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(54) Ignition coil calibration and operation

(57) A method of controlling the operation of an ignition coil comprising measuring one or more operating or environmental parameter(s) of the coil; and adjusting/setting one or more operating parameters based upon on said measured parameters, wherein said operating or environmental parameters are measured, set or adjusted at the coil level.

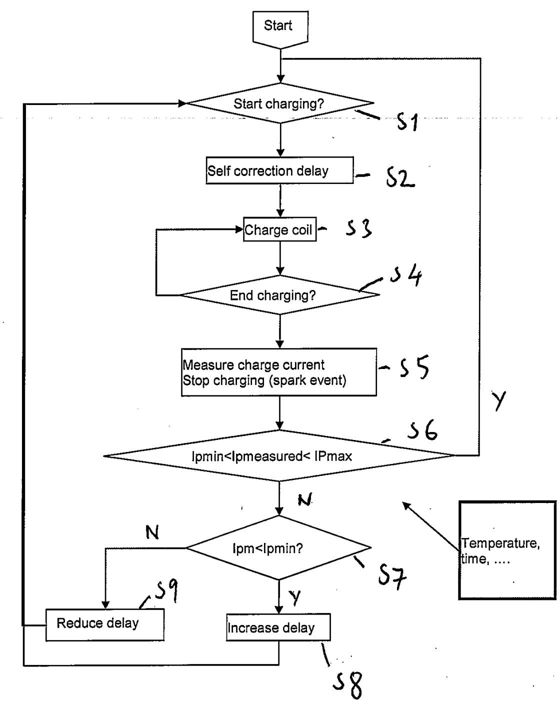

Fig 1

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Description

Technical Field

[0001] This invention relates to ignition coils and to a method of calibrating and operating ignition coils. It has particular, but not exclusive, application to automotive systems. Aspects apply to the calibration, such as setting up of operating parameters of coils during manufacture, as well as controlling parameters during operation, i.e. use.

Background of the Invention

[0002] Inductive ignition systems have been known for some time. Typically, use is made of a transistor such as an Insulated Gate Bipolar Transistor to turn on current to a primary winding of an ignition coil so as to store energy in the coils magnetic circuit, before discharge.

[0003] With inductive ignition systems, the time taken to charge the ignition is called the dwell time. The control of dwell time in operation is currently performed using complex closed-loop control implemented by a vehicle's Electronic Control Unit (ECU) often referred to alternatively as Electronic Control Module. The current in the primary winding of the coil is typically estimated by the ECU ,which in turn adjusts the dwell time to ensure that the target current in the primary coil is always reached. Should the current in the primary coil rise above target, the transistor will partially turn off so as to limit the current.

[0004] Thus, one parameter under consideration is the time to charge (dwell time, Tch) to a defined primary current (Ip). Currently, variations in current are compensated in the ECU via closed loop monitoring of the combustion events. This type of closed-loop control, although adequate, does not ensure that the coil is protected from overstress in certain circumstances. As a result, the operating characteristics of coils can be detrimentally affected, as well as the lifetime of coils being reduced.

[0005] In addition, in conventional systems, the ECU sets the dwell time based on complex internal mapping; thus the ECU is required to have such mapping functionality.

[0006] Furthermore as far as calibration is concerned, the mapping may have to be programmed correctly for the particular coil used. Not only is this complicated but requires a process where both the ECU and the particular coil have to be present during the calibration process.

[0007] Moreover, wear and tear of the coil will occur during its lifetime. Electrical and mechanical properties of the components and their materials will change over time as a result of being exposed to thermal stress, electrical stress, vibrations, and such like. In other words, the characteristics of an ignition coil will varying during the lifetime of the coil due to ageing. However the ECU has a fixed map and thus does not consider such variations in the coil itself.

[0008] It is an object of the invention to overcome such problems.

Summary of the Invention

[0009] In one aspect of the invention is provided a method of controlling the operation of an ignition coil comprising measuring one or more operating and/or environmental parameter(s) of the coil; and adjusting/setting one or more operating parameters based upon on said measured parameters, wherein said operating or environmental parameters are measured, set or adjusted at the coil level.

[0010] The operating parameter is set or adjusted independently of non-coil parameters. An operating parameter may be dwell time.

[0011] The measured parameters may include the maximum or charge current, Ip, in the coil primary winding.

[0012] The method may include the step of comparing said maximum/charge current with an upper and/or lower limit, and adjusting the dwell time depending on whether the said current lies outside said limit(s). The dwell time may be set or adjusted as a function of coil temperature. The upper and/or lower limits may be a function of said measured operating temperature.

[0013] In a second aspect is provided a method of calibrating an ignition coil comprising: measuring one or more operating or environmental parameters of the coil; adjusting or setting one or more operating parameters based upon on said measured parameters.

[0014] The method may be implemented before assembly of said system into a vehicle.

[0015] The operating parameter may include dwell time.

[0016] The measured parameters may include the maximum or charge current in the coil primary winding.

[0017] The method may include the step of comparing said maximum or charge current with an upper and/or lower limit, and adjusting or setting the dwell time depending on whether this current lies outside said limit(s). The coil or plant temperature may be a measured parameter. The upper and lower limits may be e dependent on said measured operating temperature.

[0018] In a third aspect is provided an ignition coil or system therefor, including an ignition coil and means to control the operation of said coil comprising means to measure one or more operating and/or environmental parameters of the coil; and means to adjust/set one or more operating parameters of said coil based upon on said measured parameters, wherein said operating or environmental parameters are measured, set or adjusted at the coil level.

[0019] The means to set or adjust said operating parameter may be independent of non-coil parameters. The control and/or adjusting/setting means may be integral with said coil.

[0020] The operating parameter may include dwell time. The measured parameters may include the maximum or charge current in the coil primary winding. The ignition coil/system may include means to compare said maximum/charge current with an upper and/or lower limit, and adjust the dwell time depending on whether the said current lies outside said limit(s). It may have means to set said dwell time as a function of coil temperature.

[0021] The term "at the coil level" should be interpreted as such and includes a coil self-adjusting method. Thus, one or more operating parameters are determined, adjusted or set at the coil level. Effectively therefore the setting of certain operating parameters such as dwell time is done independently, e.g. autonomously. This may be autonomously or independently from the ECU. The operating parameter may be determined independently of non-coil parameters. Circuitry of processing means may be located internally or integrally within or with the coil, though they may located distally or remotely. The term "at the coil level" includes all these aspects.

[0022] Aspects of the invention provide for a closer, more direct control of ignition coils, such that the coil control can be autonomous, rather than by means of interaction with the ECU. This provides advantages and eliminates and overcomes the above mentioned problems. Furthermore, according to certain embodiments of the invention, there is no requirement to have both the ECU and coil present together when calibrating the coil, and furthermore it is not necessary to remap the ECU when coil characteristics change.

Brief Description of the Drawings

[0023] The present invention will now be described, by way of example, with reference to the accompanying drawings, in which:

Figure 1 shows a flow chart representing a first aspect of the invention.

Figure 2 shows a flow chart representing a second aspect of the invention.

Description of the Preferred Embodiments

[0024] In a conventional ECU control inductive ignition systems, the coil current in the primary winding of a coil will ramps up until a plateau is reached to target current Ip for a short time before discharging.

[0025] According to aspects of the invention, methodology carried out, at the coil level, adjusts the dwell time such that no overstepping of limits can occur. In one aspect the current level Ip of the primary winding at the end of the dwell time is measured, and compared with ideal levels.

[0026] In refined examples, other parameters like coil temperature is measured, and dwell time adjusted in dependence of this parameter, either alternatively or in addition to coil primary current. Thus in some embodiments, both temperature and Ip may be measured and used to determine and adjust dwell time.

[0027] Comparing with ideal or optimal levels may include determining if the measured current/temperature or other parameter lies within an acceptable or preferred range, and if not the dwell time may be adjusted, i.e. for the next charge time. If the current (in the primary winding) is used as the parameter to consider adjustment of charge (dwell) time, then the tolerance levels (preferred range limits) may be varied as a function of other parameters such as temperature.

[0028] Figure 1 shows a flow chart illustrating an example of the methodology which may be embedded in the coil (i.e. implemented at the coil level). In the first step of the process S1, the coil starts to charge and at step S2 a self-correction delay is applied, and in step S3 coil charging takes place and ends in step S4. At the end of the charge period, in step S5 the achieved charge current Ip is measured. The coil is then discharged for a sparking event to take place. In step S6, the measured value of Ip is compared with minimum and maximum values. If the measured value lies within this acceptable range, the process then goes back to the start and no change in the delay is made. It is then determined if the charge current Ip is less than a minimum acceptable (threshold) value at step S7; if so the delay is increased at step S8; if the value is above a maximum threshold the delay is consequentially decreased at step S9.

[0029] In refined examples, effects of coil temperature and/or other parameters can be taken into account. The values of Ipmin and Ipmax, and/or the dwell time applied can be varied dependent on such parameters. It would be clear to the person skilled in the art how such refinements can be implemented, such as using test data which provides relationships between the parameters and Ip, to map/determine any appropriate control.

[0030] The above methodology takes place at the coil level, for example by a microcontroller integrated with the coil. The term integrated does not necessarily mean that the circuitry or processing means be located internally within the coil but can be located externally or even remotely from the coil.

[0031] Thus according to aspects of the invention, the methodology utilises (e.g. closed loop monitoring) at the coil level to adjust dwell time - that is autonomously and independently. In aspects therefore, such control of dwell time is only dependent on coil parameters. The methodology thus in summary, may continuously monitor the current level reached at the end of the dwell time (as well as other parameters such as temperature) and compensate or correct parameters such as dwell time at the next ignition event to get closer to the targeted Ip current while protecting the coil to overstress. The spark event will remain at the requested time.

[0032] Aspects of the invention provide a method of avoiding critical operating conditions in the ignition coil, such as avoiding overstepping the operating temperature (by excessive power dissipation), protecting internal components from overheating. Thus durability is increased. In addition the level of complexity of the ECU can be reduced.

[0033] A further aspect of the invention concerns manufacture/assembly of ignition coils. An ideal ignition coil assembly built with ideal components will have ideal characteristics. In reality, all components will have tolerances and the characteristics of manufactured parts will inevitably vary. One such characteristic is the primary current (Ip) as a function of the dwell time. Even if all (e.g. environmental/test) parameters such as temperature, pressure, humidity, are the same, the dispersion of the Ip current for a specific dwell time in a coil will be a function of the tolerances of the different components of the coil such as varying dimensions and material characteristics of such as magnet, transformer, wires, etc.

[0034] According to an aspect of the invention, a method provides for the reduction of the dispersion of the Ip current around the ideal/target value (that is the variability) by a calibration process which includes adjusting or setting the charge/dwell time for a particular coil during manufacture, installation or operation. In such a way, varying component tolerances can be catered for. Furthermore manufacturing tolerances can even be increased, reducing the intensity and accuracy of the manufacturing process, and thus reducing costs. Additionally, having a calibration method which allows for a wider tolerance margin, results in less rejection during any final assembly or test.

[0035] Once the coil is installed in a vehicle, an ECU can still be used to control the coil so as to change the dwell time and therefore alter the Ip characteristics.

[0036] According to the calibration methodology in one aspect, Ip current level at the end of the dwell time is measured and compared with ideal levels. If this measured current is more than a certain tolerance limit; i.e. away from the ideal current level, than a calibration delay is added/included so as to adjust the set dwell time. It is to be noted that such a calibration methodology can be performed before installing the coil, i.e., during manufacture, and/or can be performed in situ, i.e. in normal operation.

[0037] In a simple example that may be applied to a coil during manufacture, testing is performed by charging the coil for a set dwell time, at the end of the charge time, initiating a sparking event. The charge current Ip is measured. Depending on the measured value of Ip, dwell time is either increased or decreased, i.e. a self-correction delay applied to a dwell time is either increased or decreased. The dwell time/self-correction delay is saved, i.e. set and/or stored. Alternatively, the process may be repeated until the value of Ip is within certain limits. The process of calibration may be similar to that described with reference to the first aspect. The delay time can be adjusted and set so that the Ip (maximum) lies within an accepted range or value.

[0038] The calibration methodology may be implemented after coil assembly and before installation of the coil into a vehicle. Alternatively or additionally, such calibration methodology may be performed/applied in situ, i,e. after the coil has been installed in an engine, for example in a plant which assembles engines or vehicle.

[0039] Furthermore, the methodology can be performed in use; i.e. during vehicle operation, say at regular intervals. Figure 2 illustrates an example of a coil calibration process according to such an aspect. The methodology is similar to the first aspect.

[0040] In the first step of the process S1, the coil starts to charge and at step S2 a self-correction delay may be applied. This is determined in later steps. In steps S3 and S4 coil charging takes place. At the end of the charge period, in step S5 the charge current Ip may be measured. The coil is then discharged for a sparking event to take place.

[0041] In step S6, a decision is made as to whether a calibration mode should be implemented. If so in step S7, it is determined to see if the measured value of Ip compared with minimum and maximum values. If the measured value lies within this acceptable range, the calibration is complete and no change in the delay is made. A determination is made at step S8 to see if the value of Ip is less than a minimum acceptable (threshold) value, then the delay is increased at step S9 if the value is above a maximum threshold the delay is consequentially decreased at step S10. At step S11 any new correction delays are saved.

[0042] Thus figure 2 shows how a calibration method can be applied during normal operation of a vehicle. Of course, the calibration method steps can be carried out at any suitable or appropriate time or interval; the calibration method may be carried at regular intervals such as once a month to cater for any wear and tear and consequential changes in component characteristics. Thus the calibration methodology of the process can be performed after manufacture of the coil as well as during manufacture of the coil and/or during assembly of a coil into a vehicle.

[0043] In preferred embodiments, other parameters such as temperature may be measured, estimated or otherwise determined and used as described above to set or adjust the delay or dwell time.

[0044] In a preferred embodiment both the calibration process/method as well as the autonomous (coil level) adjustment of the first aspect includes a temperature measurement capability. Temperature may influence coil performance due consequential changes of inductivity from thermal expansion phenomena, demagnetization issues, primary resistance variation. In current systems, the ECU does not consider and thus does not cater for actual temperature. In a manufacturing plant there will be variations in shop floor temperature. Furthermore, there may also be a delay between the time coils or components thereof are produced and installed. Components made on say a Friday afternoon may be significantly colder than those ready to be installed on a Monday morning. These variations would change the coil characteristics and introduce variability. The calibration method of the above described aspects help eliminating the effect of tolerance spread arising from such variable conditions.

[0045] Thus the methodology allows lower tolerances for ignition coils and parameters, and there is no need to limit coil operation to worst case conditions. As a consequence, and additional benefit is that there is less wastage and scrap.

[0046] For both the first and second aspects, the feature of measuring temperature for coil operation or calibration will cater for temperature changes and also effectively provide for temperature control itself (by reducing unnecessary charge) and avoid overheating. This will also reduce degradation through aging.

[0047] The above description is considered that of the preferred embodiments only. Modifications of the invention will occur to those skilled in the art and to those who make or use the invention. Therefore, it is understood that the embodiments shown in the drawings and described above are merely for illustrative purposes and not intended to limit the scope of the invention, which is defined by the following claims as interpreted according to the principles of patent law, including the doctrine of equivalents.

Claims

1. A method of controlling the operation of an ignition coil comprising measuring one or more operating and/or environmental parameter(s) of the coil; and adjusting/setting one or more operating parameters based upon on said measured parameters, wherein said operating or environmental parameters are measured, set or adjusted at the coil level.

2. A method as claimed in claim 1 where said operating parameter is set or adjusted independently of non-coil parameters.

3. A method as claimed in claim 1 or 2 wherein said operating parameter is dwell time.

4. A method as claimed in claims 1 to 3 wherein said measured parameters includes the maximum or charge current, Ip, in the coil primary winding.

5. A method as claimed in claims 1 to 4 including the step of comparing said maximum/charge current with an upper and/or lower limit, and adjusting the dwell time depending on whether the said current lies outside said limit(s).

6. A method as claimed in claims 1 to 5 wherein said dwell time is set or adjusted as a function of coil temperature.

7. A method as claimed in claims 1 to 6 wherein where said upper and/or lower limits are a function of said measured operating temperature.

8. A method of calibrating an ignition coil comprising: measuring one or more operating or environmental parameters of the coil; adjusting or setting one or more operating parameters based upon on said measured parameters.

9. A method as claimed in claim 8 which is implemented before assembly of said system into a vehicle.

10. A method as claimed in claim 8 or 9 wherein said operating parameter includes dwell time

11. A method as claimed in claims 8 to 10 wherein said measured parameters includes the maximum or charge current in the coil primary winding.

12. A method as claimed in claims 8 to 11 including the step of comparing said maximum or charge current with an upper and/or lower limit, and adjusting or setting the dwell time depending on whether this current lies outside said limit(s).

13. A method as claimed in claims 8 to 12 wherein coil or plant temperature is a measured parameter.

13. A method wherein where said upper and lower limits are dependent on said measured operating temperature.

14. An ignition coil or system therefor, including an ignition coil and means to control the operation of said coil comprising means to measure one or more operating and/or environmental parameters of the coil; and means to adjust/set one or more operating parameters of said coil based upon on said measured parameters, wherein said operating or environmental parameters are measured, set or adjusted at the coil level.

15. An ignition coil or system therefor, as claimed in claims 14 wherein means to set or adjust said operating parameter is independent of non-coil parameters.

16. An ignition coil or system therefor, as claimed in claims 14 or 15 wherein said control and/or adjusting/setting means are integral with said coil.

17. An ignition coil or system therefor, as claimed in claims 14 to 16 wherein said operating parameter includes dwell time.

18. An ignition coil or system therefor, as claimed in claims 14 to 17 wherein said measured parameters includes the maximum or charge current in the coil primary winding.

19. An ignition coil or system therefor, as claimed in claims 14 to 18 including means to compare said maximum/charge current with an upper and/or lower limit, and means to adjust the dwell time depending on whether the said current lies outside said limit(s).

20. An ignition coil or system therefor or system as claimed in claims 14 to 19 having means to set said dwell time as a function of coil temperature.

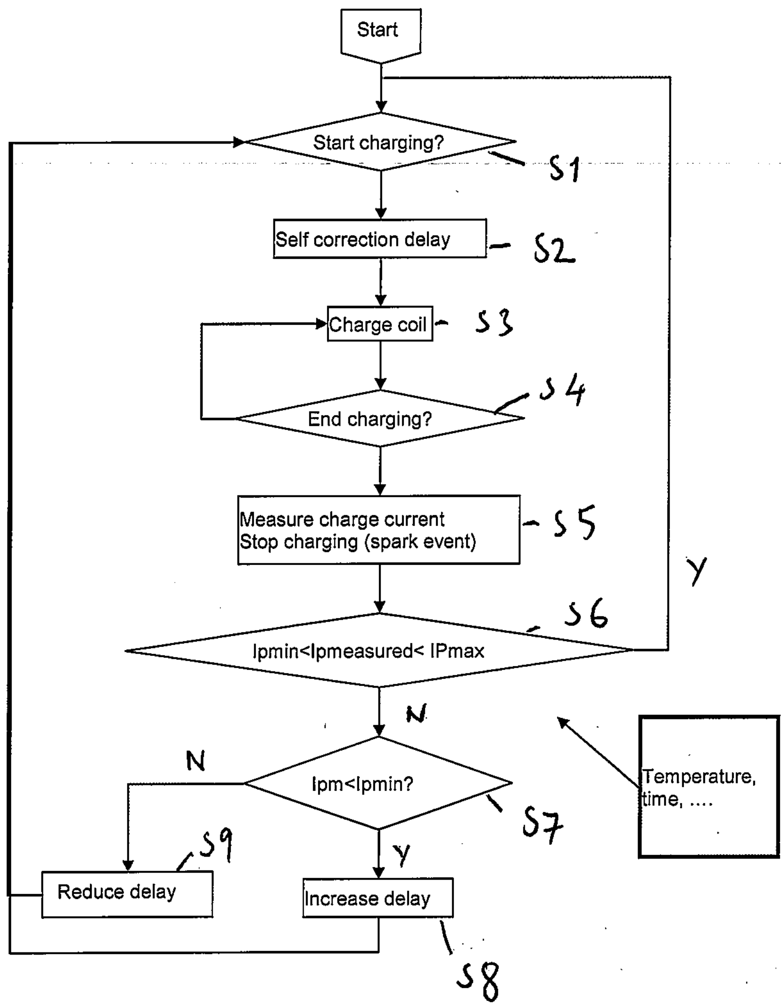
Start
Start charging?
S1
Self correction delay
S2
Charge coil
S3
End charging?
S4
Measure charge current
Stop charging (spark event)
S5
Y
S6
Ipmin<Ipmeasured< IPmax
N
Temperature, time, ...
N
Ipm<Ipmin?
S7
S9
Y
Reduce delay
Increase delay
S8

FIG 1

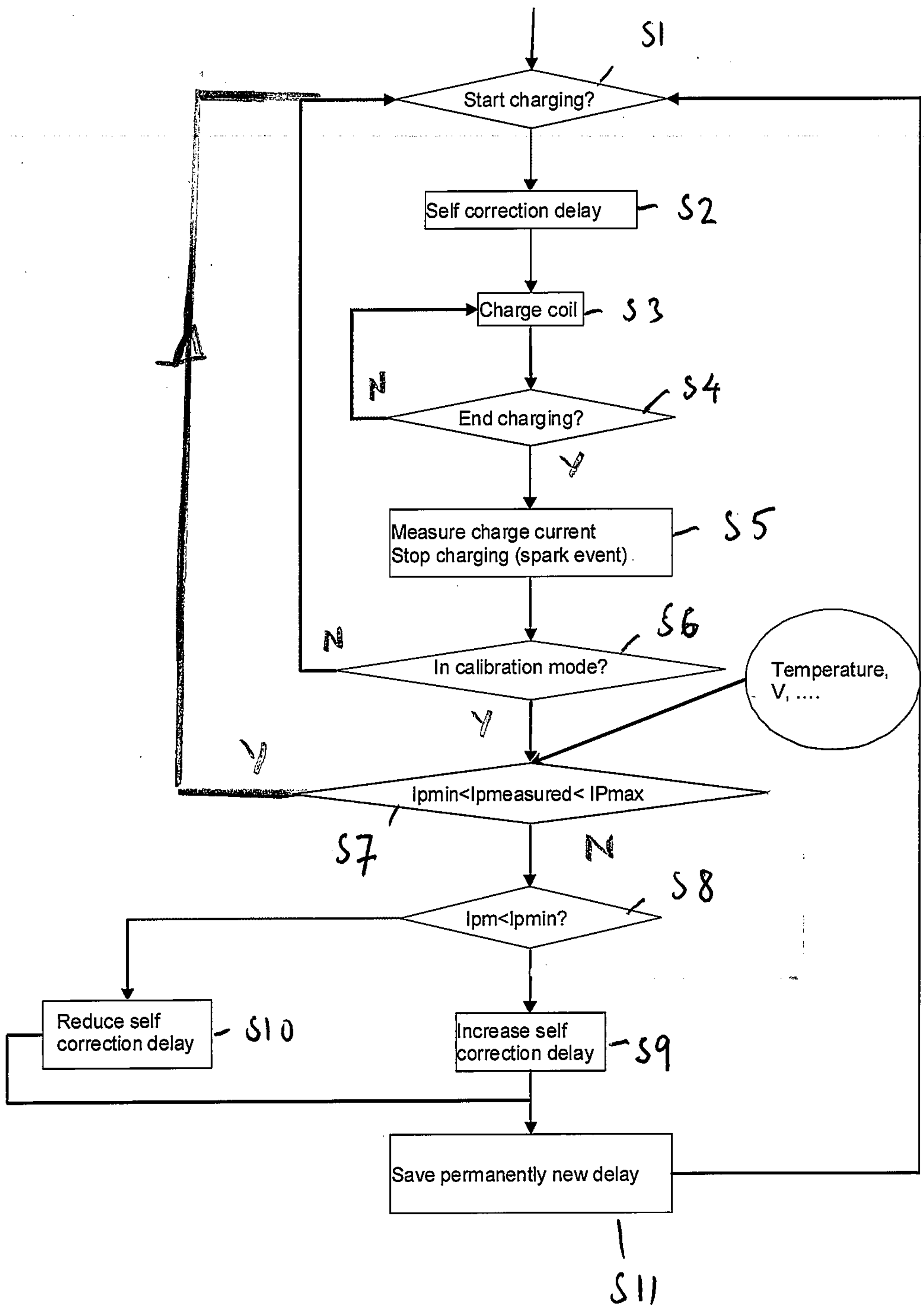
S1
Start charging?
Self correction delay
S2
Charge coil
S3
N
End charging?
S4
Y
Measure charge current
Stop charging (spark event)
S5
N
S6
In calibration mode?
Temperature,
V, ...
Y
Y
Ipmin<Ipmeasured< IPmax
S7
N
S8
Ipm<Ipmin?
Reduce self
correction delay
S10
Increase self
correction delay
S9
Save permanently new delay
S11

Fig 2

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EUROPEAN SEARCH REPORT

Application Number
EP 13 16 4155

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The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	18 September 2013	Ulivieri, Enrico

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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