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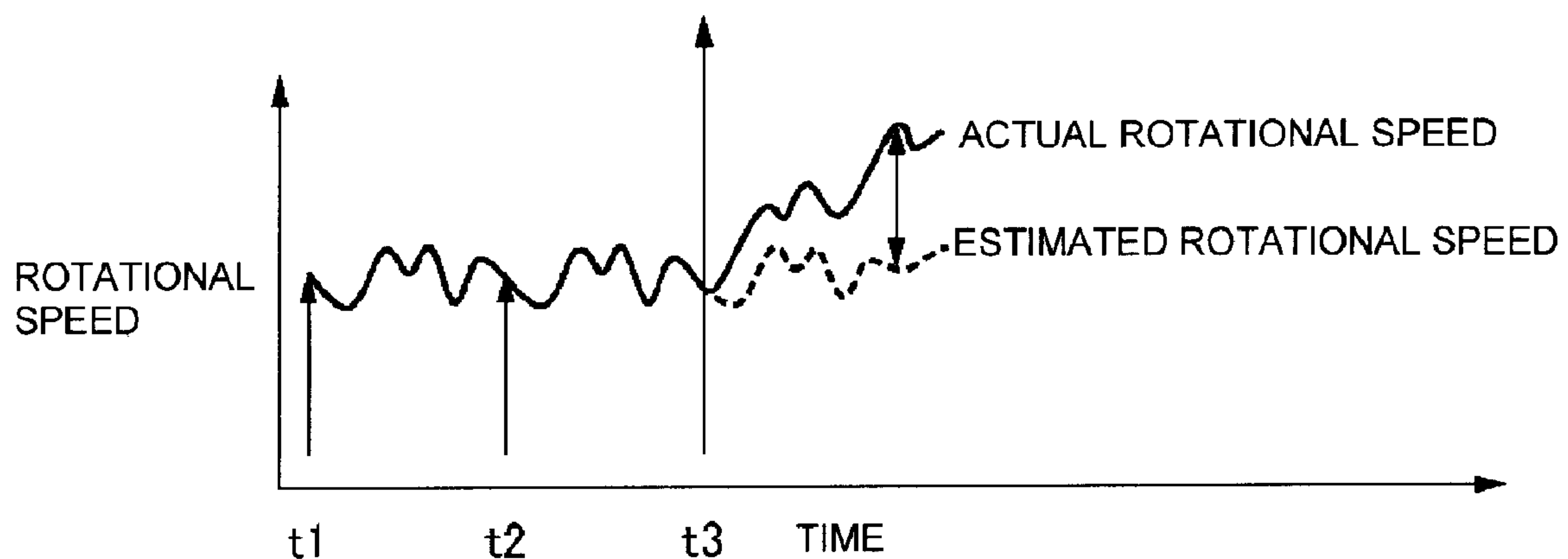
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(54) Titre : APPAREIL DE CHARGE DE BATTERIE POUR VEHICULE

(54) Title: BATTERY CHARGING APPARATUS FOR VEHICLE



(57) Abrégé/Abstract:

To suppress a decrease in the charging efficiency of a battery when a gap occurs between a power generation period and an energization period. A driver converts three-phase AC power outputted from a winding of each phase of a stator of a generator into DC power using a plurality of switching elements to supply the DC power to a battery. A control unit controls switching between an energized state and non-energized state of each of the switching elements. A position detection unit outputs a position detection signal indicating a position of a rotor of the generator. The control unit obtains a next estimation power generation period of the generator on the basis of the previous position detection signal and determines a next energization period of each of the switching elements on the basis of the estimation power generation period. The control unit judges start of the energization period on the basis of input of the position detection signal, and, if a period until next input of the position detection signal exceeds the energization period, during the period until the next input of the phase detection signal, the control unit has a maintenance period in which the switching elements are maintained in the energized state or non-energized state immediately before the period until the next input exceeds the energization period.

ABSTRACT OF THE DISCLOSURE

To suppress a decrease in the charging efficiency of a battery when a gap occurs between a power generation period and an energization period. A driver converts three-phase AC power outputted from a winding of each phase of a stator of a generator into DC power using a plurality of switching elements to supply the DC power to a battery. A control unit controls switching between an energized state and non-energized state of each of the switching elements. A position detection unit outputs a position detection signal indicating a position of a rotor of the generator. The control unit obtains a next estimation power generation period of the generator on the basis of the previous position detection signal and determines a next energization period of each of the switching elements on the basis of the estimation power generation period. The control unit judges start of the energization period on the basis of input of the position detection signal, and, if a period until next input of the position detection signal exceeds the energization period, during the period until the next input of the phase detection signal, the control unit has a maintenance period in which the switching elements are maintained in the energized state or non-energized state immediately before the period until the next input exceeds the energization period.

SUMMARY OF THE INVENTION

Accordingly, an object of the present invention is to suppress a decrease in the charging efficiency of a battery when a gap occurs between a power generation period
5 and an energization period.

As one means for achieving the above-mentioned object, the present invention includes the following constitution.

10 A feature of the present invention is that a battery charging apparatus for a vehicle includes: a driver unit that converts three-phase AC power outputted from a winding of each phase of a stator of a three-phase AC generator into DC power using a plurality of switching elements ($Q_{U1}, \dots, Q_{W2}$) to supply the DC power to a battery; a control unit that controls switching between an energized state and non-energized state of each of
15 the plurality of switching elements; and a position detection unit that outputs a position detection signal (T_p) indicating a position of a rotor of the three-phase AC generator. The control unit obtains a next estimation power generation period (T_E) of the three-phase AC generator on the basis of the previous position detection signal and determines a next energization period of each of the plurality of switching
20 elements on the basis of the estimation power generation period. The control unit judges start of the energization period on the basis of input of the position detection signal, and, if a period until next input of the position detection signal exceeds the energization period, during the period until the next input of the position detection signal, the control unit has a maintenance period in which the plurality of switching
25 elements are maintained in the energized state or non-energized state immediately before the period until the next input of the position detection signal exceeds the energization period.

According to the first aspect of the invention, even when an actual power generation
30 period becomes longer relative to the estimation power generation period due to the occurrence of rotational fluctuation, the generated electricity can be efficiently stored in the battery.

A feature of another aspect of the invention is that the maintenance period is limited
35 up to a predetermined period (T_{max}).

According to the above aspect of the invention, the flow of an excessive current to the switching elements can be prevented.

5 A feature of another aspect of the invention is that an input period of the position detection signal is determined by an interval between falling edges or between rising edges of the position detection signal, and the control unit obtains the estimation power generation period on the basis of a previous input period of the position detection signal and a variation (ΔP) thereof.

10 According to the above aspect of the invention, the estimation accuracy of the power generation period is improved, and the generated electricity can be efficiently stored in the battery.

15 A feature of a further aspect of the invention is that, if the next input of the position detection signal is not given even after a lapse of the predetermined period, the control unit switches the plurality of switching elements to an all-phase short-circuited state during the period until the next input of the position detection signal.

20 According to the above aspect of the invention, the flow of an excessive current to the switching elements can be prevented.

A feature of yet another aspect of the invention is that the predetermined period is changed in proportion to the estimation power generation period.

25 According to the above aspect of the invention, the time period when the switching element is maintained in the energized state or the non-energized state can be set to the time corresponding to the rotational fluctuation.

30 A feature of another aspect of the invention is that the predetermined period is a period of a predetermined phase angle of the estimation power generation period.

According to the above aspect of the invention, the predetermined period can be changed in accordance with the estimation power generation period.

35 A feature of a further aspect of the invention is that the control unit includes an energization pattern with a preset order of switching between the energized state and non-energized state of each of the plurality of switching elements in the energization

period, and the control unit determines a next energization timing of each of the switching elements in accordance with the energization pattern upon every input of the position detection signal.

- 5 According to the above aspect of the invention, the energization timing can be determined by the preliminarily prepared energization pattern. Thus, the control load is lightened, and responsiveness is improved.

10 A feature of yet another aspect of the invention is that the energization pattern sets the energization timing of the switching element connected to each phase of the three-phase AC generator, and the control unit simultaneously determines and updates the next energization timing of the switching element connected to each phase upon every input of the position detection signal.

- 15 A feature of another aspect of the invention is that the control unit detects a voltage (V_B) of the battery, and controls the energization timing to an advance side or a retard side so that the voltage of the battery becomes a predetermined voltage (V_T); the energization pattern includes an advance pattern and a retard pattern; and the control unit determines the energization timing of the switching element in accordance with
20 the advance pattern or the retard pattern.

According to the above aspects of the invention, the energization timing of the switching element connected to each phase can be simultaneously determined and updated by the preliminarily prepared energization pattern. Thus, the control load is
25 lightened, and responsiveness is improved.

A feature of a further aspect of the invention is that the battery charging apparatus further includes a throttle opening detector for detecting a throttle opening of an internal combustion engine. The rotor rotates based on rotation of the internal
30 combustion engine. The control unit corrects the estimation power generation period on the basis of a variation in the throttle opening.

A feature of yet another aspect of the invention is that the battery charging apparatus further includes a shift position detector for detecting a shift position of a transmission
35 disposed between the internal combustion engine and a driving wheel of the vehicle. The control unit corrects the estimation power generation period on the basis of the variation in the throttle opening and the shift position.

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A feature of another aspect of the invention is that the control unit includes as map data a predetermined variation in rotational speed of the internal combustion engine based on the variation in the throttle opening and the shift position and corrects the
 5 estimation power generation period on the basis of the map data.

According to the above aspects of the invention, even if the actual power generation period changes with respect to the estimation power generation period due to the occurrence of a rotational fluctuation in the internal combustion engine, generated
 10 electric power can be efficiently stored in the battery.

BRIEF DESCRIPTION OF THE DRAWINGS

Preferred embodiments of the invention are shown in the drawings, wherein:

15 Fig. 1 illustrates the electrical connection between a three-phase AC generator and a battery charging apparatus;

Fig. 2 is a timing chart for illustrating the outline of charge control by the battery charging apparatus;

Fig. 3 shows energization patterns of switching elements;

20 Fig. 4A is a flowchart showing an example of energization control;

Fig. 4B is a flowchart showing an example of energization control;

Fig. 5 shows an example of the relationship between an actual rotational speed and an estimated rotational speed of an internal combustion engine;

25 Fig. 6 is a block diagram showing an example of the connection for efficiently charging a battery following a rotational fluctuation;

Fig. 7 is a flowchart showing an example of the processing for correcting an estimated power generation period; and

Fig. 8 shows an example of map data.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

30 Hereinafter, a battery charging apparatus for a vehicle according to an embodiment of the present invention will be described in detail with reference to the accompanying drawings.

35 Fig. 1 illustrates the electrical connection between a three-phase AC generator and a battery charging apparatus.

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A three-phase AC generator (hereinafter referred to as the generator) 11 shown in Fig. 1 is a magnet generator driven by a prime mover such as an internal combustion engine. The magnet generator has: a rotor (rotator) 12 in which a magnetic field is formed by attaching permanent magnets to a yoke; and a stator (stationary part) 13 that is composed of an armature core and armature windings wound around the core. The rotor 12 is attached to a rotating shaft of the prime mover, and the stator 13 is fixed to an attaching portion that is attached to a case, a cover and the like of the prime mover.

10 The three-phase AC power outputted by the armature windings of the generator 11 is converted into DC power by a driver 14 that includes a full-wave rectifier, and is supplied to a battery 15 that is a secondary battery so as to charge the battery 15. Note that although an example of delta connection of the armature windings is shown in Fig. 1, a star connection is also possible.

15 In charging the battery 15, a control circuit 16 applies a control voltage to the armature windings by controlling the energization or non-energization of the switching elements arranged in parallel with diodes of the driver 14, and controls the output voltage of the generator 11 so as to obtain a voltage appropriate as a charging voltage of the battery 15. That is, the control circuit 16 detects a terminal voltage V_B of the battery 15 and controls the energization or non-energization of a plurality of switching elements of the driver 14 so that the terminal voltage V_B becomes a predetermined voltage V_T .

25 A position detection unit 17 includes a reluctor that is fixed to the rotor 12 of the generator 11 and a pulse generator that is fixed to an attaching portion of the generator 11 for example so as to oppose the reluctor. The position detection unit 17 produces a position detection signal T_p indicating the detection of the reluctor every time the reluctor that rotates along with the rotor 12 passes near the pulse generator.

30 A CPU 161 of the control circuit 16 executes control of each part of the vehicle by executing various control programs stored in a ROM 163 with a RAM 162 as a work memory. The control programs include the program regarding the charge control according to this embodiment. The control circuit 16 has an analog-digital converter (ADC) 165 for detecting the terminal voltage V_B of the battery 15. Further, the control circuit 16 has an input-output port (IO) 164 for outputting a drive signal to control the

energization or non-energization of each switching element of the driver 14 and inputting the position detection signal T_p outputted by the position detection unit 17.

Fig. 2 is a timing chart for illustrating the outline of charge control by the battery charging apparatus.

Fig. 2(a) shows the relationship between the position detection signal T_p and the energization period of, for example, a U phase, when prime-mover speed N_e is in a stable state. Fig. 2(a) shows a state in which the position detection signal T_p falls at every electrical angle of 360° , and thereafter, the energization period of the U phase starts when the electrical angle is advanced by a predetermined angle, and ends when the electrical angle is further advanced by 180° .

The CPU 161 measures the power generation period of the generator 11 by detecting the falling of the position detection signal T_p and measuring an interval between falling edges of the position detection signal T_p , and estimates a next power generation period from the measurement result. It should be noted that, hereinafter, the detection of falling of the position detection signal T_p by the CPU 161 is simply referred to as "detection of T_p ", "input of T_p " or the like. It should be also noted that the estimated power generation period is referred to as the "estimation period".

The next power generation period (estimation period TE_2 shown in Fig. 2(a)) may be estimated from the result of period measurement M_0 shown in Fig. 2(a), but is preferably estimated by including the measurement results of a previous power generation period in consideration of fluctuation in the rotational speed N_e . More specifically, whether the rotational speed N_e is on an upward trend or downward trend is judged from the measurement results of the previous power generation period, and, with the judgment result taken into consideration, the power generation period is estimated. For example, in Fig. 2(a), an estimation period TE_0 is estimated from the results of period measurements M_0 to M_2 .

The reference timing for starting the energization period is, for example, the timing at which the induction voltage of the U phase is inverted from negative polarity to positive polarity (hereinafter, referred to as the inversion from negative to positive). Fig. 2(a) shows an example where there is a slight difference between the detection timing of T_p and the reference timing for starting the energization period which corresponds to the timing of inversion from negative to positive of the U phase. This

difference in timing is related to the location of the position detection unit 17, and the electrical angle corresponding to the timing difference is always constant. Furthermore, this timing is changed by performing advance/retard control of the energization period. The advance/retard control will be described later. Therefore, if
5 an estimation period TE is obtained, it is possible to estimate at which timing the U phase is to be inverted from negative to positive after the detection of T_p . For example, when the electrical angle corresponding to the timing difference is defined as Δ , the point of time when $TE \cdot \Delta/360$ seconds elapses from start of time counting upon detection of T_p can be set as the reference timing for starting the energization period.

10 Fig. 3 shows energization patterns of the switching elements of the driver 14. In Fig. 3, the energization patterns for one energization period are shown, wherein "ON" indicates a closed state (ON, an energized state) of the switching element and "OFF" indicates an open state (OFF, an non-energized state) of the switching element.

15 Fig. 3(a) schematically shows an induction voltage of each phase of U, V, and W. When the timing at which the induction voltage of the U phase is inverted from negative to positive is defined as an electrical angle of 0° , the induction voltages of the V and W phases are inverted from negative to positive at 120° and 240° , respectively.

20 Since the energization control of each switching element needs to be performed on the basis of the positive/negative inversion of the induction voltage, the relationship between opening and closing of each switching element can be summarized as an energization pattern shown in Fig. 3(b). As shown in Fig. 3(b), the energization pattern
25 defines first to sixth stages for phase divisions each having an electrical angle of 60° which are obtained by dividing one period of each phase into six equal parts. The CPU 161 produces a drive signal of each switching element while shifting the first to sixth stages in this order with the detection of T_p as a reference. It should be noted that the period of each stage is calculated by $TE/6$ ($= TE \cdot 60/360$) with respect to the
30 estimation period TE . It should be noted that the phase division of each stage is not limited to an electrical angle of 60° , but may be an electrical angle of less than 60° , such as an electrical angle of 30° .

35 In this manner, the energization/non-energization switching order of each of the plurality of switching elements in the energization period is determined in accordance with the energization pattern.

The energization pattern shown in Fig. 3(b) is a reference energization pattern. On the other hand, FIGS. 3(c) and 3(d) show an advance pattern and a retard pattern, respectively, which can be set at the time of controlling the amount of power generation. It should be noted that energization patterns for switching elements Q_{U2} , Q_{V2} , and Q_{W2} are formed by inverting those for switching elements Q_{U1} , Q_{V1} , and Q_{W1} forming push-pull pairs therewith, and therefore the description about the energization patterns for the switching elements Q_{U2} , Q_{V2} , and Q_{W2} is omitted in FIGS. 3(c) and 3(d).

- 10 The advance/retard control is to control an increase/decrease in the amount of power generation of the generator 11 by moving the energization period of the switching element toward an advance side or a retard side with respect to the power generation period.
- 15 When the battery voltage V_B is the predetermined voltage V_T or more, the CPU 161 judges that the charging to the battery 15 is excessive. Then the CPU 161 determines a next estimation period TE_{i+1} and sets the advance pattern (see Fig. 3(c)) as the energization pattern, which starts at the second stage and goes through the sixth stage to the first stage, to decrease the amount of power generation, thereby allowing
- 20 prevention of excessive charging to the battery 15.

- On the other hand, when the battery voltage V_B is less than the predetermined voltage V_T , the CPU 161 judges that the charging to the battery 15 is insufficient. Then the CPU 161 determines the next estimation period TE_{i+1} and sets the retard pattern (see
- 25 Fig. 3(d)) as the energization pattern, which starts at the sixth stage and goes into the first stage and ends at the fifth stage, to increase the amount of power generation, thereby allowing an increase in the amount of charge to the battery 15.

- In this manner, the control circuit 16 executes the advance/retard control so that the
- 30 battery voltage V_B becomes the predetermined voltage V_T by performing switching among the reference pattern, advance pattern, and retard pattern depending on the state of the battery voltage V_B .

- Next, referring back to Fig. 2(b), the charge control in the case of the occurrence of
- 35 rotational fluctuation in the prime mover will be described. Fig. 2(b) shows the relationship between T_p and the energization period of each phase in the case where the power generation period becomes longer due to rotational fluctuation in the prime

mover. Note that in Fig. 2(b), the above-described timing difference is defined as zero ($\Delta = 0$) in order to simplify the explanation.

In an estimation period TE_2 , T_p is not detected until the end of the estimation period, and further, after a lapse of a period t_1 , T_p is detected. In this case, after the end of the estimation period TE_2 , the CPU 161 starts counting of time t from the end of the estimation period while maintaining the energized state or non-energized state of each switching element at the end of the estimation period. It should be noted that hereinafter, maintaining the energized state or non-energized state of each switching element is referred to as the "state maintenance".

When T_p is detected before counting of the time t reaches a predetermined limiting period T_{max} , the CPU 161 determines a next estimation period TE_3 and starts the next energization period. That is, the count time t_1 , after the end of the estimation period TE_2 , does not reach the limiting period T_{max} ($t_1 < T_{max}$), and the state maintenance is performed in the period t_1 .

In the next estimation period TE_3 , again, T_p is not detected until the end of the estimation period, and further, after a lapse of a period $t_2 + t_3$, T_p is detected. Also in this case, after the end of the estimation period TE_3 , the CPU 161 starts counting of the time t from the end of the estimation period while performing the state maintenance corresponding to the state at the end of the estimation period.

When T_p is not detected and counting of the time t reaches the limiting period T_{max} , the CPU 161 sets an all-phase short-circuited state (all phase short-circuit) in which the switching elements Q_{U1} , Q_{V1} , and Q_{W1} are brought into an open state and the switching elements Q_{U2} , Q_{V2} , and Q_{W2} are brought into a closed state, and continuously counts the time t . Thereafter, when T_p is detected at the timing at which the period $t_2 + t_3$ elapses, the CPU 161 determines a next estimation period TE_4 and starts the next energization period. That is, after the end of the estimation period TE_3 , the count time t_2 reaches the limiting period T_{max} , and the all-phase short-circuited state is set for a period (i.e., the period from t_2 to t_3) until T_p is detected next.

The limiting period T_{max} , which is the maximum state-maintenance period, is set, for example, in proportion to the estimation period TE . That is, the limiting period is calculated by the equation, $T_{max} = k_1 \cdot TE$, where k_1 represents the proportion of the limiting period T_{max} to the estimation period TE . Furthermore, the state-

maintenance period may be controlled as a predetermined phase angle of the estimation period TE .

Figs. 4 are flowcharts showing an example of energization control. The energization control is executed by the CPU 161 and is a processing for causing the battery voltage V_B to converge to the target voltage V_T under PI control. The CPU 161 constantly monitors the position detection signal T_p , and, when detecting T_p , starts the processing from step S11.

- 10 The CPU 161 calculates a power generation period P_i from a first previous T_p detection timing and a second previous T_p detection timing (S11), and calculates an estimation period TE_i in consideration of a variation ΔP of the power generation period estimated before an electrical angle of, for example, 720° , according to the following equation (S12):

15

$$TE_i = P_i + \Delta P \cdot k_2 \quad (1),$$

where k_2 represents a predetermined coefficient.

- For example, in the case of calculating the estimation period TE_0 shown in Fig. 2, the first previous T_p detection timing is equivalent to T_0 ; the second previous T_p detection timing is equivalent to T_{-1} ; and the variation ΔP estimation timing is equivalent to T_{-2} .

- Next, the CPU 161 determines, from detection intervals of T_p , an energization phase angle limiting value θ_L for each of the advance side and the retard side which corresponds to the power generation period (S13). Then the CPU 161 obtains the current battery voltage V_B (S14) and calculates a current voltage deviation ΔV_i which is the difference between the battery voltage V_B and the target voltage V_T (S15).

- Subsequently, the CPU 161 calculates an energization phase angle θ_i on the basis of the value of the current voltage deviation ΔV_i (S16) and determines whether or not the calculated energization phase angle θ_i is within an allowable range (S17). When the energization phase angle θ_i is out of the allowable range, the CPU 161 changes the energization phase angle θ_i to the energization phase angle limiting value θ_L (S18). Then the CPU 161 determines an energization pattern from among the reference pattern, advance pattern, and retard pattern on the basis of the energization phase angle θ_i , and determines an energization timing of each switching element in accordance with the determined energization pattern (S19).

Subsequently, the CPU 161 calculates the limiting period $T_{\max}$ on the basis of the estimation period TE_i (S20).

5 Subsequently, the CPU 161 counts the above-described timing difference $TE_i \cdot \Delta/360$ seconds and judges the reference timing for starting the energization period by the detection of T_p (S21). At the reference timing for starting the energization period, the CPU 161 outputs a drive signal for driving each switching element in accordance with the energization timing determined in the step S19 (S22). Then the CPU 161 judges
10 whether or not the estimation period TE_i ends (S23). If it is not ended, the CPU 161 judges whether or not T_p is detected (S24). If T_p is not detected, the CPU 161 returns the processing to the step S22 and continues to output the drive signal. On the other hand, if T_p is detected in the step S24, the CPU 161 returns the processing to the step S11 and repeats the subsequent processing.

15 If the estimation period TE_i ends before the detection of T_p , the CPU 161 performs the state maintenance and starts counting of the time t (S25). Then the CPU 161 judges whether or not the time t reaches the limiting period $T_{\max}$ (S26). In the case of $t < T_{\max}$, the CPU 161 judges whether or not T_p is detected (S27). If T_p is not detected,
20 the CPU 161 returns the processing to the step S26 and repeats the limiting period judgment. On the other hand, if T_p is detected in the step S27, the CPU 161 returns the processing to the step S11 and repeats the subsequent processing.

When the time t reaches the limiting period $T_{\max}$ before the detection of T_p , the CPU
25 161 sets the all-phase short-circuited state (S28). Then the CPU 161 judges whether or not T_p is detected (S29), and, if it is detected, the CPU 161 returns the processing to the step S11 and repeats the subsequent processing.

30 It should be noted that the flows shown in Figs. 4 are illustrative only and may be any flow as long as it allows the achievement of processing, such as the control of the battery voltage V_B by the advance/retard control, the control in the state-maintenance period, or the setting of the all-phase short-circuited state after the end of the state-maintenance period.

35 In this manner, when the estimation period is shorter than the actual power generation period, after the end of the estimation period, the state maintenance is performed and the electricity for charging is extracted from the generator 11. Thus, it is possible to

suppress a decrease in the charging efficiency of the battery 15 when a gap occurs between the power generation period and the energization period. However, if the power generation period is long, and accordingly, the state-maintenance period becomes long, an excessive current might flow to the switching elements. In order to prevent the flow of an excessive current to the switching elements, the limiting period T_{max} which is the maximum state-maintenance period is provided, and, when the state-maintenance period reaches the limiting period T_{max} , the all-phase short-circuited state is set.

10 In the above description, the energization period is started with the falling of the position detection signal T_p as a reference. However, the energization period may be started with the rising of the position detection signal T_p as a reference. In that case, the "detection of T_p " and "input of T_p " correspond to the detection of the rising of the position detection signal T_p by the CPU 161.

15 Fig. 5 shows an example of the relationship between an actual rotational speed and an estimated rotational speed of the internal combustion engine, wherein the estimated rotational speed corresponds to $1/\text{the estimation period}$. It should be noted that, if the generator 11 has a plurality of poles, the estimated rotational speed corresponds to $1/(\text{the estimated rotational speed} \times \text{the number of poles of the generator})$. In Fig. 5, the solid-line curve represents the actual rotational speed of the internal combustion engine, and the dashed curve represents the estimated rotational speed. Furthermore, the up arrow represents a throttle opening.

25 Because there is no significant change in throttle opening between timing t_1 and t_2 and the fluctuation in actual rotational speed is relatively small, the rotational speed estimated on the basis of the position detection signal T_p outputted by the position detection unit 17 is substantially consistent with the actual rotational speed. However, the rotation of a throttle grip after the timing t_2 causes a major change in throttle opening between the timing t_2 and timing t_3 . As a result, the estimated rotational speed becomes lower than the actual rotational speed due to an increase in actual rotational speed, leading to a difference between the actual rotational speed and the estimated rotational speed.

35 In other words, if the power generation period is estimated on the basis of the position detection signal T_p outputted by the position detection unit 17, when a rotational fluctuation occurs in the internal combustion engine, the actual power generation

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period changes with respect to the estimated power generation period, resulting in the occurrence of a period of time during which generated electric power cannot be efficiently stored in the battery 15.

5 Hereinafter, the amount of change in throttle opening which causes a difference between the estimated power generation period and the actual power generation period is referred to as an "opening change threshold". In Fig. 5, the amount of change in the throttle opening at the timing t3 with respect to the throttle opening at the timing t2 exceeds the opening change threshold.

10

Fig. 6 is a block diagram showing an example of the connection for efficiently charging the battery 15 following a rotational fluctuation. It should be noted that like reference signs are used for the same elements as shown in Fig. 1, and a detailed description thereof will not be repeated. It should be also noted that, on the assumption that the control circuit 16 shown in Fig. 1 exists in an electronic control unit (ECU) 26, the description thereof is omitted.

15

Referring to Fig. 6, the rotor 12 of the generator 11 is connected to the internal combustion engine 21 through gears, chain, belt and the like, and rotates based on the rotation of the internal combustion engine 21. A transmission 22 is disposed between the internal combustion engine 21 and a driving wheel 25 of the vehicle. The rotation of the internal combustion engine 21 is decelerated by the transmission 22 and transmitted to the driving wheel 25. The shift position of the transmission 22 is operated by a shift pedal 23 disposed on a side surface of the vehicle.

20

The ECU 26 can detect a shift position of the transmission 22 through a detector 24 disposed on the transmission 22. Furthermore, the ECU 26 detects an operating state (rotational angle) of a throttle grip 27 disposed on a handlebar of the vehicle, as a throttle opening through a detector 28 and controls the rotation of the internal combustion engine 21 in accordance with the throttle opening.

25

The transmission 22 which allows an occupant to operate the shift position with the shift pedal 23 is shown for example in Fig. 6. However, the transmission 22 may be such that the shift position is controlled by the ECU 26 in response to the operation of a shift up/down switch disposed on the handlebar of the vehicle, or on the basis of the vehicle speed, the rotational speed of the internal combustion engine 21, etc.

30

35

Fig. 7 is a flowchart showing an example of the processing for correcting the estimated power generation period. After the calculation of the estimation period TE_i shown in Fig. 4A (S12), the correction processing is performed by the CPU 161 of the control circuit 16 before the calculation of the limiting period T_{max} (S20).

5

The CPU 161 detects a variation ΔTH in throttle opening (S101). It should be noted that the variation ΔTH is detected, for example, as a rotational angle of the throttle grip 27 per millisecond. Then the CPU 161 judges whether or not the variation ΔTH exceeds the above-described opening change threshold th (S102), and, if it is equal to or smaller than the opening change threshold ($\Delta TH \leq th$), the processing is ended.

10

On the other hand, if the variation exceeds the opening change threshold ($\Delta TH > th$), the CPU 161 calculates a rotational speed Ne corresponding to the rotational speed of the internal combustion engine 21 from the estimation period TE_i calculated in the step S12, according to the following equation (S103):

15

$$Ne = k3 / TE_i \quad (2)$$

where $k3$ represents a coefficient for converting the reciprocal (rotational speed of the rotor 12) of the estimation period into the rotational speed of the internal combustion engine 21.

20

Next, the CPU 161 obtains information showing the shift position of the transmission 22 (S104). Then the CPU 161 estimates an increment ΔNe in the rotational speed of the internal combustion engine 21 using map data 29 (S105).

25

Fig. 8 shows an example of the map data 29. The map data 29 represent the increment ΔNe [rpm/ms] in the rotational speed of the internal combustion engine 21 with respect to the variation ΔTH [deg/ms] in throttle opening, with the shift position of the transmission 22 as a parameter. It should be noted that the map data 29 are preliminarily measured and stored in the ROM 163 or the like. That is, the CPU 161 obtains, as an estimated value in the step S105, the increment ΔNe in rotational speed corresponding to the variation ΔTH by referring to the curve of the map data 29 corresponding to the shift position of the transmission 22.

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Next, the CPU 161 calculates a corrected estimation period TE_i from the rotational speed Ne calculated in the step S103 and the increment ΔNe in rotational speed obtained in the step S105, according to the following equation (S106):

5 $TE_i = k3 / (Ne + \Delta Ne)$ (3),

and the correction processing is ended.

10 In this manner, if the variation ΔTH in throttle opening exceeds the opening change threshold th , the processing after the step S20 in the energization control shown in Figs. 4A and 4B is performed on the basis of the corrected estimation period TE_i . As a result, a correction in accordance with a rotational fluctuation in the internal combustion engine is made to the estimated power generation period, thereby preventing a difference between the estimated power generation period and the actual
15 power generation period. Thus, generated electric power can be efficiently stored in the battery 15.

Although various preferred embodiments of the present invention have been described herein in detail, it will be appreciated by those skilled in the art, that
20 variations may be made thereto without departing from the scope of the appended claims.

THE EMBODIMENTS OF THE INVENTION IN WHICH AN EXCLUSIVE PROPERTY OR PRIVILEGE IS CLAIMED ARE DEFINED AS FOLLOWS:

1. A battery charging apparatus for a vehicle, comprising:
 - 5 a driver unit that converts three-phase AC power outputted from a winding of each phase of a stator of a three-phase AC generator into DC power using a plurality of switching elements to supply the DC power to a battery;
 - a control unit that controls switching between an energized state and non-energized state of each of the plurality of switching elements; and
 - 10 a position detection unit that outputs a position detection signal indicating a position of a rotor of the three-phase AC generator,
 - the control unit obtaining a next estimation power generation period of the three-phase AC generator on the basis of the previous position detection signal and determining a next energization period of each of the plurality of switching elements
 - 15 on the basis of the estimation power generation period,
 - wherein the control unit judges start of the energization period on the basis of input of the position detection signal, and, if a period until next input of the position detection signal exceeds the energization period, during the period until the next input of the position detection signal, the control unit has a maintenance period in
 - 20 which the plurality of switching elements are maintained in the energized state or non-energized state immediately before the period until the next input of the position detection signal exceeds the energization period.
2. The battery charging apparatus for the vehicle according to Claim 1, wherein
- 25 the maintenance period is limited up to a predetermined period.
3. The battery charging apparatus for the vehicle according to Claim 1 or 2, wherein an input period of the position detection signal is determined by an interval between falling edges or between rising edges of the position detection signal, and
- 30 the control unit obtains the estimation power generation period on the basis of a previous input period of the position detection signal and a variation thereof.
4. The battery charging apparatus for the vehicle according to Claim 2, wherein, if the next input of the position detection signal is not given even after a lapse of the
- 35 predetermined period, the control unit switches the plurality of switching elements to an all-phase short-circuited state during the period until the next input of the position detection signal.

5. The battery charging apparatus for the vehicle according to Claim 2 or 3, wherein the predetermined period is changed in proportion to the estimation power generation period.

5

6. The battery charging apparatus for the vehicle according to any one of Claims 2, 4 and 5, wherein the predetermined period is a period of a predetermined phase angle of the estimation power generation period.

10 7. The battery charging apparatus for the vehicle according to any one of Claims 1 to 6, wherein the control unit includes an energization pattern with a preset order of switching between the energized state and non-energized state of each of the plurality of switching elements in the energization period, and
the control unit determines a next energization timing of each of the switching
15 elements in accordance with the energization pattern upon every input of the position detection signal.

8. The battery charging apparatus for the vehicle according to Claim 7, wherein the energization pattern sets the energization timing of the switching element
20 connected to each phase of the three-phase AC generator, and
the control unit simultaneously determines and updates the next energization timing of the switching element connected to each phase upon every input of the position detection signal.

25 9. The battery charging apparatus for the vehicle according to Claim 7 or 8, wherein the control unit detects a voltage of the battery, and controls the energization timing to an advance side or a retard side so that the voltage of the battery becomes a predetermined voltage;
the energization pattern includes an advance pattern and a retard pattern;
30 and

the control unit determines the energization timing of the switching element in accordance with the advance pattern or the retard pattern.

10. The battery charging apparatus for the vehicle according to any one of Claims
35 1 to 9, further comprising a throttle opening detector for detecting a throttle opening of an internal combustion engine, wherein
the rotor rotates based on rotation of the internal combustion engine, and

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the control unit corrects the estimation power generation period on the basis of a variation in the throttle opening.

11. The battery charging apparatus for the vehicle according to Claim 10, further
5 comprising a shift position detector for detecting a shift position of a transmission
disposed between the internal combustion engine and a driving wheel of the vehicle,
wherein the control unit corrects the estimation power generation period on
the basis of the variation in the throttle opening and the shift position.
- 10 12. The battery charging apparatus for the vehicle according to Claim 11, wherein
the control unit includes as map data a predetermined variation in rotational speed
of the internal combustion engine based on the variation in the throttle opening and
the shift position and corrects the estimation power generation period on the basis of
the map data.

FIG. 1

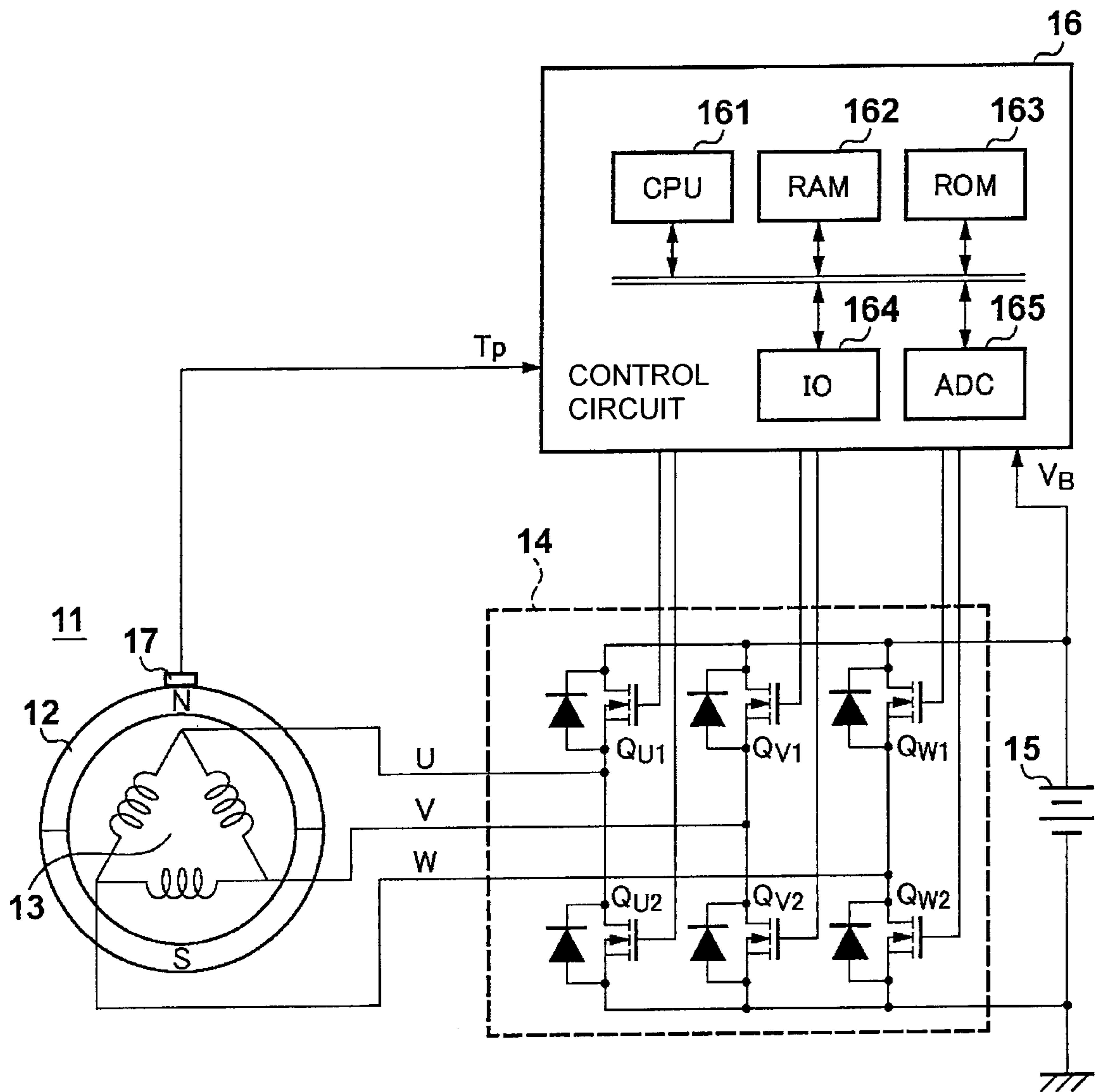


FIG. 2

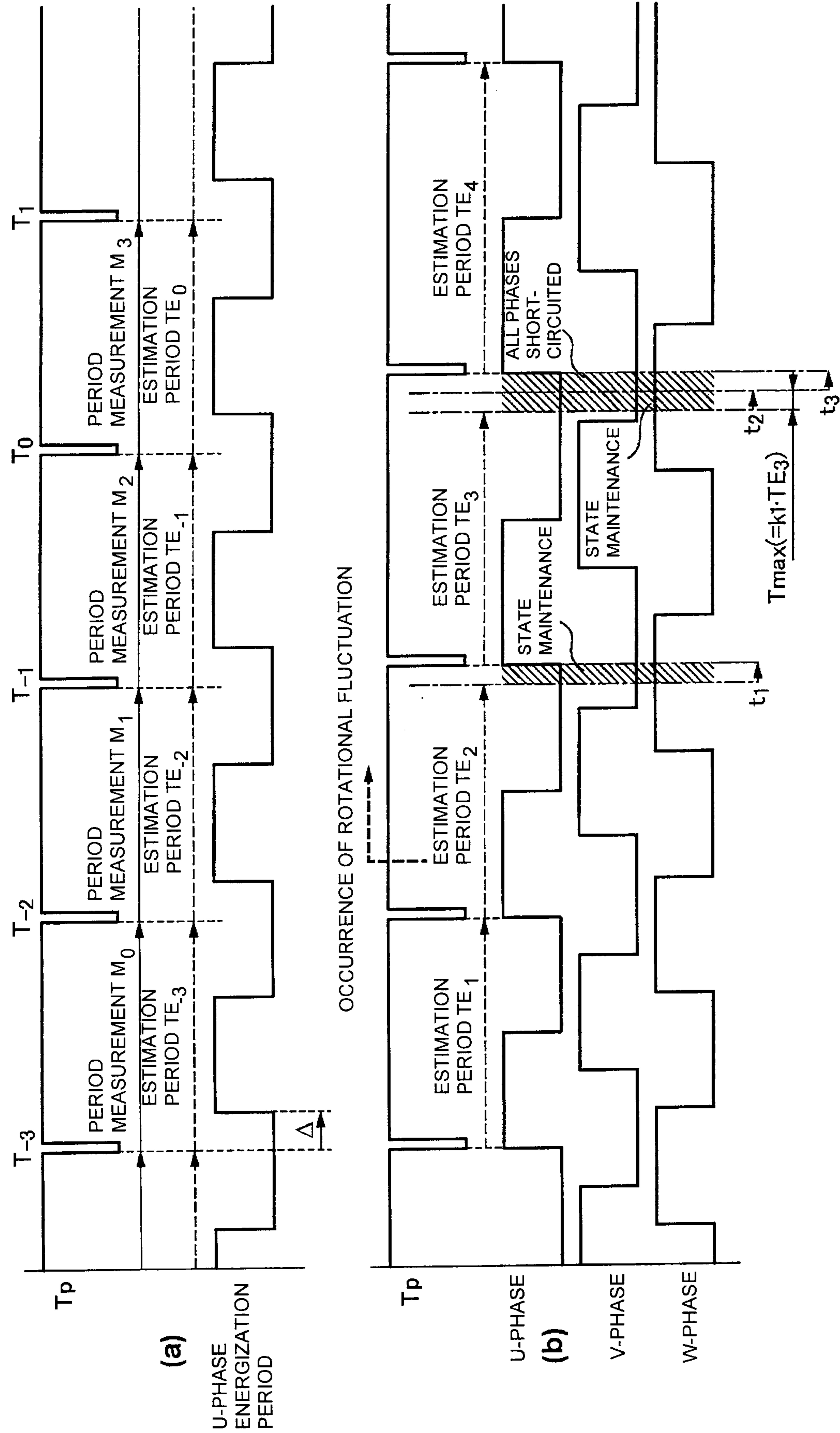


FIG. 3

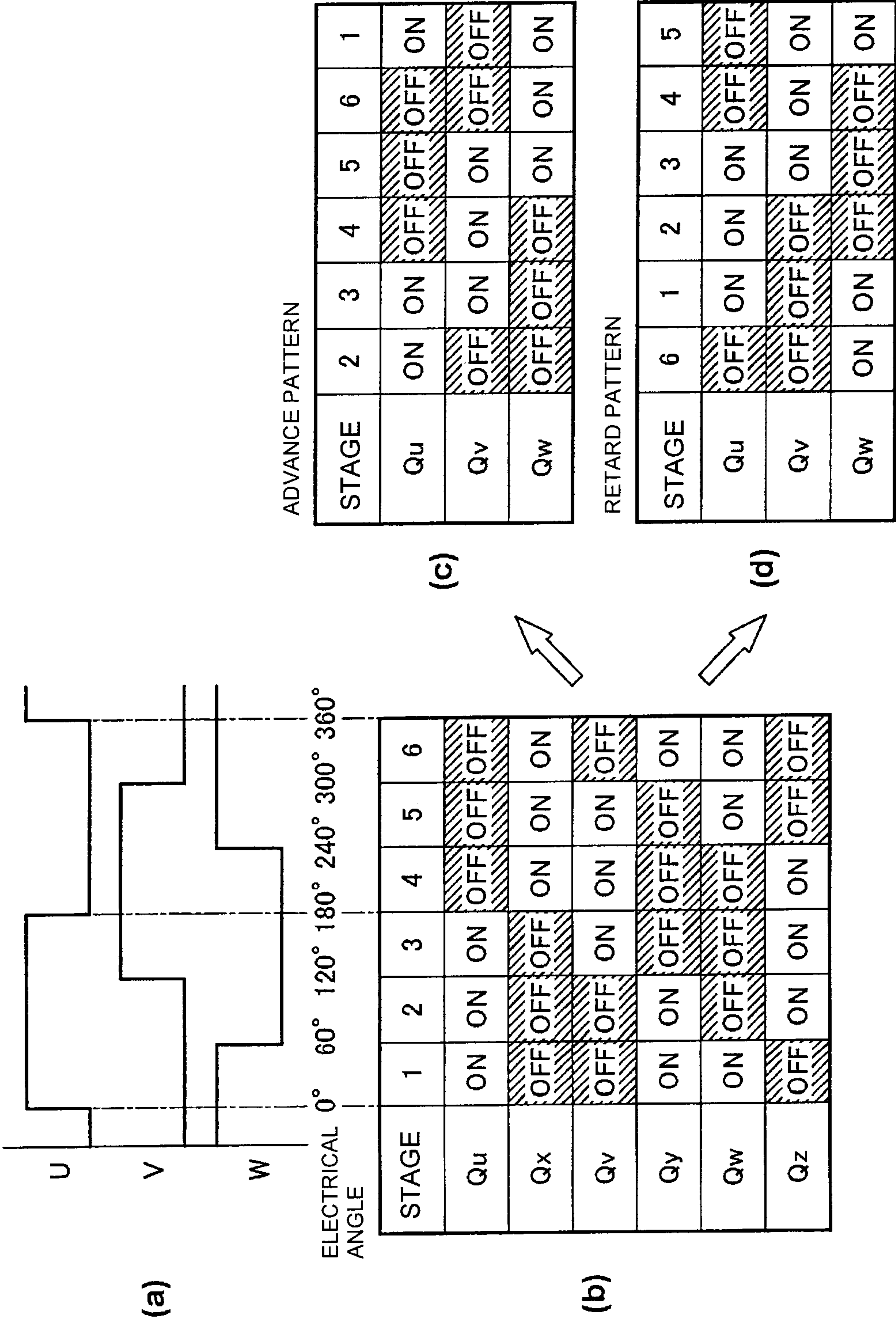


FIG. 4A

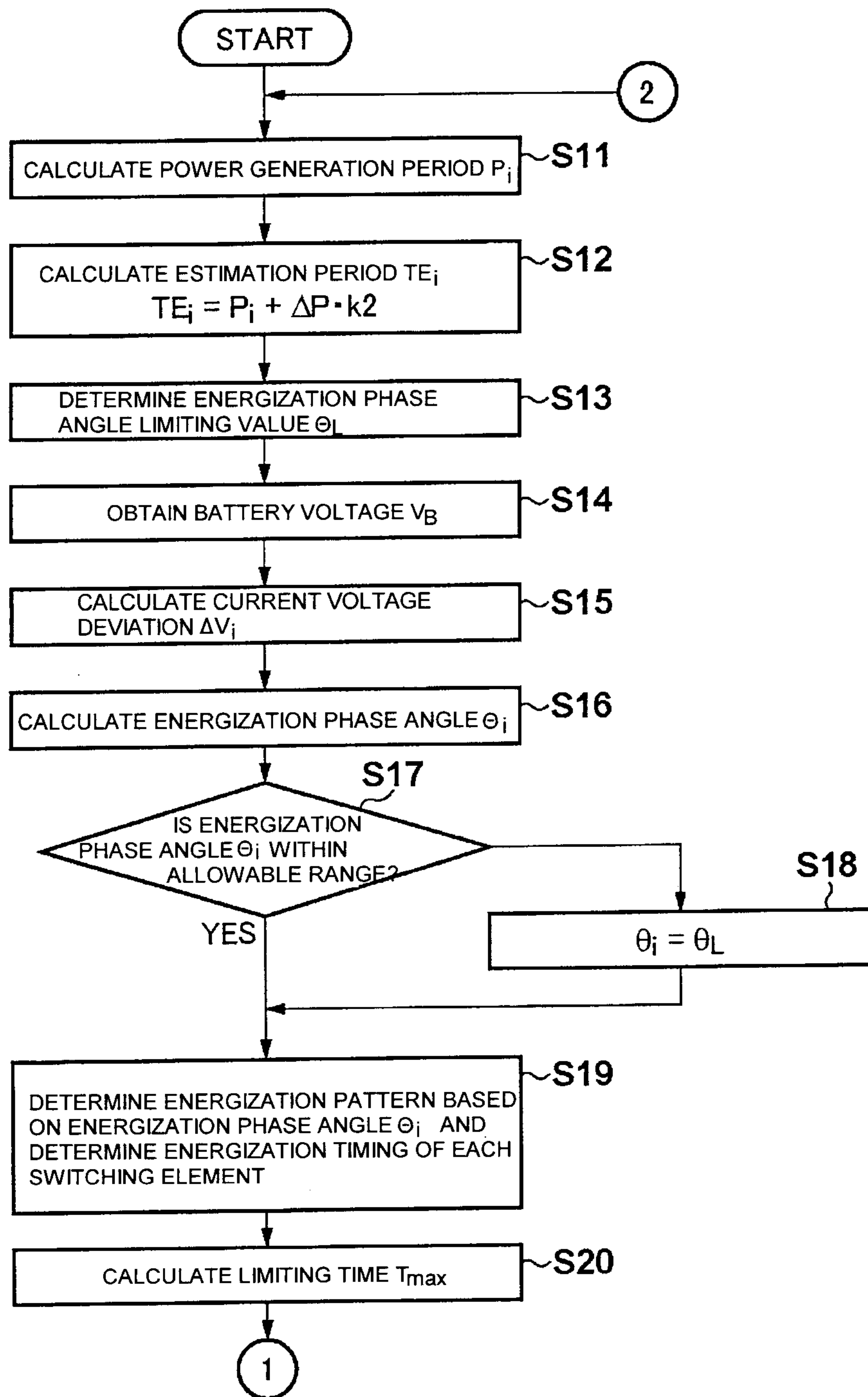


FIG. 4B

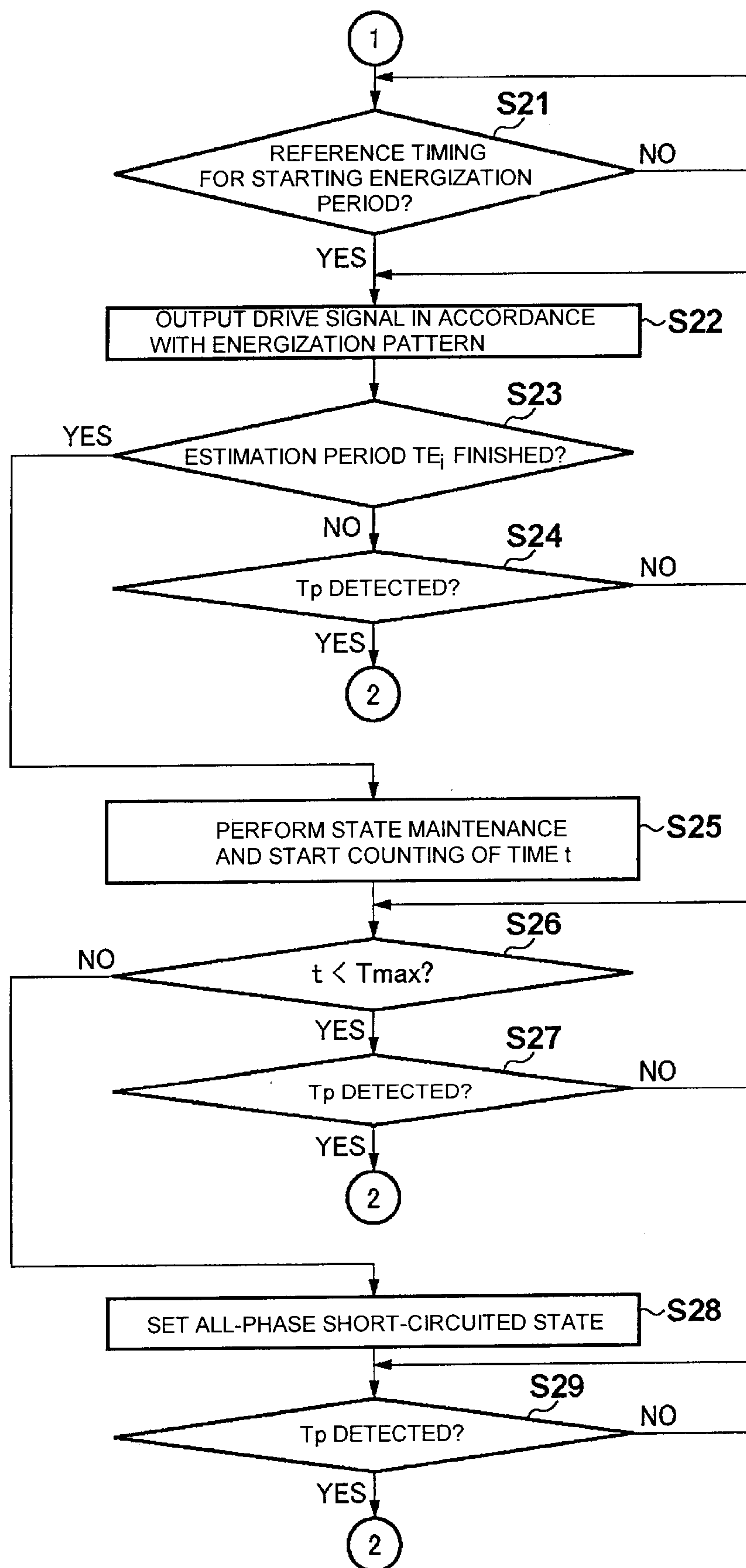


FIG. 5

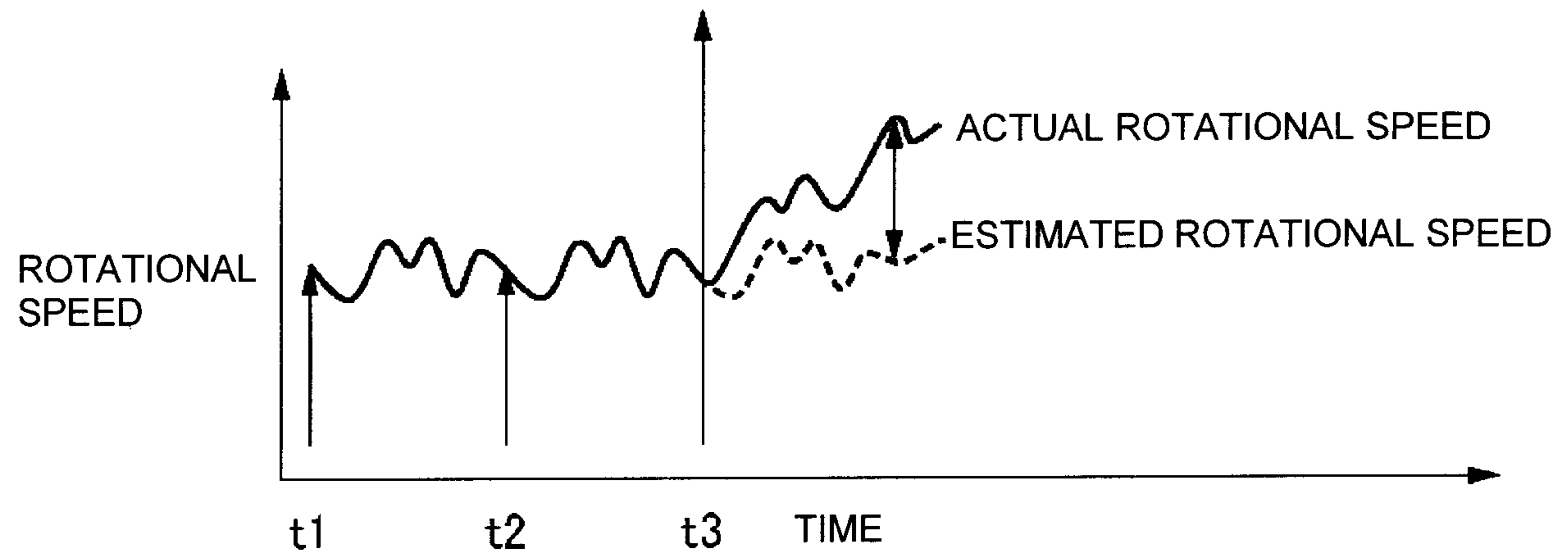


FIG. 6

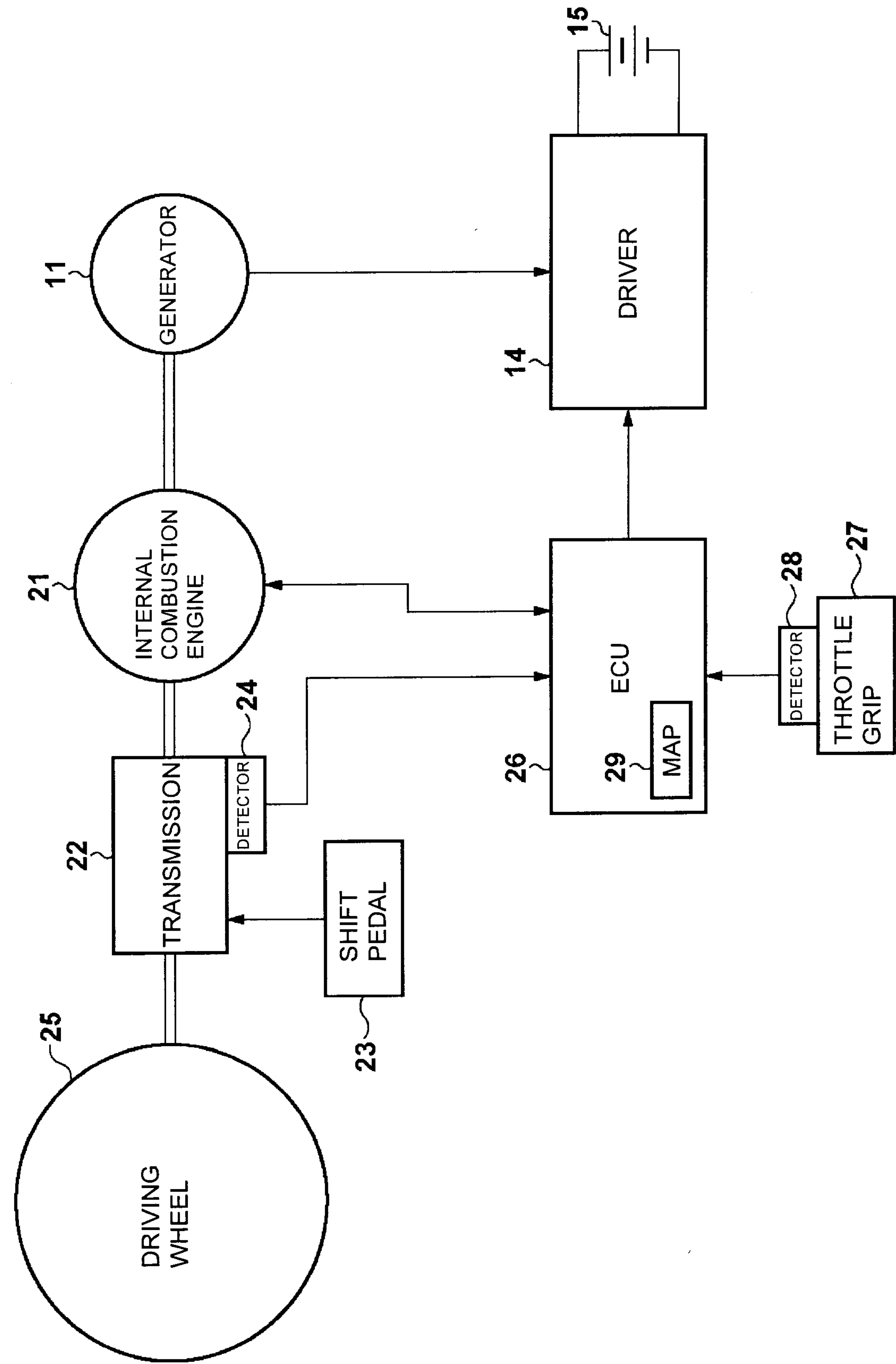


FIG. 7

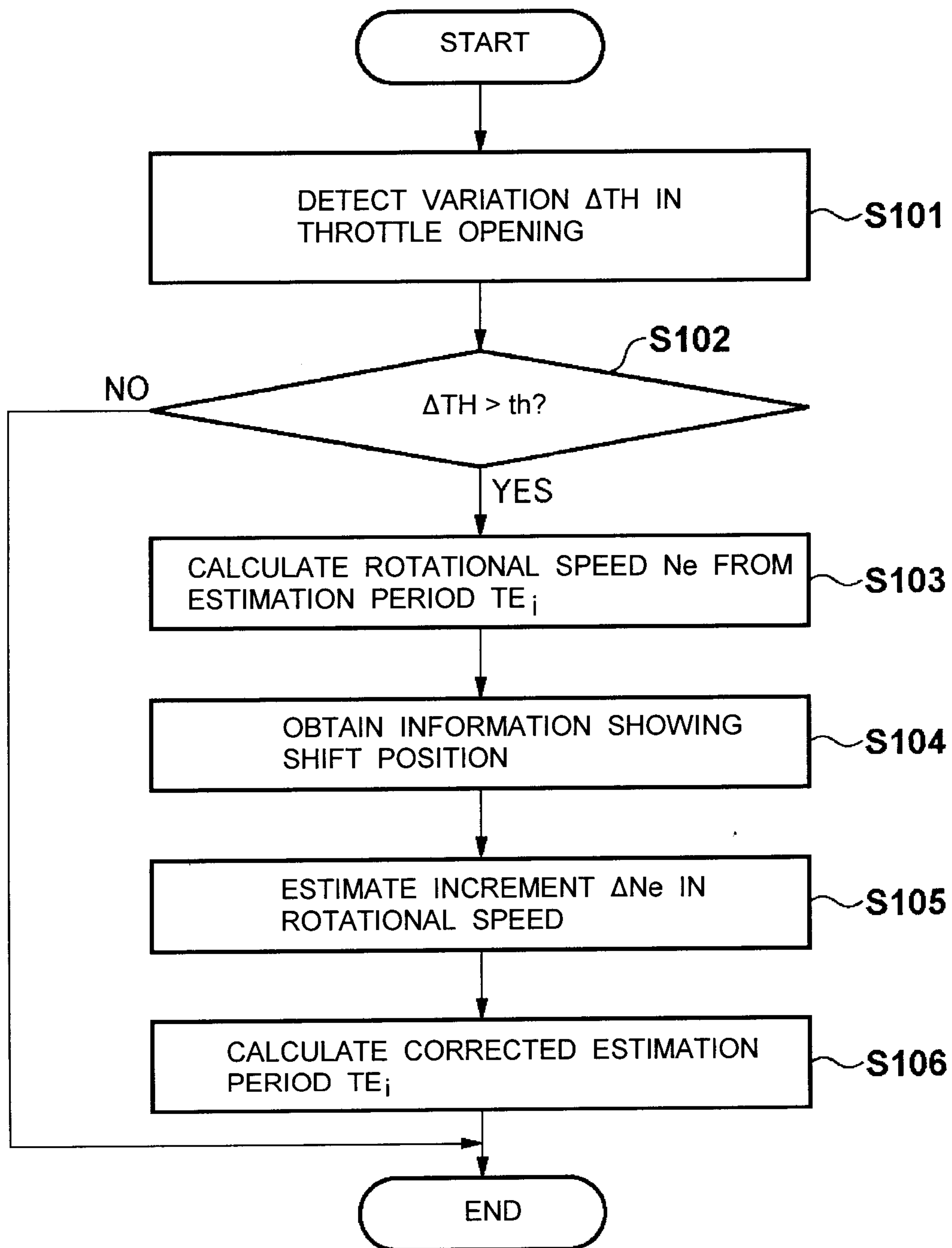


FIG. 8

