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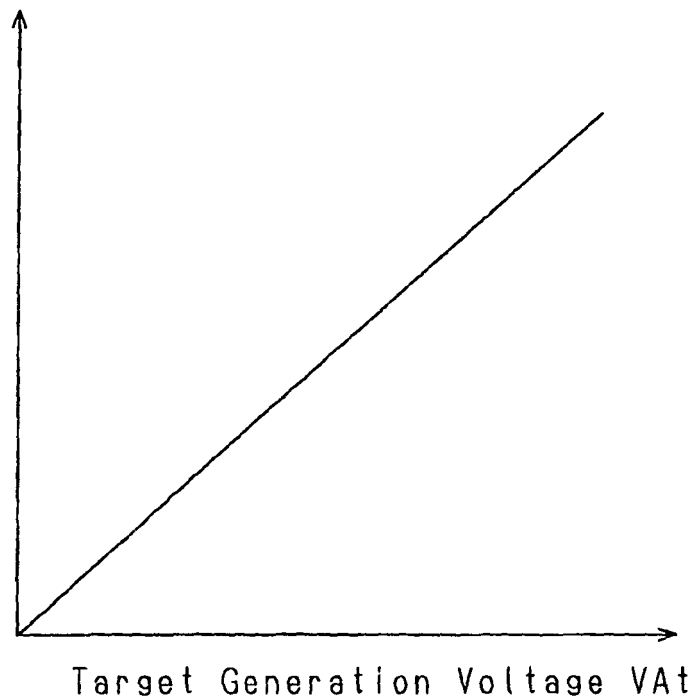
(54) **Control apparatus for internal combustion engine**

(57) A control apparatus for an engine is disclosed. The control apparatus includes a generation control section that controls electric generation by a generator driven by the engine, and an engine control section that, when a start request of the engine is made, drives the starter

motor, thereby starting the engine. The generation control section executes a generation restriction process in which the electric generation by the generator is restricted during a period from when the start request is made until when a predetermined period has elapsed after the driving of the starter motor is stopped.

**Fig.5**

Predetermined  
Period  $T_v$



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## Description

### FIELD OF THE INVENTION

**[0001]** The present invention relates to a control apparatus for an internal combustion engine, the apparatus including a generation control section that controls electric generation of a generator driven by the engine and an engine control section that drives a starter motor to rotate a crankshaft, thereby starting the engine.

### BACKGROUND OF THE INVENTION

**[0002]** Japanese Laid-Open Patent Publication discloses a control apparatus for an internal combustion engine mounted on a vehicle. The control apparatus disclosed in the publication has an automatic stop and restart function. That is, the control apparatus automatically stops the engine when the vehicle is started from a stopped state. Also, when a start request is made while the engine is in the stopped state, the control apparatus drives the starter motor to rotate the crankshaft, thereby automatically starting the engine.

**[0003]** The vehicle has a generator that is driven by rotation of the crankshaft of the engine. Electricity generated by the generator is supplied to and stored in a battery. The electricity stored in the battery is supplied to various electric auxiliary devices mounted on the vehicle. The generation voltage of the generator is controlled by the control apparatus.

**[0004]** A conventional control apparatus such as the apparatus as disclosed in the above publication, which has an automatic stop and restart function, control the generator in such a manner that a target generation voltage is obtained from the generator even when the rotation speed of the engine is low during restart. In general, since the temperature of the combustion chamber of the engine is low immediately after restart, atomization of fuel in the combustion chamber is unlikely to be promoted. This can destabilize the rotation speed of the engine. Immediately after restart, the load torque caused by driving of the generator is great among various kinds of load torque applied to the engine. As a result, the fluctuation of the engine speed is not negligible.

**[0005]** The above described problem is not unique to control apparatuses for an internal combustion engine having an automatic stop and restart function, but can arise in a control apparatus for an internal combustion engine having no automatic stop and restart function.

### SUMMARY OF THE INVENTION

**[0006]** Accordingly, it is an objective of the present invention to provide a control apparatus for an internal combustion engine, which apparatus reliably suppresses fluctuation of the engine speed caused by driving a generator immediately after the engine is started.

**[0007]** To achieve the foregoing objective and in ac-

cordance with one aspect of the present invention, a control apparatus for an internal combustion engine is provided. The apparatus includes a generation control section that controls electric generation by a generator driven by the engine, and an engine control section that, when a start request of the engine is made, drives a starter motor, thereby starting the engine. The generation control section executes a generation restriction process in which the electric generation by the generator is restricted during a period from when the start request is made until when a predetermined period has elapsed after the driving of the starter motor is stopped.

**[0008]** Other aspects and advantages of the present invention will become apparent from the following description, taken in conjunction with the accompanying drawings, illustrating by way of example the principles of the invention.

### BRIEF DESCRIPTION OF THE DRAWINGS

**[0009]** The invention, together with objects and advantages thereof, may best be understood by reference to the following description of the presently preferred embodiments together with the accompanying drawings in which:

Fig. 1 is a block diagram schematically showing a control apparatus for an on-vehicle internal combustion engine according to a first embodiment, and peripheral devices;

Fig. 2 is a flowchart showing a generation restriction process executed by the control apparatus of Fig. 1; Fig. 3 is a timing chart showing changes of a pedal depression degree, changes in a drive state of a starter motor, time elapsed from when driving of the starter motor is stopped, changes of a target generation voltage of an alternator, changes of the actual generation voltage of the alternator, changes of the engine speed, and changes of fuel injection amount; Fig. 4 is a flow chart showing a generation restriction process according to a second embodiment of the present invention;

Fig. 5 is a map showing the relationship between the target generation voltage and a predetermined period in the second embodiment; and

Fig. 6 is a map showing the relationship between the target generation voltage and a predetermined period in another embodiment.

### DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

**[0010]** A control apparatus for an internal combustion engine according to a first embodiment of the present invention will now be described with reference to Figs. 1 to 3.

**[0011]** Fig. 1 is a block diagram showing an internal combustion engine (engine) 1 mounted on a vehicle and

a control apparatus for the engine 1, as well as peripheral devices of these. The engine 1 has a function by which the engine 1 is automatically stopped and restarted when a predetermined condition is met.

**[0012]** As shown in Fig. 1, a crank pulley 12 is attached to a crankshaft 11 of the engine 1, and an alternator pulley 22 is attached to an input shaft 21 of an alternator 2. A belt 3 is engaged with the crank pulley 12 and the alternator pulley 22. The belt 3 transmits the rotational force of the crankshaft 11 to the alternator 2, so that the alternator 2 is driven. Electricity generated by the alternator 2 is supplied to and stored in a battery 4. The engine 1 also has a starter motor 5 that rotates the crankshaft 11, thereby starting the engine 1. The starter motor 5 is driven by electricity supplied from the battery 4.

**[0013]** The engine 1 has a crank angle sensor 61 that detects the rotation speed of the engine 1 (engine speed NE). The vehicle has a pedal depression sensor 62 that detects a depression degree ACCP of an accelerator pedal, a brake switch 63 that detects the depression state of the brake, a shift position sensor 64 that detects the shift position of the transmission, and a vehicle speed sensor 65 that detects the speed S of the vehicle. The battery 4 includes a voltage sensor 66 that detects battery voltage VB indicating the charging status of the battery 4.

**[0014]** Detection signals of the sensors 61 to 66 are sent to an electronic control unit 9, which will be described below. The electronic control unit 9 includes a CPU that executes calculations and determinations, a memory that stores various kinds of data, and various types of drive circuit.

**[0015]** The electronic control unit 9 has an engine control section 91 that, when a start request of the engine 1 is made, drives the starter motor 5, thereby starting the engine 1. The engine control section 91 performs automatic stop and start control of the engine 1. The engine control section 91 grasps the operating state of the engine 1 and the running state of the vehicle based on detection signals from the sensors 61 to 66, and controls fuel injection amount Q in accordance with the grasped states.

**[0016]** Next the automatic stop and restart control executed by the engine control section 91 will be explained.

**[0017]** When a predetermined stopping condition is met, for example, when the brake is depressed and the vehicle has been in stopped state for a predetermined period, the engine control section 91 stops fuel injection, thereby automatically stopping the engine 1. Also, when a predetermined starting condition is met, for example, when the brake is released during the vehicle in a stopped state, the engine control section 91 determines that a start request of the engine 1 is made, and drives the starter motor 5, thereby automatically restarting the engine 1. After starting driving the starter motor 5, the engine control section 91 stops driving the starter motor 5 when the engine speed NE reaches a predetermined speed NE1 (for example, 400 rpm). The predetermined stop condition for automatically stopping the engine 1

and the predetermined start condition for automatically starting the engine 1 are not limited to those shown above. The stopping condition and starting condition may be set based, for example, on the shift position.

**[0018]** The electronic control unit 9 includes a generation control section 92 that controls the alternator 2 such that generation voltage VA of the alternator 2 becomes equal to a target generation voltage VAt.

**[0019]** Conventionally, even if the engine speed NE is low when restarting the engine 1, the alternator 2 is controlled such that the generation voltage VA of the alternator 2 becomes equal to the target generation voltage VAt. Thus, the load torque caused by driving the alternator 2 is great among various kinds of load torque applied to the engine 1. As a result, the fluctuation of the engine speed NE is not negligible. Particularly, since the engine control section 91 performs the automatic stop and start control, the starting of the engine 1 becomes significantly frequent. Thus, the fluctuation of the engine speed NE caused by driving the alternator 2 at restart of the engine 1 is not negligible.

**[0020]** Therefore, in the present embodiment, the generation control section 92 executes a generation restriction process, in which electric generation by the alternator 2 is inhibited from when a start request is made until when a predetermined period T1 has elapsed after the driving of the starter motor 5, which has been started in response to the start request, is stopped. Accordingly, the load torque applied to the engine 1 is reduced. Also, when the engine 1 is shifted from an idling state to a non-idling state, the generation restriction process is interrupted.

**[0021]** The generation restriction process of the present embodiment will now be described with reference to Figs. 2 and 3.

**[0022]** Fig. 2 is a flowchart showing a concrete procedure of the generation restriction process of the present embodiment. When a restart request is made, the generation restriction process is repeatedly executed by the electronic control unit 9 in a predetermined cycle.

**[0023]** As shown in Fig. 2, in the generation restriction process, whether elapsed time T from when driving of the starter motor 5 is stopped is less than a predetermined period T1 is determined (step S1) first. If the elapsed time T from when the driving of the starter motor 5 is stopped is less than the predetermined period T1 (YES in step S1), whether the pedal depression degree ACCP is zero is determined (step S2). If the pedal depression degree ACCP is zero (YES in step S2), it is determined that the engine 1 is in an idling state, and electric generation by the alternator 2 is inhibited (step S3). On the other hand, if the elapsed time T from when the driving of the starter motor 5 is stopped is greater than or equal to the predetermined period T1 (NO in step S1), or when the pedal depression degree ACCP is not zero (NO in step S2), that is, when the engine 1 is shifted from the idling state to the non-idling state, it is determined that the generation restriction process does not need to be executed. Then, the alternator 2 is controlled

such that the generation voltage VA of the alternator 2 becomes the target voltage VAt (step S4).

**[0024]** Next, referring to the timing chart of Fig. 3, changes of the pedal depression degree ACCP, changes in a drive state of the starter motor 5, the time T elapsed from when the driving of the starter motor 5 is stopped, changes of the target generation voltage VAt of the alternator 2, changes of the actual generation voltage VA of the alternator 2, changes of the engine speed NE, and changes of fuel injection amount Q in the case where the generation restriction process shown in Fig. 2 is executed will be explained. In Fig. 3, changes in a case where the accelerator pedal is not depressed during the generation restriction process are shown by solid lines, and changes in a case where the accelerator pedal is depressed during the generation restriction process are shown by double-dashed lines. Changes in a case where the generation restriction process is not executed are shown by alternate long and short dash lines.

**[0025]** As shown in Fig. 3, when a restart request is made at point in time t1, the starter motor 5 is started as shown in section (b). Accordingly, the engine speed NE increases as shown in section (f). Also, as shown in section (d), after point in time t1, the target generation voltage VAt of the alternator 2 is set to a predetermined value VA1 based on the battery voltage VB at the time.

**[0026]** In the conventional generation control, as shown by the alternate long and short dash line in section (e), after point in time t1, the alternator 2 is controlled such that the actual generation voltage VA of the alternator 2 becomes equal to the target generation voltage VA1. Therefore, among various kinds of load torque applied to the engine 1, the load torque caused by driving the alternator 2 is increased. As a result, as shown by the alternate long and short dash line in section (f), the engine speed NE greatly fluctuates after point in time t1 until point in time t5, at which the predetermined period T1 has elapsed from when driving of the starter motor 5 is stopped. As shown by the alternate long and short dash line in section (g), fuel injection is started after point in time t2. The fuel injection amount Q is set to a fuel injection amount Q2, which is greater than the fuel injection amount Q1 for a state where the alternator 2 does not generate electricity ( $Q2 > Q1$ ).

**[0027]** In contrast, in the case where the generation restriction process is executed as in the present embodiment, as shown by the solid line in section (e), the alternator 2 is controlled such that the actual generation voltage VA of the alternator 2 becomes zero after point in time t1. That is, the electric generation by the alternator 2 is inhibited. Thus, no load torque is applied to the engine 1 by the alternator 2. As a result, as shown by the solid line in section (f), fluctuation of the engine speed NE is suppressed after point in time t1. At this time, as shown by the solid line in section (g), the fuel injection amount Q is set to the fuel injection amount Q1 for a state where the alternator 2 generates no electricity. Thereafter, as shown by the solid line in section (f), when the engine

speed NE reaches a predetermined engine speed NE1 (for example, 400 rpm) at point in time t3, the driving of the starter motor 5 is stopped as shown in section (b) and the elapsed time T starts being measured as shown in section (c). When the elapsed time T reaches the predetermined period T1 at point in time t5, the alternator 2 is controlled such that the generation voltage VA of the alternator 2 becomes equal to the target generation voltage VA1 as shown by the solid line in section (e). Thus, after point in time t5, the fuel injection amount Q is set to a fuel injection amount Q2, which is greater than the fuel injection amount Q1 for a state where the alternator 2 does not generate electricity ( $Q2 > Q1$ ).

**[0028]** On the other hand, when the pedal depression degree ACCP increases as the accelerator pedal is depressed at point in time t2 as shown by the double-dashed line in section (a), the engine 1 is shifted from the idling state to the non-idling state. After point in time t4, the alternator 2 is controlled such that the generation voltage VA of the alternator becomes equal to the target generation voltage VA1 as shown by the double-dashed line in section (e). Then, as shown by the double-dashed line in section (f), the engine speed NE is increased above the idle engine speed NE2 (for example, 600 rpm) after point in time t4. Thus, after point in time t4, the fuel injection amount Q is set to a fuel injection amount Q3, which is greater than the fuel injection amount Q2 for a state where the pedal depression degree ACCP is zero ( $Q3 > Q2$ ).

**[0029]** The first embodiment described above has the following advantages.

(1) Through the generation control section 92, the generation restriction process is executed in which the electric generation by the alternator 2 is inhibited from when a restart request is made to when the predetermined period T1 has elapsed after the driving of the starter motor 5 is stopped. Accordingly, the load torque applied to the engine 1 is reduced. Therefore, in a period from when the start request of the engine 1 is made to when the predetermined period T1 has elapsed after the driving of the starter motor 5 is stopped, that is, in a period where the load torque applied to the engine 1 due to the driving of the alternator 2 constitutes a major cause of fluctuation of the engine speed NE, the fluctuation of the engine speed NE is reliably suppressed. The fuel consumption of the engine 1 is reduced by an amount corresponding to the reduction of the load torque applied to the engine 1 due to the inhibition of electric generation.

(2) Through the generation control section 92, the generation restriction process is interrupted if the engine 1 is shifted from the idling state to the non-idling state during the period from when a start request of the engine 1 is made to when the predetermined period T1 has elapsed since the driving of the starter

motor 5 is stopped. Therefore, the electric generation by the alternator 2 can be started before the predetermined period T1 has elapsed after the driving of the starter motor 5 is stopped.

**[0030]** A second embodiment of the present invention will now be described with reference to Figs. 4 and 5.

**[0031]** The present embodiment is different from the first embodiment in the following points. That is, in the present embodiment, a predetermined period Tv that defines the point in time of the completion of the generation restriction process is not a fixed value, but is varied based on the target generation voltage VAt of the alternator 2. The predetermined period Tv is set to be continuously changed in accordance with the target generation voltage VAt such that the higher the target generation voltage VAt, the longer the predetermined period Tv becomes.

**[0032]** The generation restriction process of the present embodiment will now be described with reference to Figs. 4 and 5.

**[0033]** Fig. 4 is a flowchart showing a concrete procedure of the generation restriction process of the present embodiment. When a restart request is made, the generation restriction process is repeatedly executed by the electronic control unit 9 in a predetermined cycle. Fig. 5 is a calculation map defining the relationship between the target generation voltage VAt and the predetermined period Tv.

**[0034]** As shown in Fig. 4, in this generation restriction process, the predetermined period Tv is set based on the target generation voltage VAt by referring to the calculation map shown in Fig. 5 (step S10). The relationship between the target generation voltage VAt and the predetermined period Tv shown in the calculation map is obtained through experiments and stored in the memory of the electronic control unit 9 in advance. As shown in Fig. 5, the predetermined Tv is proportional to the target generation voltage VAt such that the higher the target generation voltage VAt, the longer the predetermined period Tv becomes.

**[0035]** After the predetermined period Tv is set in the above described manner, whether the elapsed time T from when the driving of the starter motor 5 is stopped is less than the predetermined period Tv is determined (step S11). If the elapsed time T is less than the predetermined period Tv (YES in step S11), whether the pedal depression degree ACCP is zero is determined (step S12). If the pedal depression degree ACCP is zero (YES in step S12), it is determined that the engine is in an idling state, and electric generation by the alternator 2 is inhibited (step S13). On the other hand, if the elapsed time T from when the driving of the starter motor 5 is stopped is greater than or equal to the predetermined period Tv (NO in step S11), or when the pedal depression degree ACCP is not zero (NO in step S12), that is, when the engine 11 is shifted from the idling state to the non-idling state, it is determined that the generation restriction process does not need to be executed. Then, the alternator

2 is controlled such that the generation voltage VA of the alternator 2 becomes the target voltage VAt (step S14).

**[0036]** In addition to the advantages (1), (2) of the first embodiment, the second embodiment has the following advantages.

(3) When the target generation voltage VAt of the alternator 2 is high, the load torque applied to the engine 1 is great compared to a case where the target generation voltage VAt is low. Also, as the elapsed time from the start of the engine becomes longer, the engine speed NE tends to be more stabilized and fluctuation of the engine speed NE is less likely to occur. Through the generation restriction process is extended as the target generation voltage VAt of the alternator 2 is raised in the present embodiment. Thus, fluctuation of the engine speed NE is reliably suppressed not only before the predetermined period Tv has elapsed from when the driving of the starter motor 5 is stopped, but also after the predetermined period Tv has elapsed.

(4) Through the generation control section 92, the predetermined Tv is continuously varied such that the higher the target generation voltage VAt of the alternator 2, the longer the predetermined period Tv becomes. Therefore, the predetermined period Tv is set in a manner more suitable to the relationship between the target generation voltage VAt and the load torque applied to the engine 1. Regardless of the value of the target generation voltage VAt of the alternator 2, fluctuation of the engine speed NE when the predetermined period Tv has elapsed is reliably suppressed.

**[0037]** The present invention is not to be restricted to configurations shown in the above embodiments, but may be modified as shown below.

**[0038]** The second embodiment may be modified, for example, as shown in Fig. 6. In the modification of Fig. 6, the predetermined period Tv is set to a predetermined period T3 when the target generation voltage VAt is less than or equal to a predetermined value VA2, and to a predetermined period T2, which is longer than the predetermined period T3, when the target generation voltage VAt is greater than the predetermined value VA2. That is, the predetermined period Tv may be changed discretely in accordance with the target generation voltage VAt.

**[0039]** The longer the period of automatic stop, the lower the temperature in the combustion chamber of the engine 1 becomes and the more unstable the combustion immediately after the restart becomes. Accordingly, fluctuation of the engine speed due to the driving of the alternator 2 becomes significant. Therefore, for example, instead of or in addition to the target generation voltage VAt, the predetermined period Tv may be varied such

that the longer the period of automatic stop, the longer the predetermined period  $T_v$  becomes.

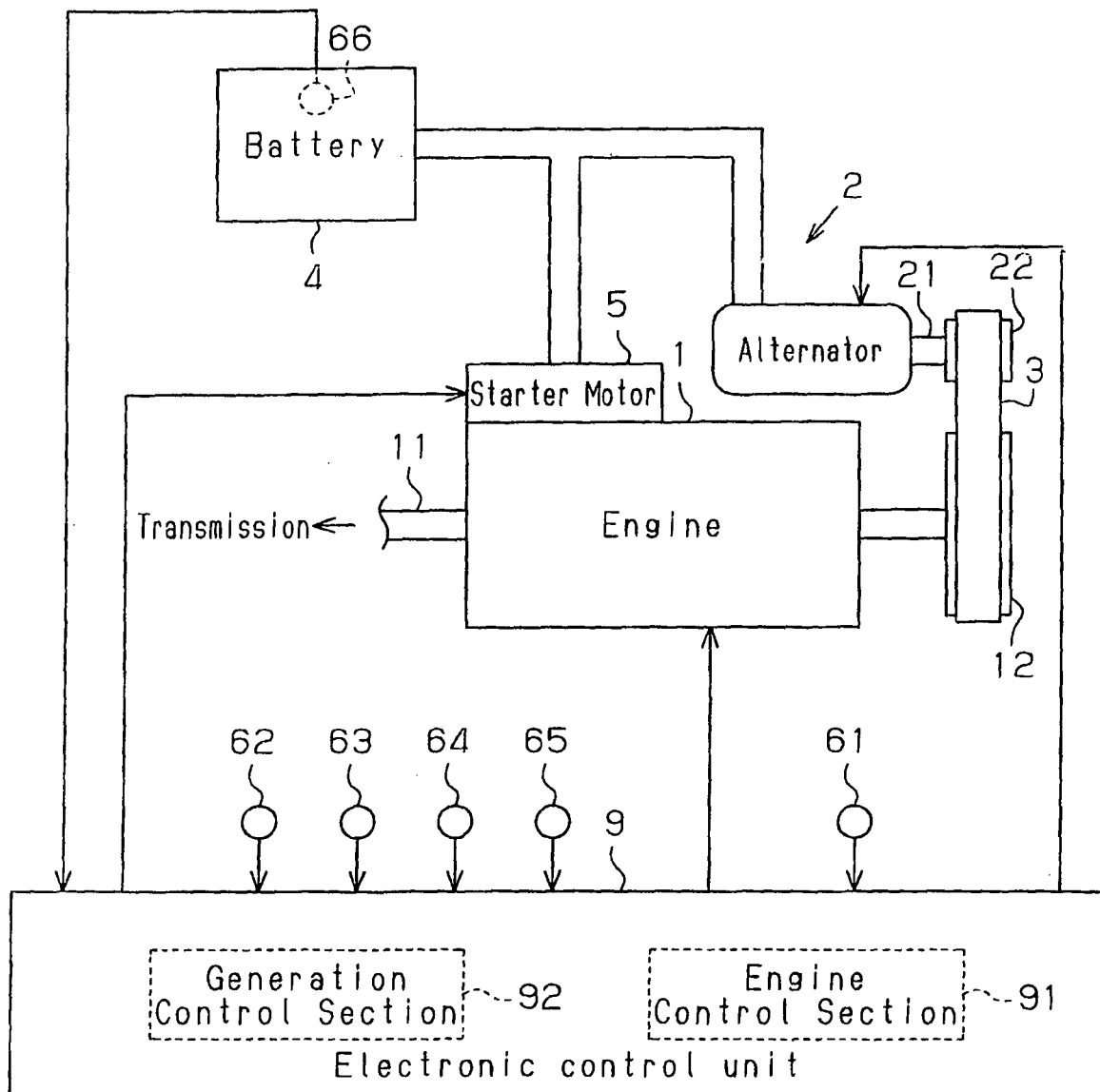
[0040] In the above described embodiments, the electric generation by the alternator 2 is inhibited in the generation restriction process. However, the configuration for limiting the electric generation of the alternator 2 is not restricted to this. For example, it may be configured such that the actual generation voltage  $V_A$  of the alternator 2 is lower than the target generation voltage  $V_{At}$  at the time. In short, any configuration may be adopted as long as the electric generation of the alternator 2 is limited.

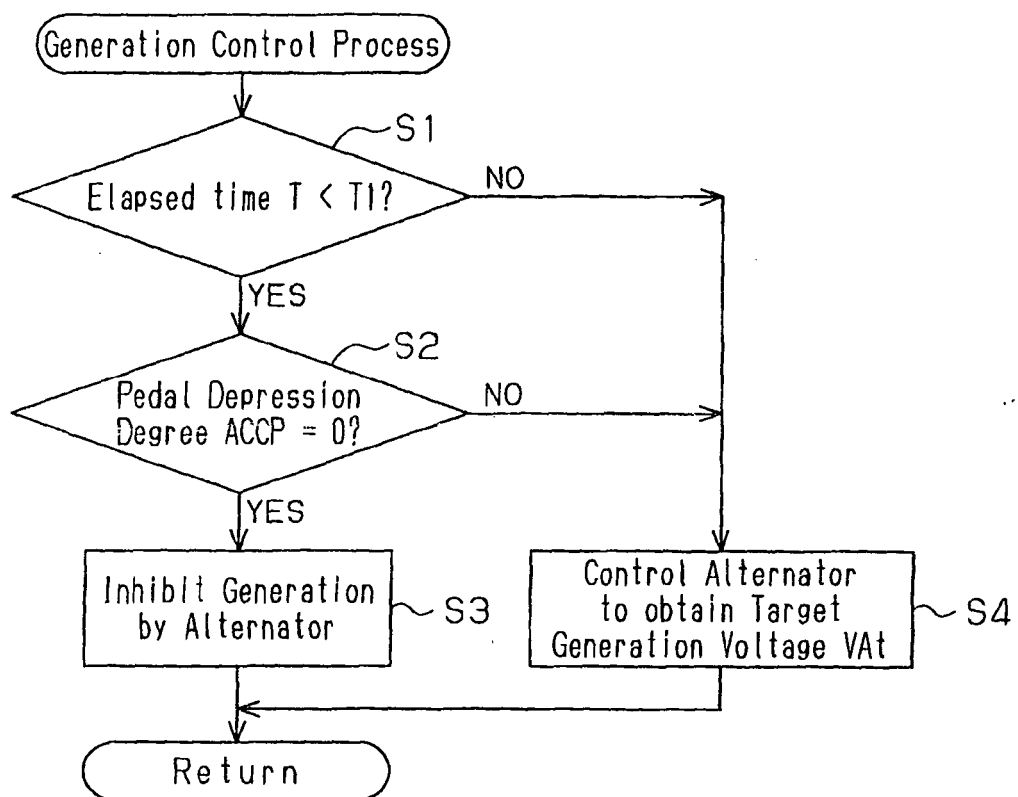
[0041] In the above described embodiments, the present invention is applied to the alternator 2, which is an AC generator. However, the present invention may be applied to a DC generator. In short, the present invention may be applied to any generator as long as it is driven by an internal combustion engine.

## Claims

1. A control apparatus for an internal combustion engine, the apparatus including a generation control section that controls electric generation by a generator driven by the engine, and an engine control section that, when a start request of the engine is made, drives a starter motor, thereby starting the engine, the apparatus being **characterized in that** the generation control section executes a generation restriction process in which the electric generation by the generator is restricted during a period from when the start request is made until when a predetermined period has elapsed after the driving of the starter motor is stopped.
2. The control apparatus according to claim 1, **characterized in that** the generation control section inhibits electric generation by the generator during the generation restriction process.
3. The control apparatus according to claim 1 or 2, **characterized in that** the generation control section sets a generation voltage of the generator to a value lower than a target generation voltage during the generation restriction process.
4. The control apparatus according to claim 3, **characterized in that** the generation control section interrupts the generation restriction process when the engine is shifted from an idling state to a non-idling state.
5. The control apparatus according to claims 3 or 4, **characterized in that** the generation control section sets the predetermined period such that the higher the target generation voltage of the generator, the longer the predetermined period becomes.
6. The control apparatus according to claim 5, **characterized in that** the generation control section continuously varies the predetermined period in accordance with the target generation voltage of the generator.
7. The control apparatus according to any one of claims 1 to 6, **characterized in that** the engine control section automatically stops the engine when a predetermined stopping condition is met, wherein, when a predetermined starting condition is met during the automatic stopping of the engine, the engine control section determines that the start request is made and drives the starter motor, thereby automatically restarting the engine.
8. The control apparatus according to claim 7, **characterized in that** the generation control section sets the predetermined period such that the longer the automatic stopping period, the longer the predetermined period becomes.

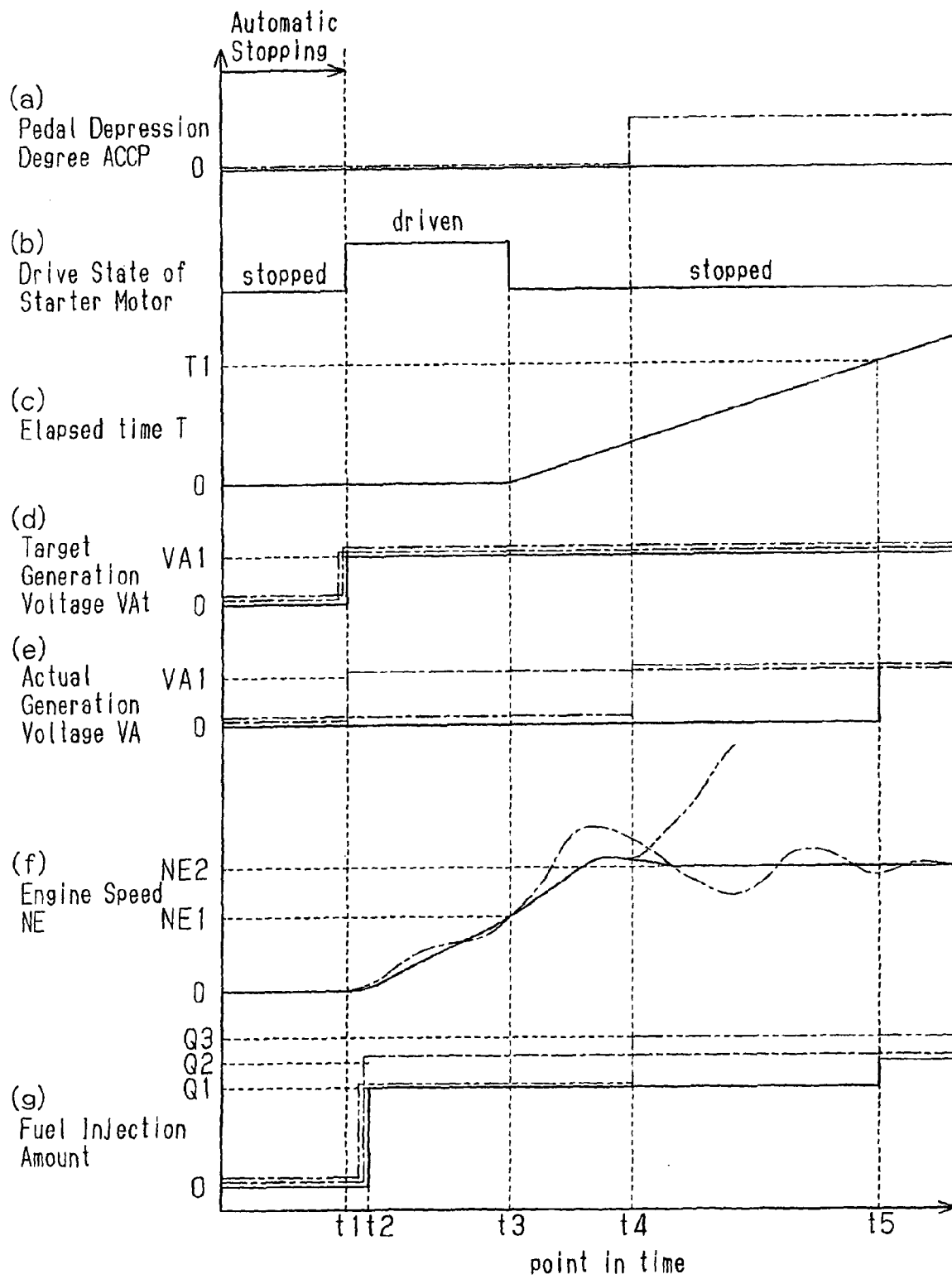
### Fig.1

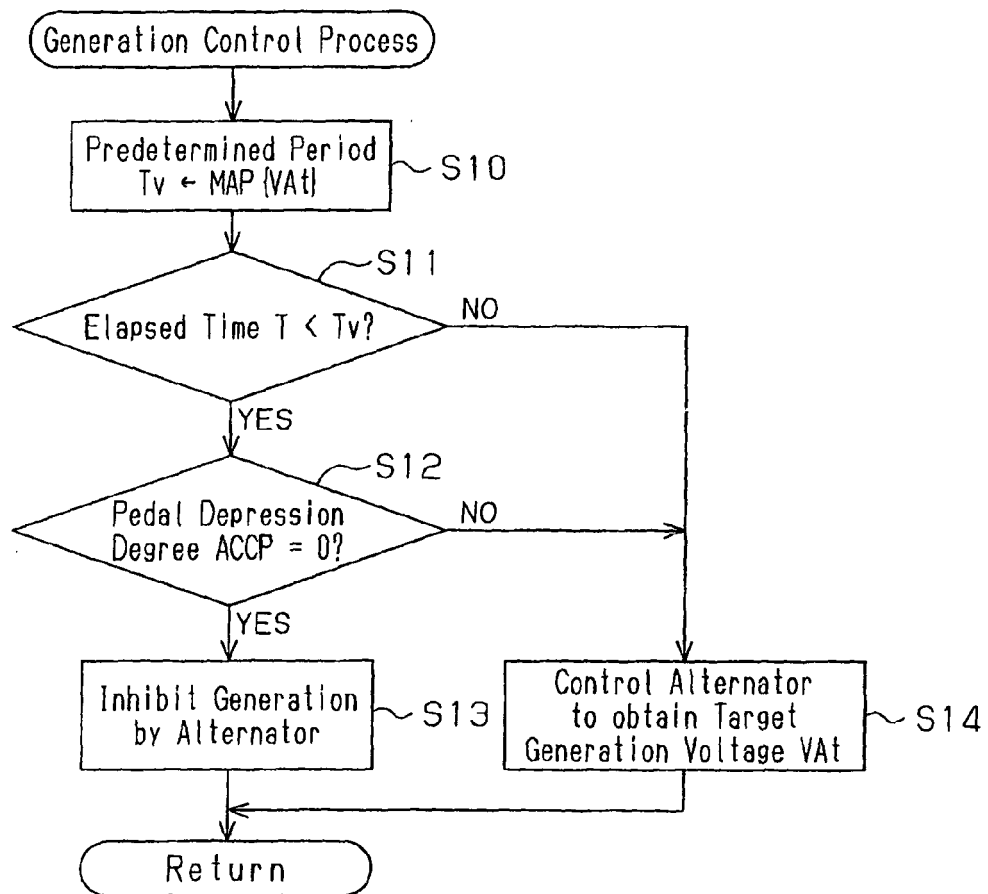


**Fig.2**

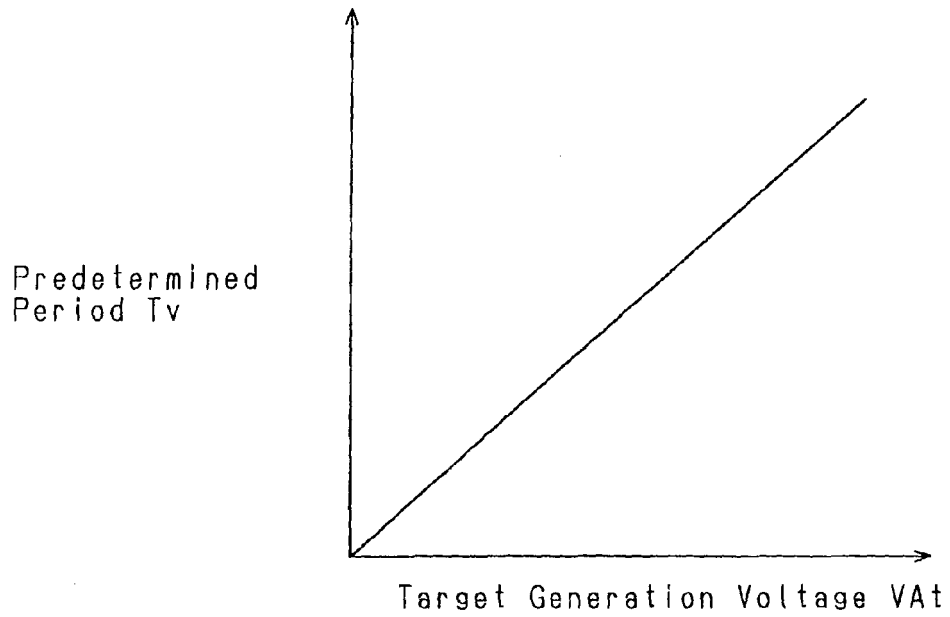


**Fig.3**



**Fig.4**

**Fig.5**



**Fig.6**

