage changes from 47V to 51V (programmable latching value), the generator voltage then gradually increasing.

At 11:02 the current achieves the limiter, set at 100A; once achieved the equalization voltage (typical value 56V), the charge current begins decreasing towards the minimum value (30A).

After the 4 hours of the cycle, the generator turns off. Lastly, after a discharge cycle of about 3 hours, the engine is started again and a new charge cycle begins.

From what above it is clearly apparent that, according to the present invention, the voltages and/or currents indicated in the charge specification are intended as target voltages and/or currents, and the equipment is so managed as to have, on the bus connecting the equipment and the battery, voltages and/or (load) currents increasingly close to the target ones.

For example, with reference to Fig. 1 again, the charge specifications shown therein indicate that the charge voltage at t1 shall be approximately equal to 53,5 Volt. According to the present invention, at t1 the actual voltage on the bus is measured and compared with the target (53,5 Volt), and the engine is managed in order that the voltage on the bus achieves the target one. If, for example, the measured voltage is too low, the number of revolutions of the engine is increased; contrariwise, if the measured voltage is too high, the engine is slowed down (the number of revolutions is decreased).

Therefore, the control card, based on the differences between target and measured voltages, manages the number of revolutions of the engine through the regulating means (RPM regulator).

The same applies to the time t2 indicated in Fig. 1, as well as for any other time tn in the charge cycle, wherein the number of pursuing attempts (i.e. the number of times the target voltage and the measured voltage are compared, and the number of revolutions is adjusted based on the result of the comparison) can be set according to the needs and/or circumstances.

Fig. 5 shows a “normal” cycle, activated and performed to charge the batteries by using the time necessary with the engine working, so as to complete the right step of battery equalization.

In the case of Fig. 5 again, the curves relate to:

1. VB: DC bus voltage, in volts
2. VG: generator voltage, in volts
3. IB: battery charge current, in amperes.

Fig. 5 shows a normal charge cycle for a 600Ah battery pack, wherein the limit current is 100A.

As shown in the figure, at the beginning of the charge cycle the voltage changes from 47V to 51V (programmable latching value), the generator voltage then gradually increasing.

At 11:02 the current achieves the limiter, set at 100A; once achieved the equalization voltage (typical value 56V), the charge current begins decreasing towards the minimum value (30A).

At 14:48 the complete equalization steps begins, and, once the eight hours set for the cycle have finished, the generator turns off.

The flow diagram of Fig. 6 explains the general concept underlying the present invention and summarized above.

As shown in Fig. 6 (assuming a constant DC load of 3kW connected to the system generator + batteries, the total generator load being therefore, during the battery charge, equal to the sum IB_load + IL), when the batteries achieve the generator activation critical voltage, the generator activates together with the algorithm.

A set point (SETPOINT_TARGET) is then calculated, variable based to the programming made by the user (depending, in turn, on the charge specifications) and on the active charge step. In particular, in Fig. 6:

- SETPOINT_TARGET = 57 during the equalization step
- V_BUS = real-time measured voltage on the DC bus.

Through analogue output, the set point of the outer regulator (SETPOINT_REG) is modified by programmable steps, pursuing the SETPOINT_TARGET variable based on the difference ERROR.

- SETPOINT_REG = 0% to have the minimum number of revolutions of the engine
- SETPOINT_REG = 100% to have the maximum number of revolutions of the engine

When the absolute value of the error between SETPOINT_TARGET and measured voltage (V_BUS) is lower than a settable threshold, the value of the analogue output stabilizes, and therefore the SETPOINT_REG remains constant.

The system always tries to return to the condition SETPOINT_TARGET ok based on the difference ERROR.

If the difference (ERROR) is significant, the increase or decrease in SETPOINT_REG will occur more often, wherein the increase or decrease frequency decreases proportionally as the error decreases.

When the maximum value of the charge current, that can be set by the user and depends on the charge capacity of the battery pack, has been achieved (HIGH_CHARGE_CURRENT), the SETPOINT_REG limits itself independently of the error. The increase action is therefore aborted. As the voltage increases, the total current required to the generator (battery charge + load) decreases, allowing a progressive increase in the number of revolutions of the engine in order to maintain the right voltage on the common V_BUS.

Figure 7 shows the correlation between the charge volume of the battery pack and the power supplied by the generator to feed the load and, at the same time, to charge the batteries.

The low current equalization step may be necessary to keep the effectiveness of batteries and prolong the useful life thereof for the maximum number of charge cycles.

Figure 8 shows the trend over time of the engine revolutions

as the power supplied by the generator varies to maintain the right voltage during the charge cycle. When the power demand decreases due to the effect of the battery charge, the generator slows down and keeps the voltage constant.
For almost all the operation of the generator, the set engine-alternator-rectifier operates in a high-efficiency area, always greater than 86%. Contrariwise, the traditional systems usually have a declared efficiency of maximum 86%.
Figure 9 shows the power curves for the generator with constant voltage. As it is clearly apparent, as the supplied current decreases, the number of revolutions necessary to keep the voltage constant decreases.
As it is clearly apparent and proved from the description above of the embodiments shown in the figures, the present invention allows to achieve the above mentioned objects and purposes. Particularly, the equipment according to the present inventions allows effectively to limit both the manufacturing and managing costs, effectively to limit the overall bulk of the equipment, and to limit the complexity of the equipment, by eliminating, where possible, the more complex and critical components of the prior art equipment.
The present invention also allows to increase the reliability of the equipment by decreasing the risk of failure and therefore simplifying and limiting, at least indirectly, the maintenance interventions, and to increase the conversion efficiency of the equipment.
Even if the equipment according to the invention has been explained in the above detailed description of the embodiments shown in the drawing, however the present invention is not limited to the embodiments described above and illustrated in the figures. Contrariwise, the scope of the present invention is defined by the appended claims.

CLAIMS

1. Equipment for voltage (V) and current (I) feed of an electric load comprised of a load (LOAD) with substantially fixed current absorption and of a storage battery (Battery BANK) with current absorption variable according to the actual charge volume (Charge Volume) thereof, said equipment comprising a variable RPM engine (Engine) and an alternator (PMG) actuated by means of said engine (Engine), the equipment furthermore comprising regulating means (RPM regulator) for regulating the number of revolutions (RPM) of said engine (Engine) so as to generate an output voltage (VG) from said alternator (PGM) variable according to the number of revolutions (RPM) of said engine (Engine), characterized by furthermore comprising first measuring means designed to measure voltage (VB) on a bus common to said load (LOAD) and to said storage battery (Battery BANK), by comprising an electronic controller card (TE controller) connected to both said measuring means and said regulating means (RPM Regulator), and characterized in that said controller card (TE Controller) is so configured as to control the regulation of the number of revolutions (RPM) of said engine (Engine) by means of said regulating means (RPM regulator) according to the difference between said voltage (VB) on said bus and a target voltage.

2. Equipment according to claim 1, wherein said electronic controller card (TE Controller) is so configured as to control the increase of the number of revolutions (RPM) of said engine (Engine) by means of said regulating means (RPM regulator) when the difference between said voltage (VB) on said bus and said target voltage is greater than a given threshold (ERROR).

3. Equipment according to claim 2, wherein said electronic controller card (TE Controller) is so configured as to

control the increase of the number of revolutions (RPM) of said engine (Engine) by means of said regulating means (RPM regulator) according to pre-set increasing steps.

4. Equipment according to any one of claims 1 to 3, wherein said electronic controller card (TE Controller) is so configured as to allow a user to set and/or to modify said target voltage.

5. Equipment according to claim 4, wherein said electronic controller card (TE Controller) is so configured as to allow the user to set a plurality of target voltages, and to control the increase of the number of revolutions (RPM) of said engine (Engine) by means of said regulating means (RPM regulator) according to pre-set time intervals when, in each said pre-set time interval, the difference between said voltage (VB) on said bus and one of said target voltages is greater than a given threshold (ERROR).

6. Equipment according to claim 5, wherein said electronic controller card (TE Controller) is so configured as to allow a user to set and/or to modify one or more of said target voltages of said plurality of target voltages.

7. Equipment according to any one of claims 1 to 6, wherein said equipment furthermore comprises second measuring means designed to measure the instant current (IB) actually absorbed by said storage battery (Battery BANK), wherein said controller card (TE Controller) is so configured as to subordinate the regulation of the number of revolutions (RPM) of said engine (Engine) made by said regulating means (RPM regulator) to said instantaneous current (IB) actually absorbed by said storage battery (Battery BANK).

8. Equipment according to claim 7, wherein said controller card (TE controller) is so configured as to control the decrease of the number of revolutions (RPM) of said engine (Engine) by means of said regulating means (RPM regulator)

according to the reduction in the current absorption of the system (LOAD + Battery BANK) due to the charge completion of said storage battery (Battery BANK).

9. Equipment according to claim 8, wherein said electronic controller card (TE Controller) is so configured as to control the decrease of the number of revolutions (RPM) of said engine (Engine) by means of said regulating means (RPM regulator) according to pre-set decreasing steps.

10. Equipment according to any one of claims 1 to 9, wherein said engine is an endothermic engine.

11. Equipment according to any one of the previous claims, wherein said alternator (PGM) is a 3-phase permanent magnet alternator.

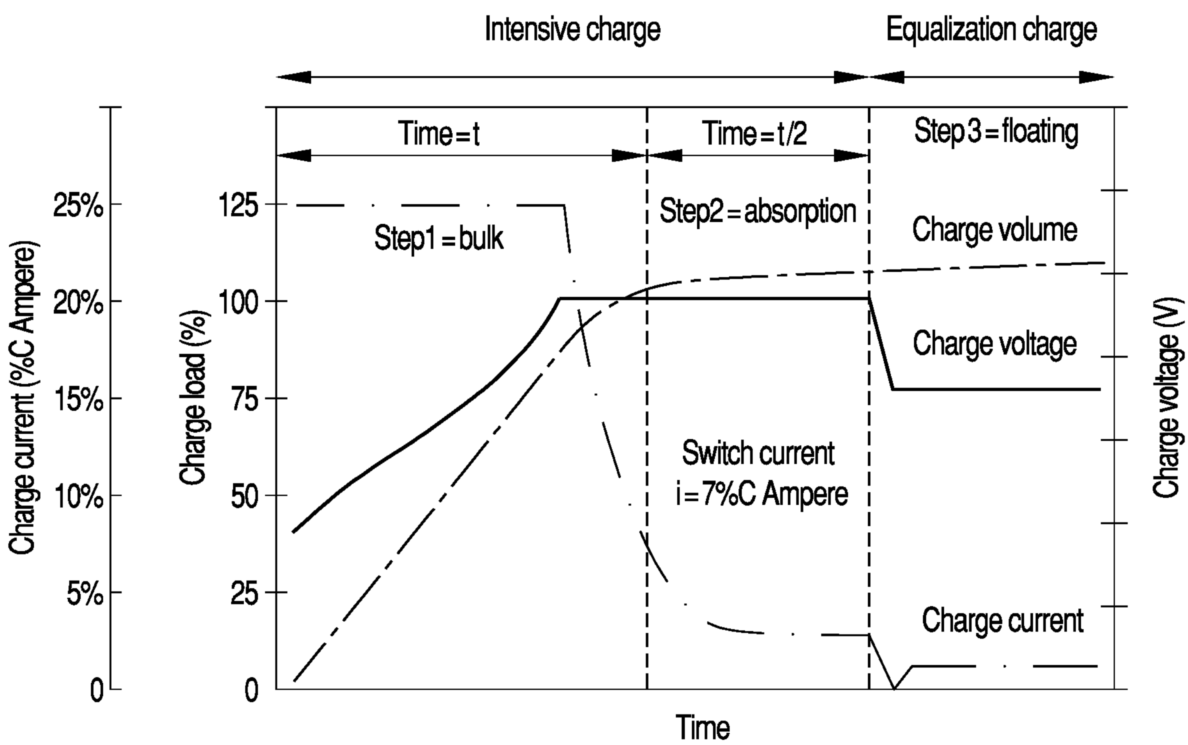

Intensive charge
Equalization charge
Time=t
Time=t/2
Step3=floating
Step1=bulk
Step2=absorption
Charge volume
Charge voltage
Switch current
i=7%C Ampere
Charge current
Charge current (%C Ampere)
Charge load (%)
Charge voltage (V)
Time
25%
20%
15%
10%
5%
0
125
100
75
50
25
0

Fig.1

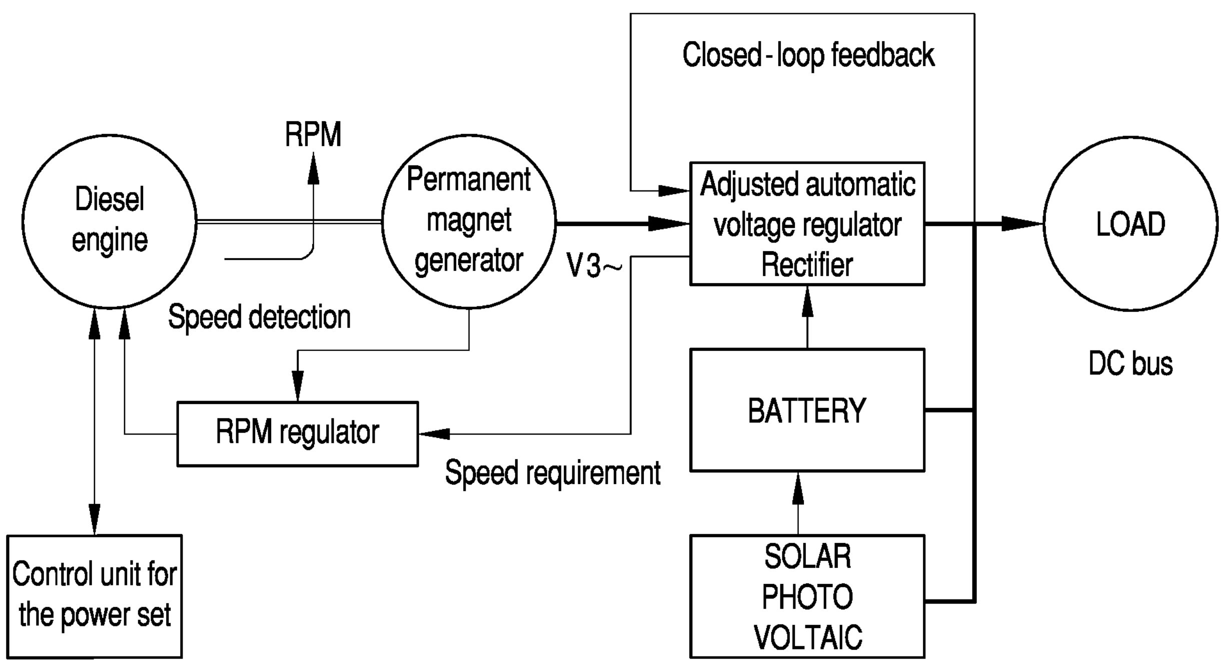
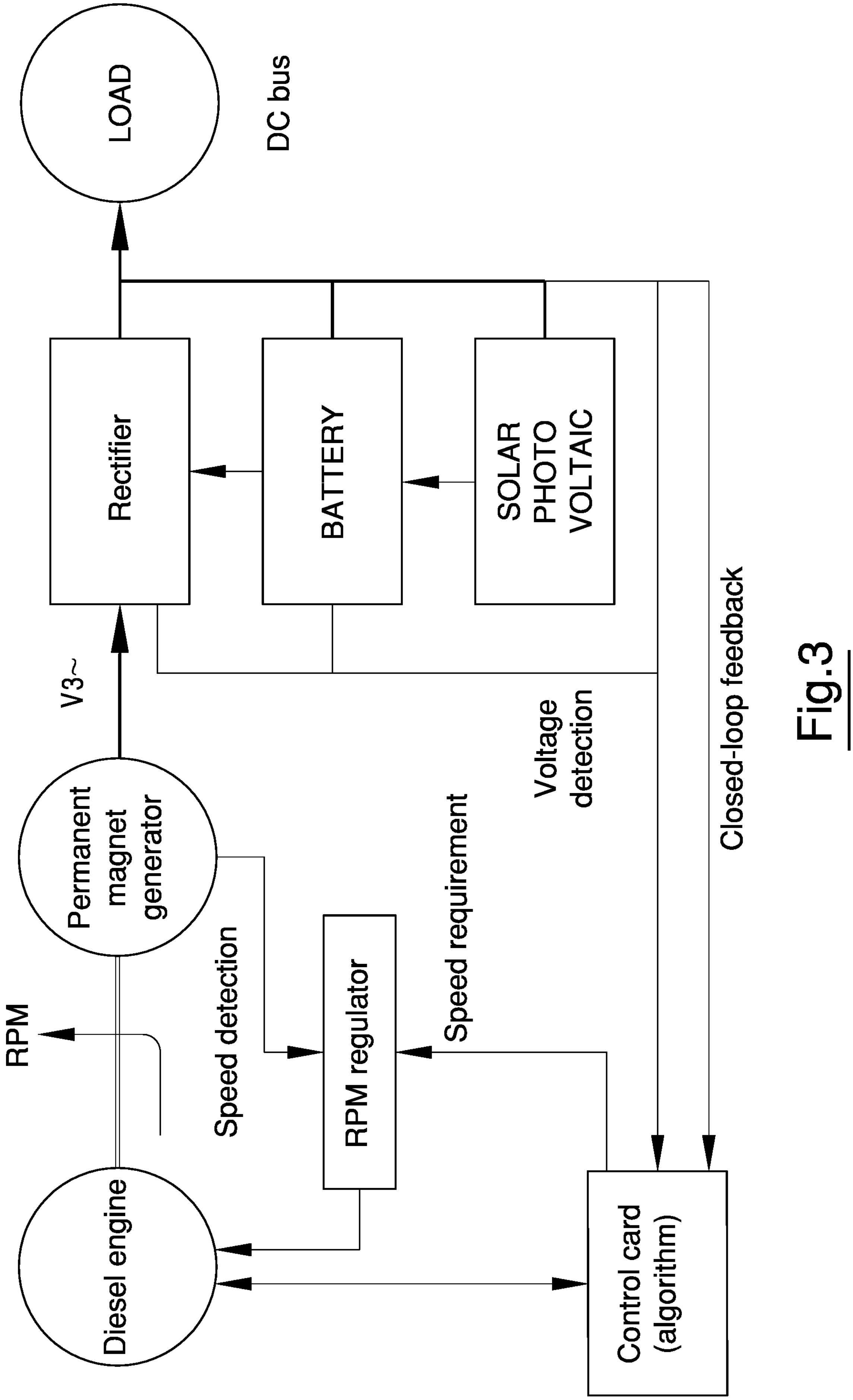

Closed-loop feedback
RPM
Diesel engine
Permanent magnet generator
Adjusted automatic voltage regulator Rectifier
LOAD
V3~
Speed detection
DC bus
RPM regulator
BATTERY
Speed requirement
Control unit for the power set
SOLAR PHOTO VOLTAIC

Fig.2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Rectifier
BATTERY
SOLAR
PHOTO
VOLTAIC
V3~
Voltage
detection
Closed-loop feedback
Permanent
magnet
generator
Speed detection
RPM regulator
Speed requirement
RPM
Diesel engine
Control card
(algorithm)

Fig.3

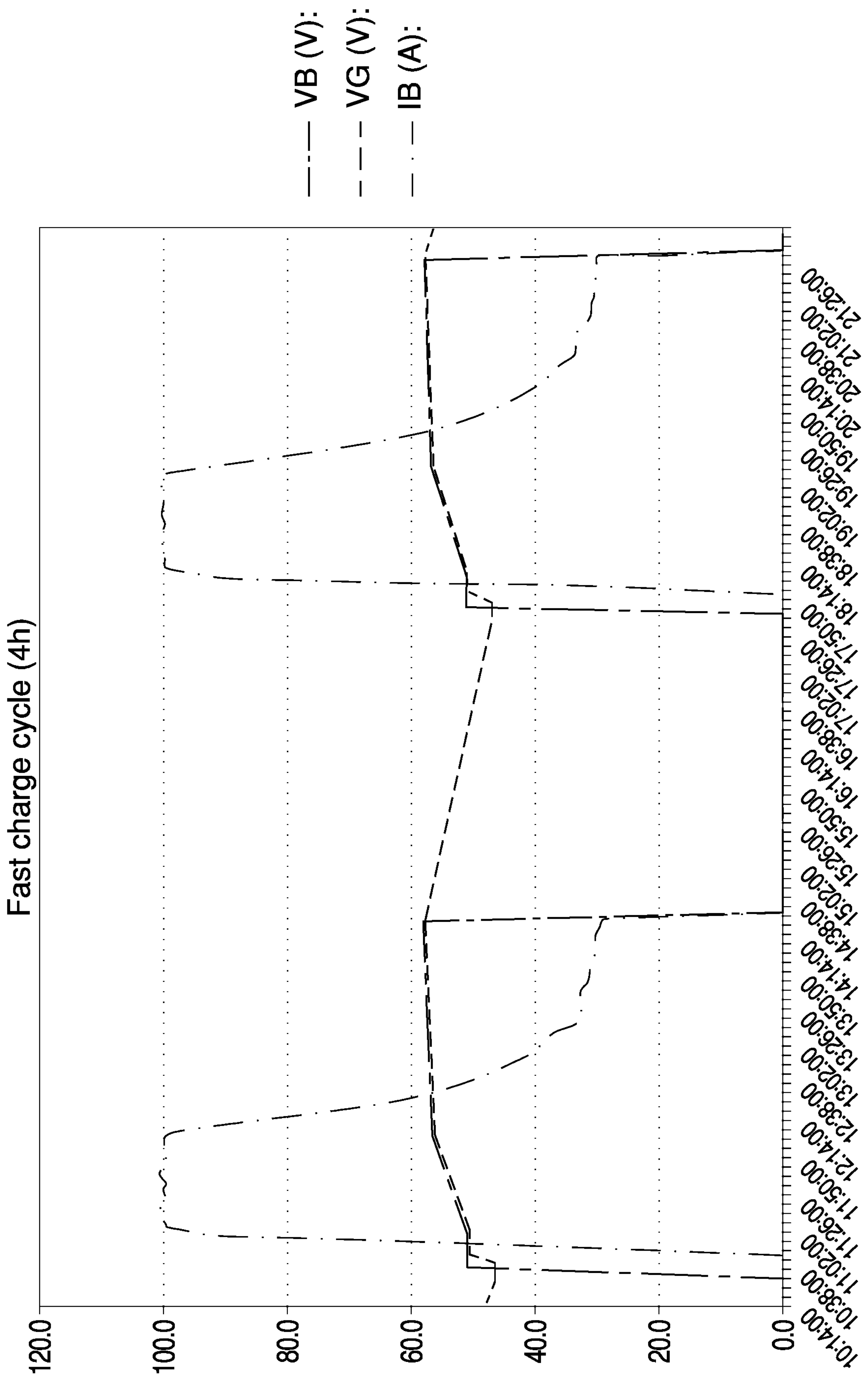

Fast charge cycle (4h)
VB (V):
VG (V):
IB (A):
120.0
100.0
80.0
60.0
40.0
20.0
0.0
10:14:00
10:38:00
11:02:00
11:26:00
11:50:00
12:14:00
12:38:00
13:02:00
13:26:00
13:50:00
14:14:00
14:38:00
15:02:00
15:26:00
15:50:00
16:14:00
16:38:00
17:02:00
17:26:00
17:50:00
18:14:00
18:38:00
19:02:00
19:26:00
19:50:00
20:14:00
20:38:00
21:02:00
21:26:00

Fig.4

Fig.5

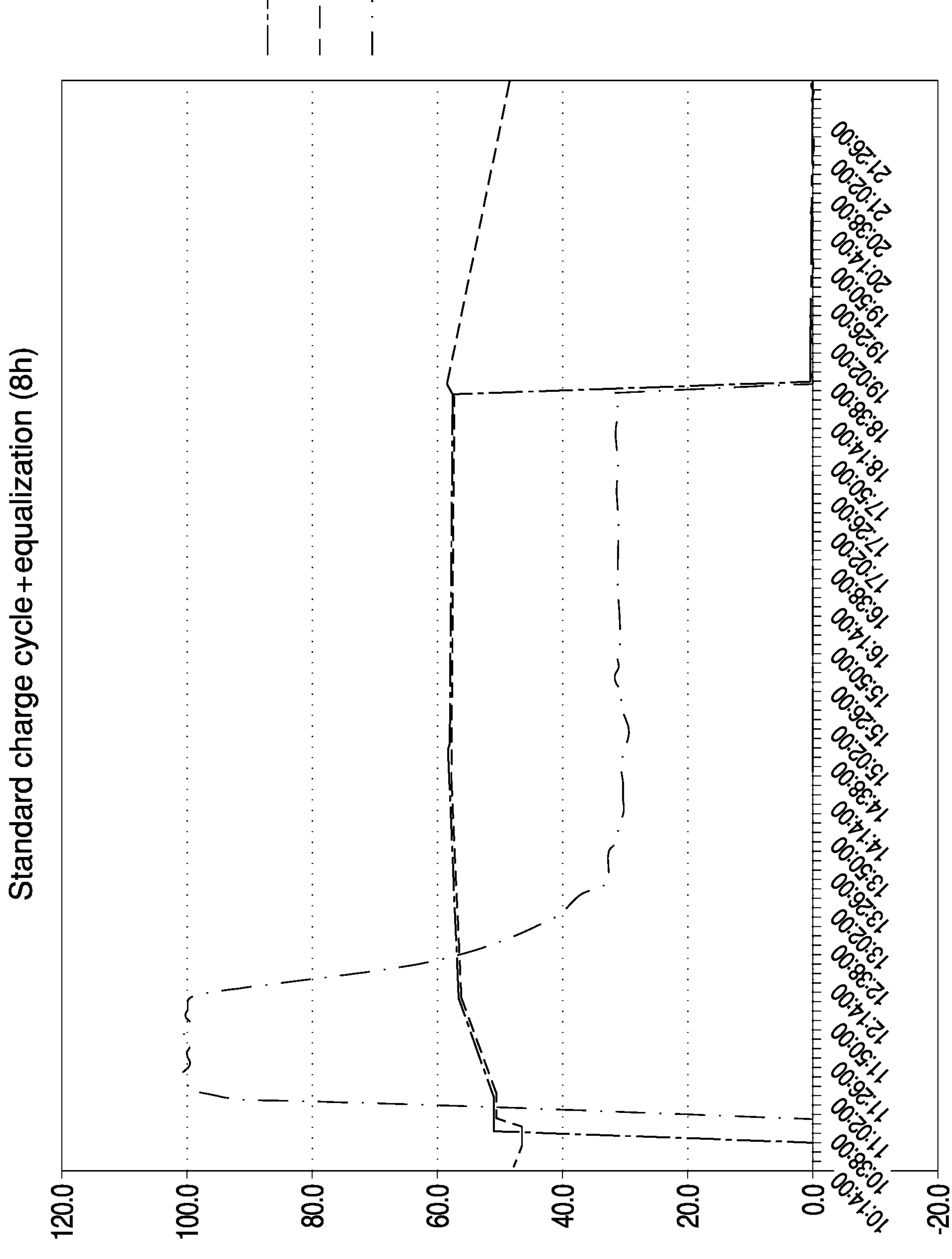

Standard charge cycle+equalization (8h)
VB (V):
VG (V):
IB (A):
120.0
100.0
80.0
60.0
40.0
20.0
0.0
-20.0
10:14:00
10:38:00
11:02:00
11:26:00
11:50:00
12:14:00
12:38:00
13:02:00
13:26:00
13:50:00
14:14:00
14:38:00
15:02:00
15:26:00
15:50:00
16:14:00
16:38:00
17:02:00
17:26:00
17:50:00
18:14:00
18:38:00
19:02:00
19:26:00
19:50:00
20:14:00
20:38:00
21:02:00
21:26:00

Fig.6

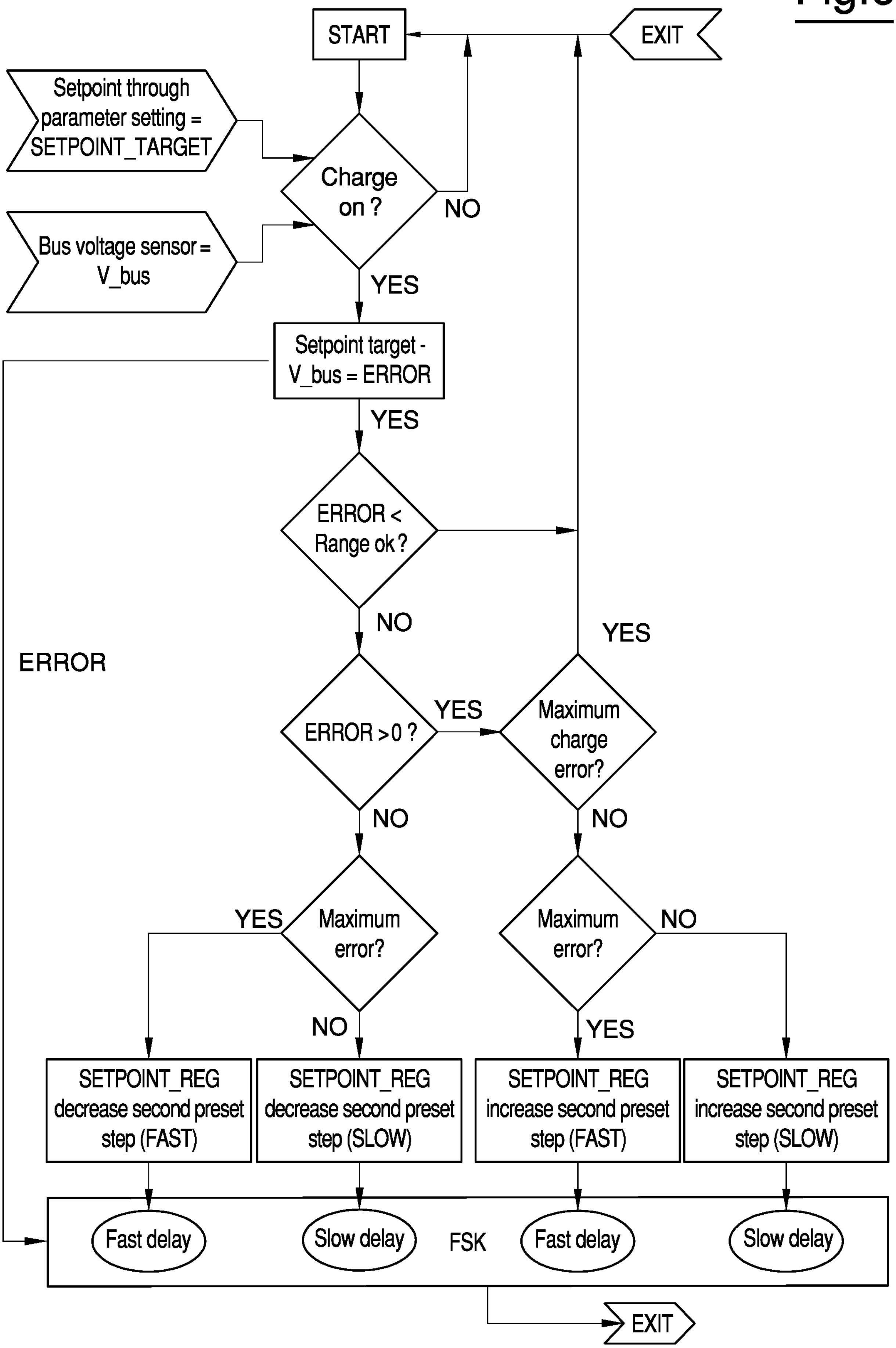

START
EXIT
Setpoint through parameter setting = SETPOINT_TARGET
Bus voltage sensor = V_bus
Charge on ?
NO
YES
Setpoint target - V_bus = ERROR
YES
ERROR < Range ok ?
NO
ERROR
ERROR >0 ?
YES
Maximum charge error?
YES
NO
NO
Maximum error?
YES
NO
Maximum error?
NO
YES
SETPOINT_REG decrease second preset step (FAST)
SETPOINT_REG decrease second preset step (SLOW)
SETPOINT_REG increase second preset step (FAST)
SETPOINT_REG increase second preset step (SLOW)
Fast delay
Slow delay
FSK
Fast delay
Slow delay
EXIT

Fig.7

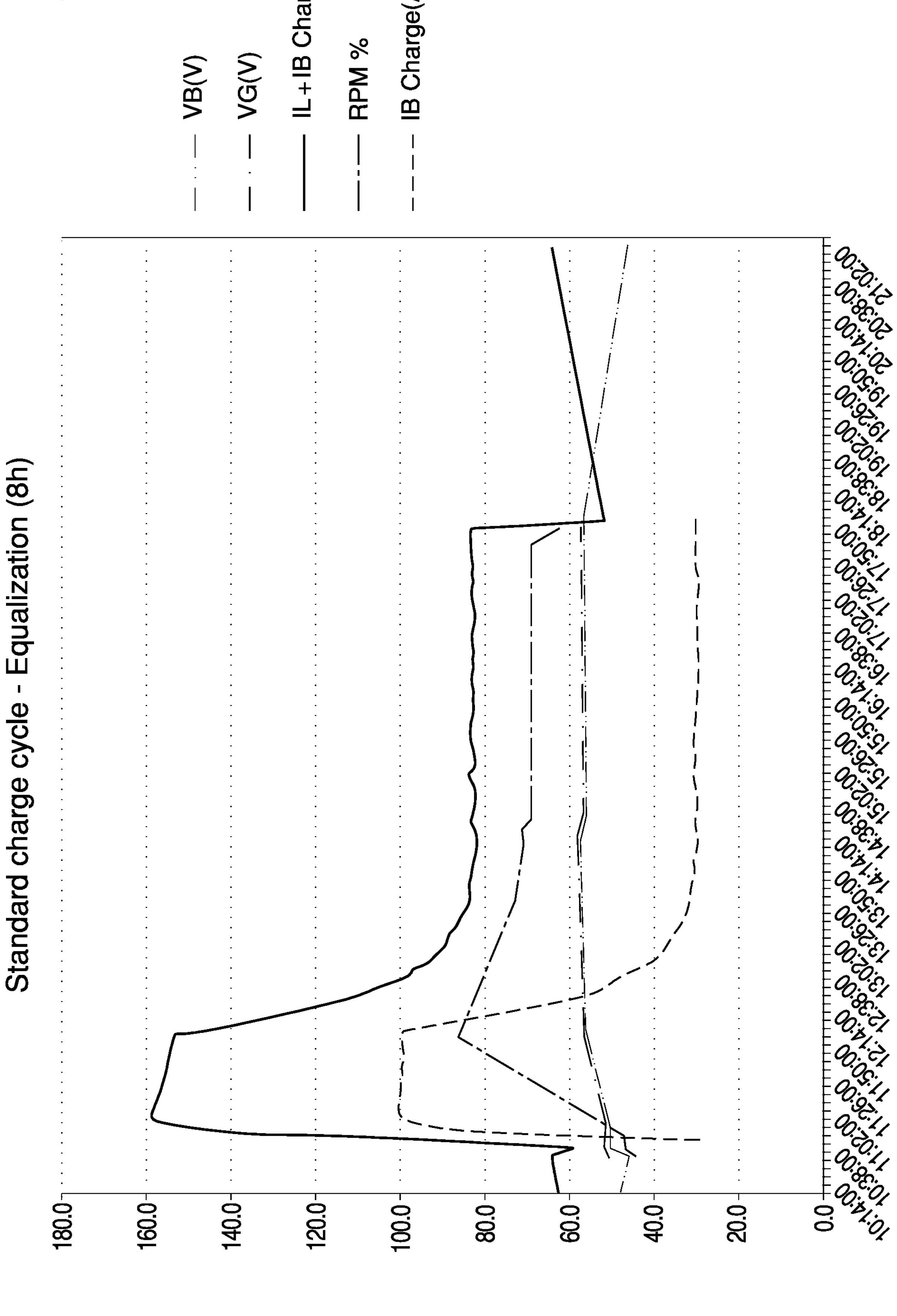

Standard charge cycle - Equalization (8h)
VB(V)
VG(V)
IL+IB Charge(A)
RPM %
IB Charge(A)
180.0
160.0
140.0
120.0
100.0
80.0
60.0
40.0
20.0
0.0
10:14:00
10:38:00
11:02:00
11:26:00
11:50:00
12:14:00
12:38:00
13:02:00
13:26:00
13:50:00
14:14:00
14:38:00
15:02:00
15:26:00
15:50:00
16:14:00
16:38:00
17:02:00
17:26:00
17:50:00
18:14:00
18:38:00
19:02:00
19:26:00
19:50:00
20:14:00
20:38:00
21:02:00

Fig.8

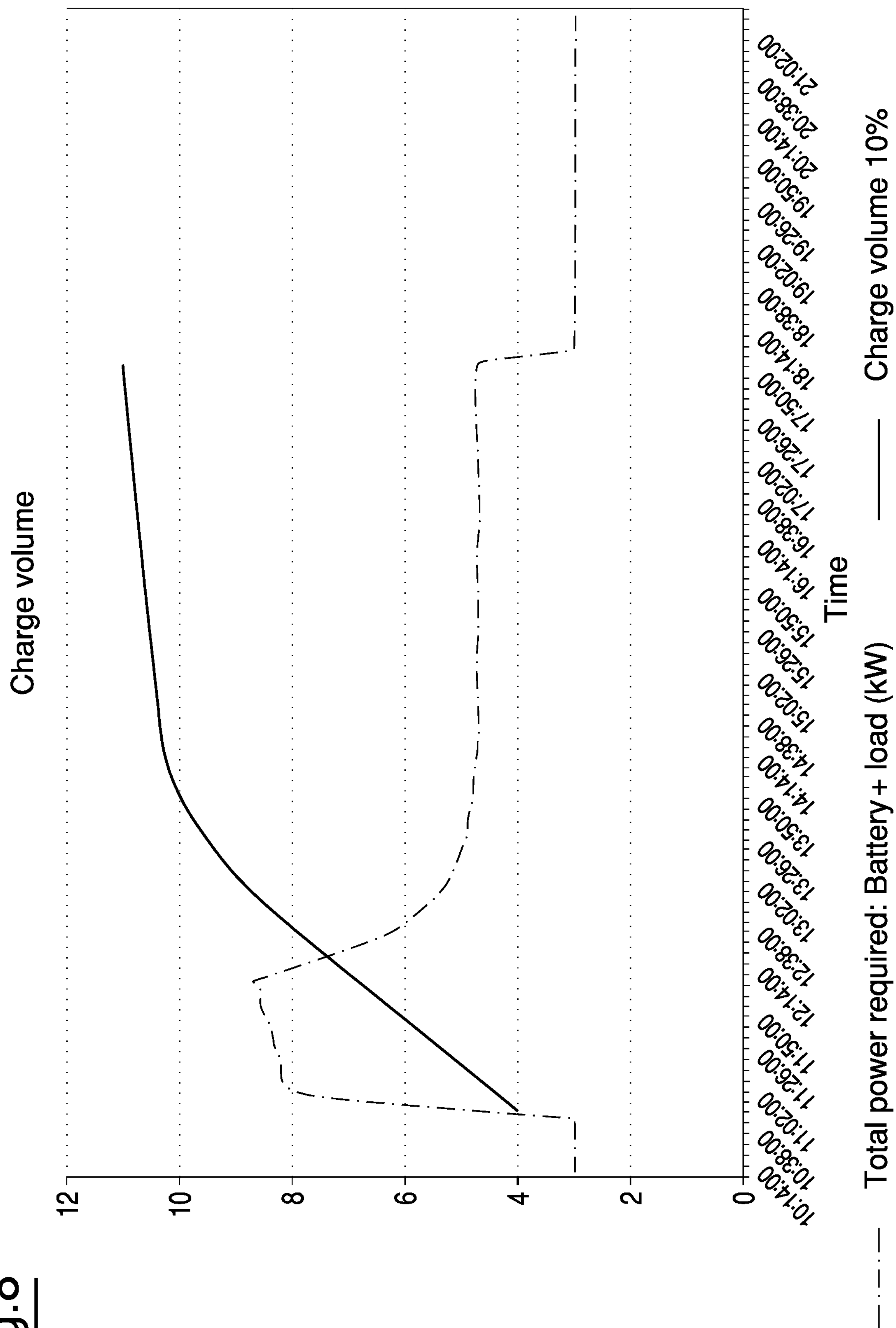

Charge volume
12
10
8
6
4
2
0
10:14:00
10:38:00
11:02:00
11:26:00
11:50:00
12:14:00
12:38:00
13:02:00
13:26:00
13:50:00
14:14:00
14:38:00
15:02:00
15:26:00
15:50:00
16:14:00
16:38:00
17:02:00
17:26:00
17:50:00
18:14:00
18:38:00
19:02:00
19:26:00
19:50:00
20:14:00
20:38:00
21:02:00
Time
Total power required: Battery + load (kW)
Charge volume 10%

Fig.9

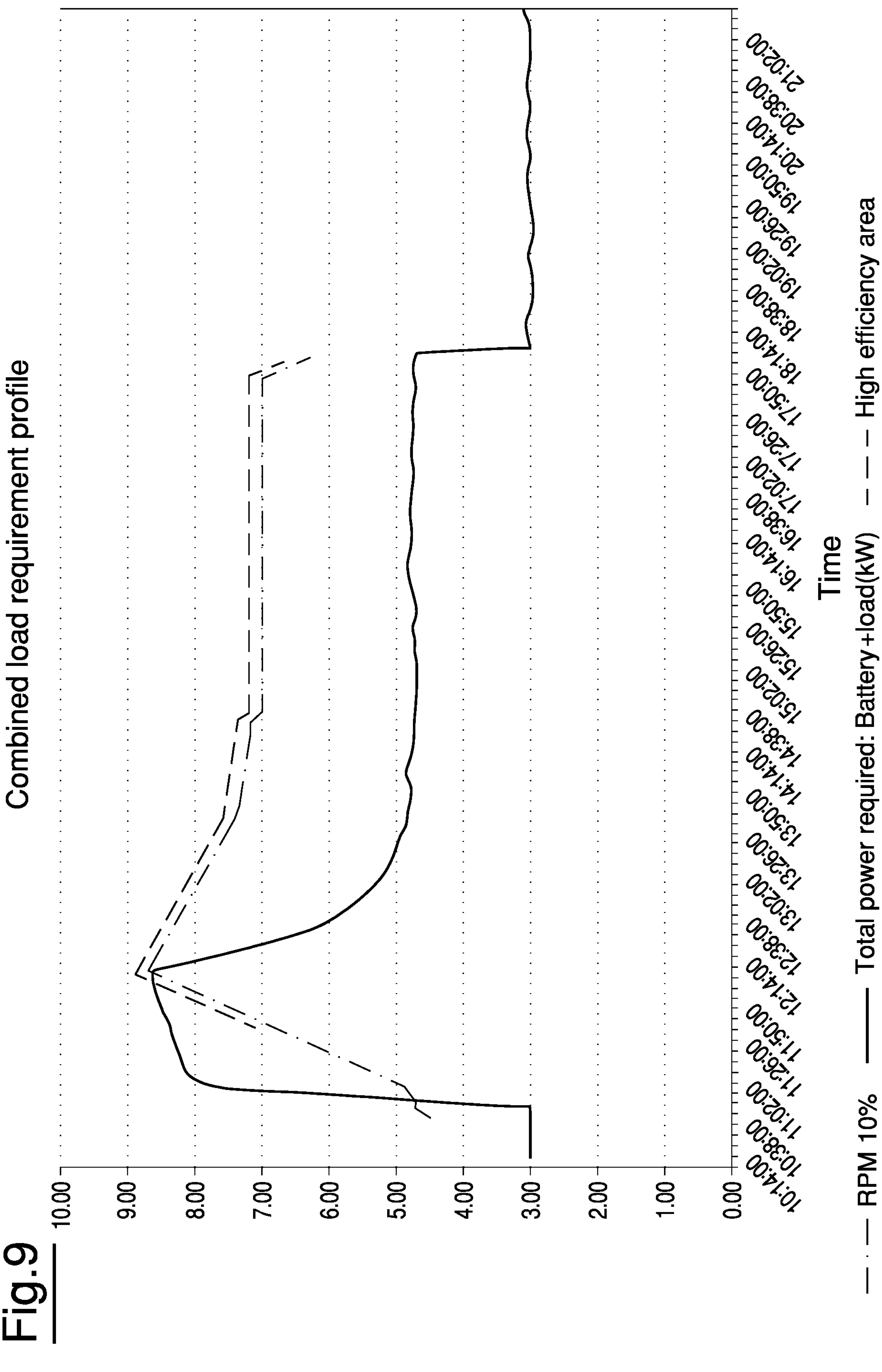
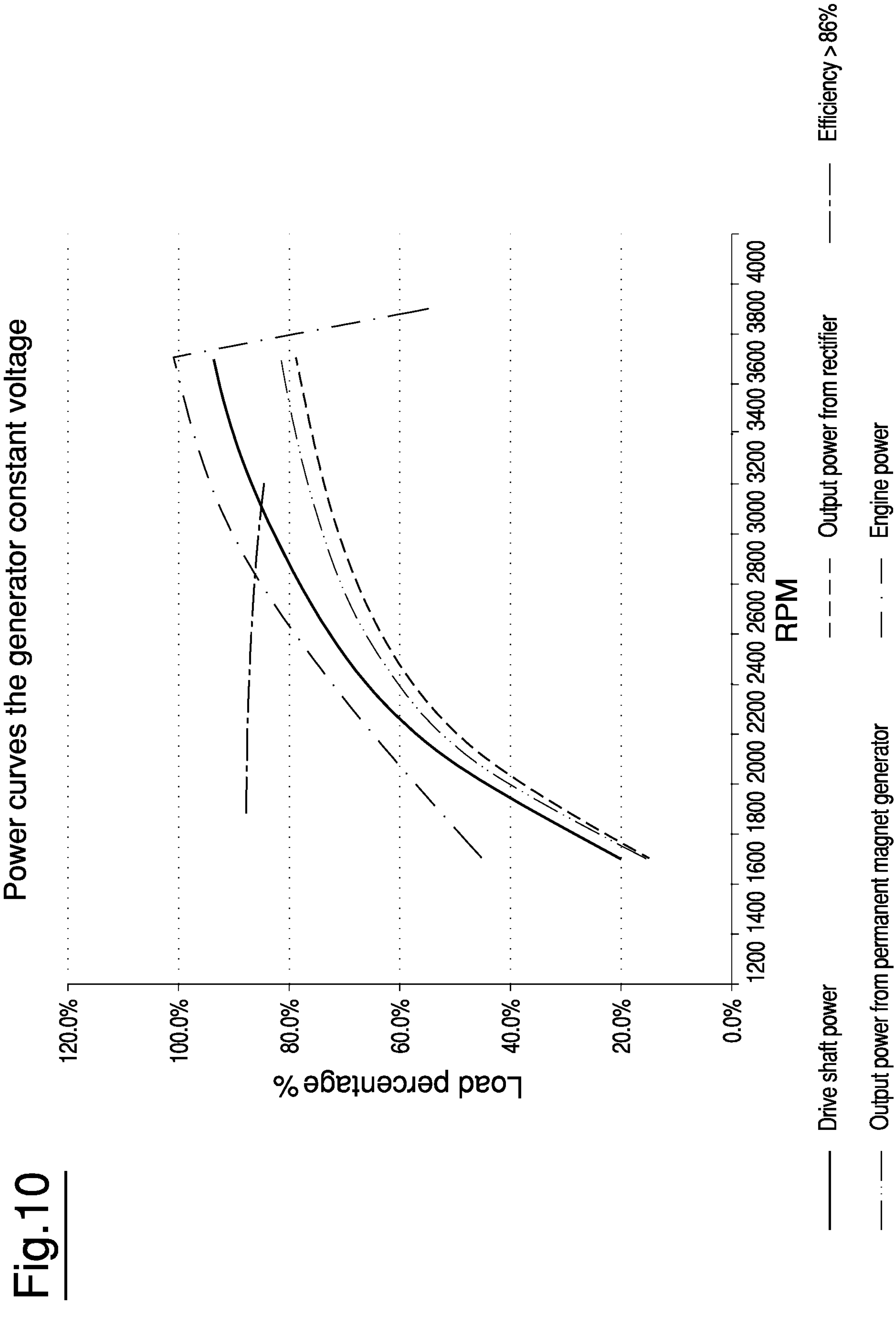

Combined load requirement profile
10.00
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
10:14:00
10:38:00
11:02:00
11:26:00
11:50:00
12:14:00
12:38:00
13:02:00
13:26:00
13:50:00
14:14:00
14:38:00
15:02:00
15:26:00
15:50:00
16:14:00
16:38:00
17:02:00
17:26:00
17:50:00
18:14:00
18:38:00
19:02:00
19:26:00
19:50:00
20:14:00
20:38:00
21:02:00
Time
RPM 10%
Total power required: Battery+load(kW)
High efficiency area

Fig.10


Power curves the generator constant voltage
Load percentage %
120.0%
100.0%
80.0%
60.0%
40.0%
20.0%
0.0%
1200 1400 1600 1800 2000 2200 2400 2600 2800 3000 3200 3400 3600 3800 4000
RPM
Drive shaft power
Output power from rectifier
Efficiency > 86%
Output power from permanent magnet generator
Engine power

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2017/053726

A. CLASSIFICATION OF SUBJECT MATTER
INV. H02J7/14 H02P9/04
ADD.

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)
H02J H02P

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2009/183712 A1 (OWENS RICHARD [US] ET AL) 23 July 2009 (2009-07-23) paragraph [0013] - paragraph [0020]; figure 1	1-11
X	US 2007/200347 A1 (SULZER BRYAN D [US]) 30 August 2007 (2007-08-30) paragraph [0021] - paragraph [0033]; figure 1	1-11
A	US 2008/278120 A1 (SATO KAZUO [JP]) 13 November 2008 (2008-11-13) paragraph [0017] - paragraph [0084]; figure 2	1-11
A	US 2008/157540 A1 (FATTAL SOUREN G [US]) 3 July 2008 (2008-07-03) abstract; figure 1	1-11

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

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"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	Date of mailing of the international search report
5 September 2017	12/09/2017

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Kreutz, Joseph

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/IB2017/053726

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2009183712 A1	23-07-2009	NONE	
US 2007200347 A1	30-08-2007	CA 2575420 A1	28-08-2007
		US 2007200347 A1	30-08-2007
US 2008278120 A1	13-11-2008	CN 101302964 A	12-11-2008
		JP 5164428 B2	21-03-2013
		JP 2008283799 A	20-11-2008
		TW 200922110 A	16-05-2009
		US 2008278120 A1	13-11-2008
US 2008157540 A1	03-07-2008	US 2008157540 A1	03-07-2008
		US 2008157591 A1	03-07-2008
		US 2008157594 A1	03-07-2008
		US 2008157724 A1	03-07-2008
		US 2011227408 A1	22-09-2011