US012395079B2

(12) **United States Patent**
Oshima et al.

(10) **Patent No.: US 12,395,079 B2**
(45) **Date of Patent: Aug. 19, 2025**

(54) **POWER SUPPLY DEVICE FOR CONTROLLING VOLTAGE**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 336 days.

(21) Appl. No.: **18/124,746**

(22) Filed: **Mar. 22, 2023**

(65) **Prior Publication Data**

US 2023/0223848 A1 Jul. 13, 2023

Related U.S. Application Data

(63) Continuation of application No. PCT/JP2020/039566, filed on Oct. 21, 2020.

(51) **Int. Cl.**
H02M 3/156 (2006.01)
H02M 1/00 (2006.01)

(52) **U.S. Cl.**
CPC ***H02M 3/156*** (2013.01); ***H02M 1/0003*** (2021.05)

(58) **Field of Classification Search**
CPC H02M 3/156; H02M 1/0003; H02M 3/04; H02M 1/0025; H02M 1/0048; H02M 7/48; H02M 1/007
See application file for complete search history.

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(57) **ABSTRACT**

A method includes calculating power consumption of a DC-DC converter, controlling the DC-DC converter so that an output direct current voltage output from the DC-DC converter becomes higher than a target voltage preset in the DC-DC converter when a power consumption is less than first power, and controlling the DC-DC converter so that the output direct current voltage output from the DC-DC converter becomes lower than the target voltage when the power consumption exceeds second power greater than the first power.

9 Claims, 4 Drawing Sheets

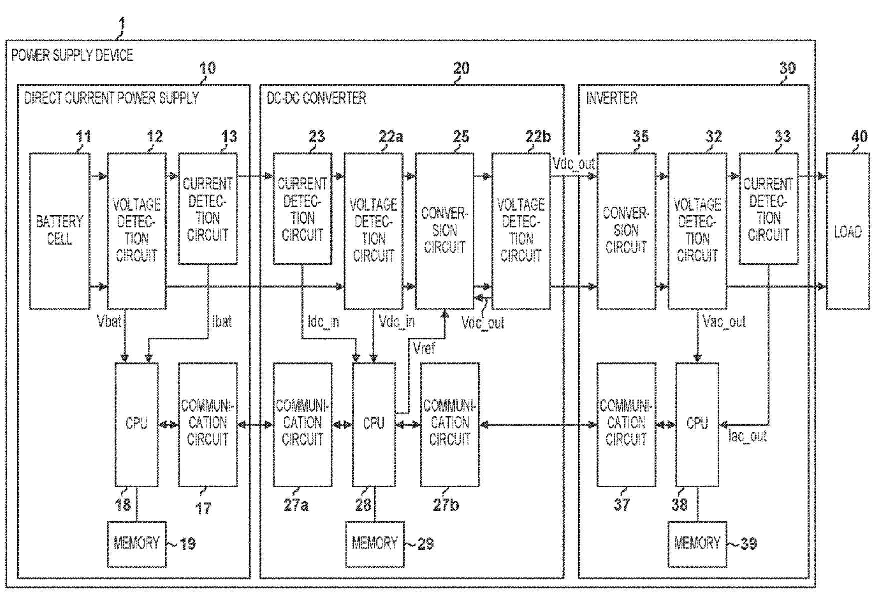

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FIG. 1

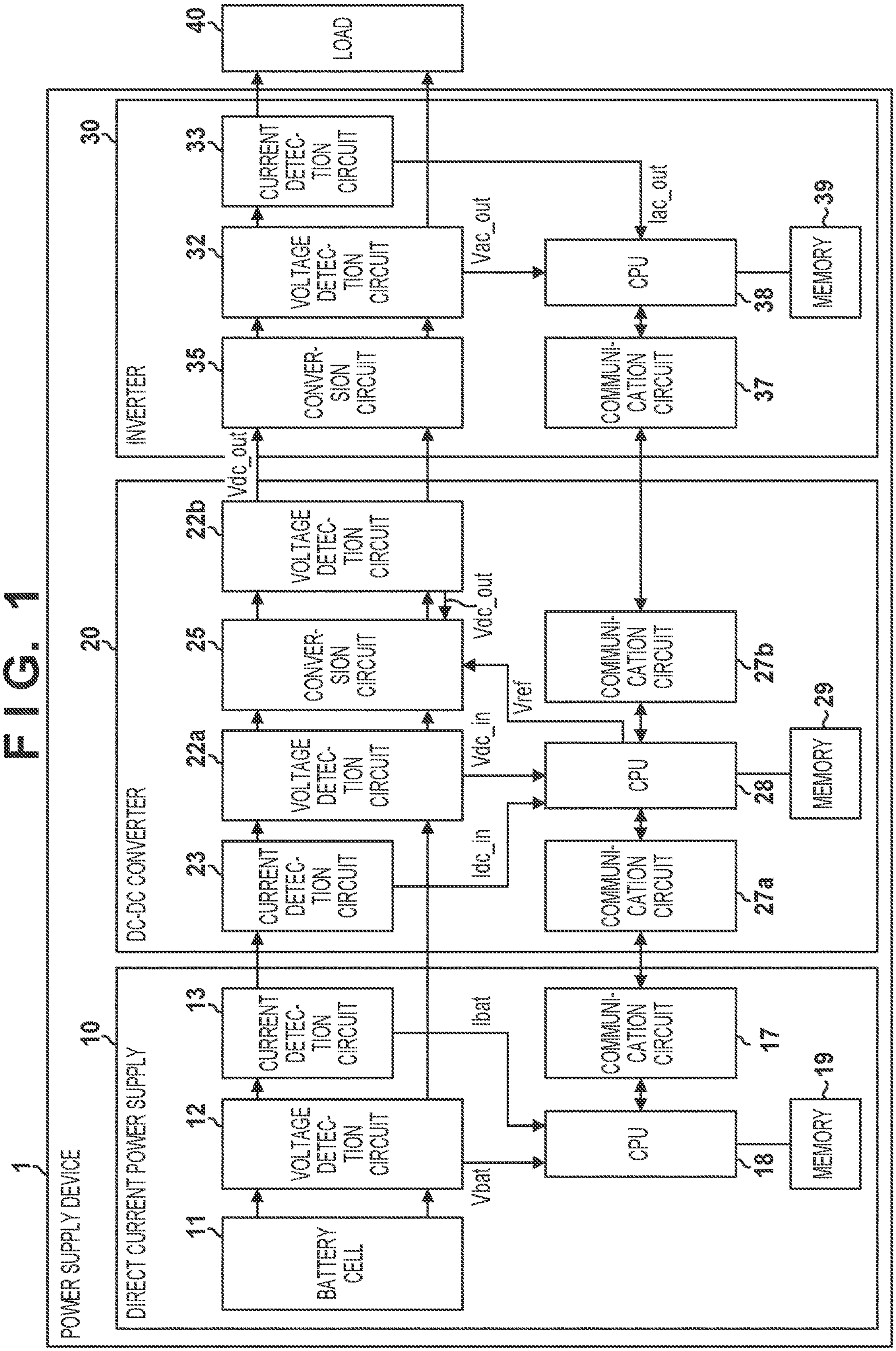
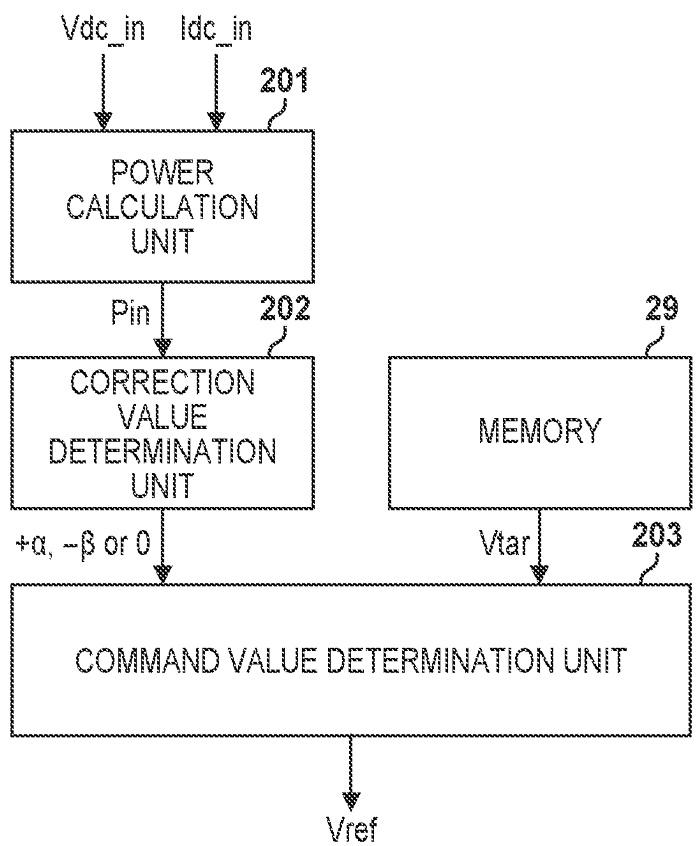
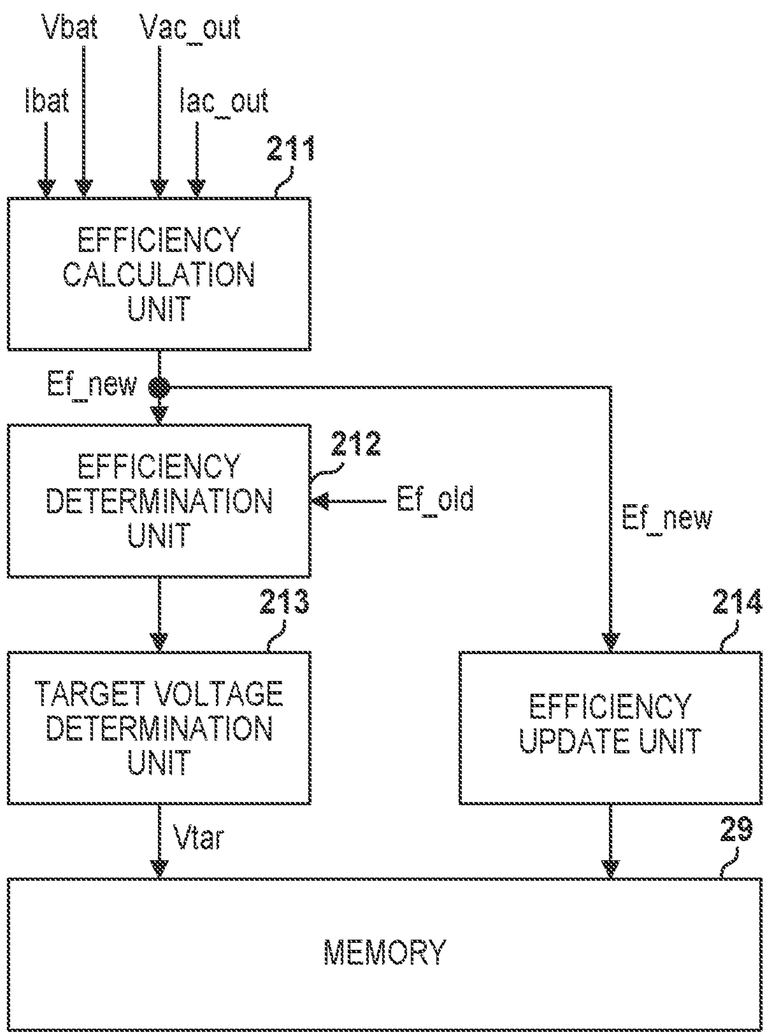

1
POWER SUPPLY DEVICE
10
DIRECT CURRENT POWER SUPPLY
11
BATTERY CELL
12
VOLTAGE DETEC-TION CIRCUIT
13
CURRENT DETEC-TION CIRCUIT
Vbat
Ibat
17
COMMUNI-CATION CIRCUIT
18
CPU
19
MEMORY
20
DC-DC CONVERTER
23
CURRENT DETEC-TION CIRCUIT
22a
VOLTAGE DETEC-TION CIRCUIT
25
CONVER-SION CIRCUIT
22b
VOLTAGE DETEC-TION CIRCUIT
Idc_in
Vdc_in
Vref
Vdc_out
27a
COMMUNI-CATION CIRCUIT
28
CPU
27b
COMMUNI-CATION CIRCUIT
29
MEMORY
30
INVERTER
Vdc_out
35
CONVER-SION CIRCUIT
32
VOLTAGE DETEC-TION CIRCUIT
33
CURRENT DETEC-TION CIRCUIT
Vac_out
Iac_out
37
COMMUNI-CATION CIRCUIT
38
CPU
39
MEMORY
40
LOAD

FIG. 2



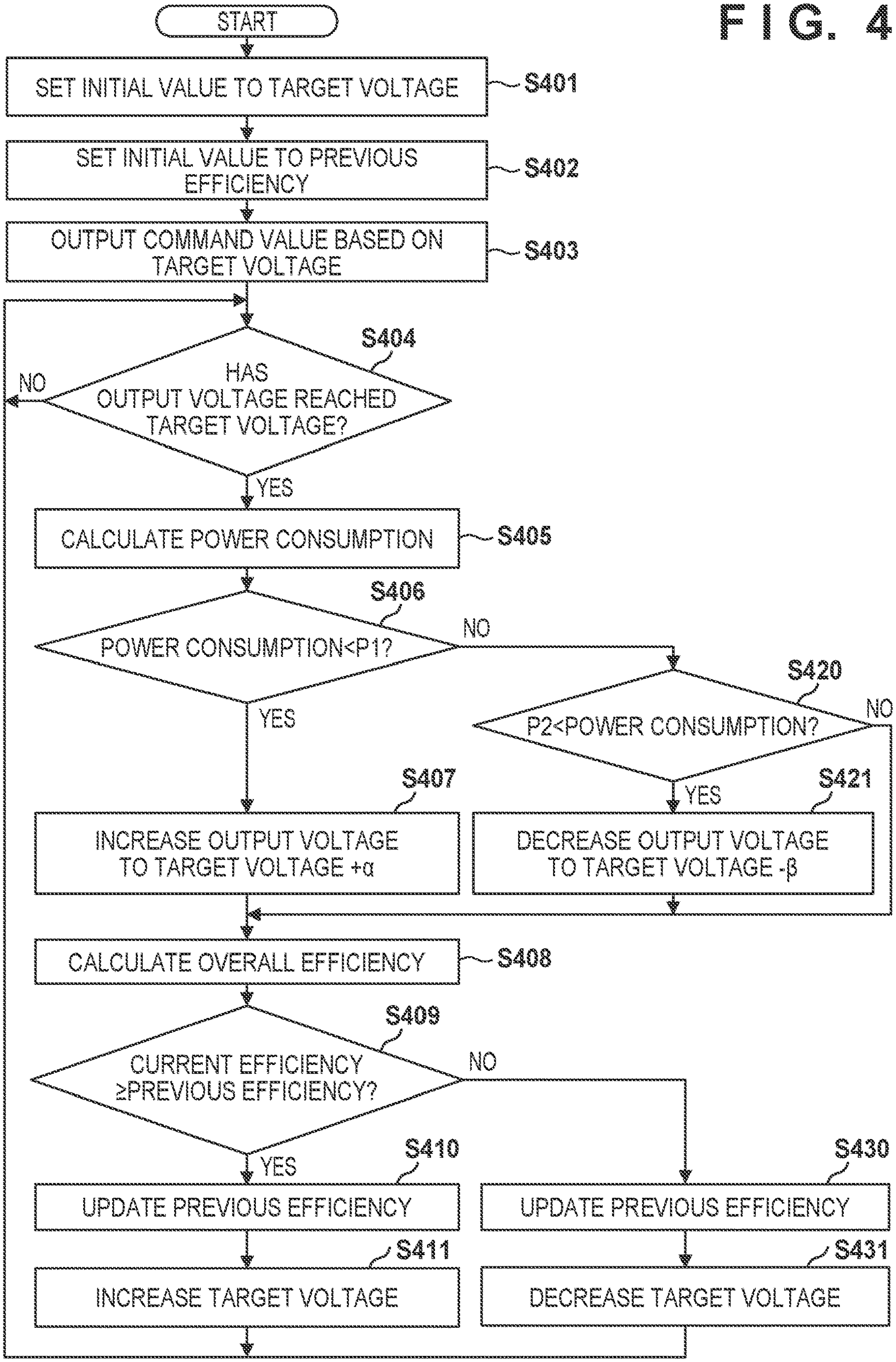
Vdc_in
Idc_in
201
POWER CALCULATION UNIT
Pin
202
CORRECTION VALUE DETERMINATION UNIT
29
MEMORY
+α, −β or 0
Vtar
203
COMMAND VALUE DETERMINATION UNIT
Vref

FIG. 3



Vbat
Vac_out
Ibat
Iac_out
211
EFFICIENCY CALCULATION UNIT
Ef_new
EFFICIENCY DETERMINATION UNIT
212
Ef_old
Ef_new
213
214
TARGET VOLTAGE DETERMINATION UNIT
EFFICIENCY UPDATE UNIT
Vtar
29
MEMORY

FIG. 4


START
SET INITIAL VALUE TO TARGET VOLTAGE
S401
SET INITIAL VALUE TO PREVIOUS EFFICIENCY
S402
OUTPUT COMMAND VALUE BASED ON TARGET VOLTAGE
S403
S404
HAS OUTPUT VOLTAGE REACHED TARGET VOLTAGE?
NO
YES
CALCULATE POWER CONSUMPTION
S405
S406
POWER CONSUMPTION<P1?
NO
YES
S420
P2<POWER CONSUMPTION?
NO
YES
S407
INCREASE OUTPUT VOLTAGE TO TARGET VOLTAGE +α
S421
DECREASE OUTPUT VOLTAGE TO TARGET VOLTAGE -β
CALCULATE OVERALL EFFICIENCY
S408
S409
CURRENT EFFICIENCY ≥PREVIOUS EFFICIENCY?
NO
YES
S410
UPDATE PREVIOUS EFFICIENCY
S430
UPDATE PREVIOUS EFFICIENCY
S411
INCREASE TARGET VOLTAGE
S431
DECREASE TARGET VOLTAGE

POWER SUPPLY DEVICE FOR CONTROLLING VOLTAGE

CROSS-REFERENCE TO RELATED APPLICATION(S)

This application is a continuation of International Patent Application No. PCT/JP2020/039566 filed on Oct. 21, 2020, the entire disclosures of which is incorporated herein by reference.

BACKGROUND OF THE INVENTION

Field of the Invention

The present disclosure relates to a power supply device for controlling a voltage.

Description of the Related Art

ADC-DC converter is a conversion circuit that converts a certain direct current (DC) input voltage into a required constant direct current output voltage (Japanese Patent Laid-Open No. 2013-192383). The required output voltage is determined by an inverter or the like connected to a subsequent stage of the DC-DC converter.

In general, the output voltage of the DC-DC converter is controlled to a constant value. In addition, the output voltage must be equal to or lower than an allowable input voltage (withstand voltage) of the inverter connected to the subsequent stage. When a load connected to the inverter rapidly decreases, the output voltage of the DC-DC converter rapidly increases. In consideration of the rapid increase in the output voltage, the output voltage of the DC-DC converter must be set lower than the withstand voltage of the inverter. On the other hand, when the load rapidly increases, the output voltage of the DC-DC converter rapidly decreases. Therefore, it is preferable that the target value of the output voltage be low as a countermeasure against the rapid increase in the output voltage, but it is preferable that the target value of the output voltage be high as a countermeasure against the rapid decrease in the output voltage. That is, the appropriate target voltage varies depending on the load.

SUMMARY OF THE INVENTION

The present disclosure provides a power supply device includes: a DC-DC converter that converts a first direct current voltage supplied from a direct current power supply to generate a second direct current voltage;

an inverter that is supplied with the second direct current voltage from the DC-DC converter and outputs an alternating current and an alternating current voltage; and

a controller that controls the DC-DC converter so that the second direct current voltage becomes a target voltage.

The controller includes power calculation unit for calculating power consumption of the DC-DC converter.

The controller is configured to:

obtain power consumption of the DC-DC converter;

control the DC-DC converter so that the second direct current voltage output from the DC-DC converter becomes higher than the target voltage when the power consumption is less than first power; and

control the DC-DC converter so that the second direct current voltage output from the DC-DC converter becomes lower than the target voltage when the power consumption exceeds second power greater than the first power.

Further features of the present invention will become apparent from the following description of exemplary embodiments (with reference to the attached drawings).

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings, which are incorporated in and constitute a part of the specification, illustrate embodiments of the invention and, together with the description, serve to explain principles of the disclosure.

FIG. **1** is a block diagram illustrating a power supply device.

FIG. **2** is a block diagram illustrating functions implemented by a CPU.

FIG. **3** is a block diagram illustrating functions implemented by the CPU.

FIG. **4** is a flowchart illustrating a control method executed by the CPU.

DESCRIPTION OF THE EMBODIMENTS

Hereinafter, embodiments will be described in detail with reference to the attached drawings. Note, the following embodiments are not intended to limit the scope of the claimed invention, and limitation is not made to an invention that requires a combination of all features described in the embodiments. Two or more of the multiple features described in the embodiments may be combined as appropriate. Furthermore, the same reference numerals are given to the same or similar configurations, and redundant description thereof is omitted.

<Power Supply Device>

FIG. **1** illustrates a power supply device **1**. The power supply device **1** includes a direct current power supply **10**, a DC-DC converter **20**, and an inverter **30**. The direct current power supply **10** is a battery, an engine-driven generator, or the like. Here, it is assumed that a battery-type direct current power supply **10** is employed. The DC-DC converter **20** converts a direct current input voltage Vdc_in supplied from the direct current power supply **10** into a direct current output voltage Vdc_out and outputs the direct current output voltage Vdc_out to the inverter **30**. The inverter **30** converts the output voltage Vdc_out supplied from the DC-DC converter **20** into an alternating current output voltage Vac_out and supplies the alternating current output voltage Vac_out to a load **40**.

Direct Current Power Supply

In the direct current power supply **10**, a battery cell **11** outputs a battery voltage Vbat. A voltage detection circuit **12** detects the battery voltage Vbat and outputs the detection result to a CPU **18**. A current detection circuit **13** detects a battery current Ibat flowing from the battery cell **11** to the DC-DC converter **20**, and outputs the detection result to the CPU **18**. The CPU **18** is a processor circuit that executes a control program stored in a memory **19**. The CPU **18** transmits the detection result of the battery voltage Vbat and the detection result of the battery current Ibat to the DC-DC converter **20** via a communication circuit **17**.

DC-DC Converter

In the DC-DC converter **20**, a current detection circuit **23** is a circuit that detects an input current Idc_in from the direct current power supply **10** and outputs the detection result to an AD port of a CPU **28**. The AD port is a port including an AD converter that converts an analog signal into a digital signal. The current detection circuit **23** includes, for example, a shunt resistor (resistor for current detection). A voltage detection circuit **22***a* is a circuit that detects an input voltage Vdc_in from the direct current power supply **10** and outputs the detection result to the CPU **28**. The voltage detection circuit **22***a* includes, for example, a plurality of voltage dividing resistors that convert the input voltage Vdc_in into a detection voltage proportional to the input voltage Vdc_in. A conversion circuit **25** is a circuit that converts the input voltage Vdc_in into the output voltage Vdc_out. The conversion circuit **25** controls the output voltage Vdc_out to a target voltage Vtar based on a voltage command value Vref output from the CPU **28**. Therefore, the voltage command value Vref is a command value indicating the target voltage Vtar. Note that the voltage command value Vref may be represented by a PWM wave (pulsed drive signal) whose pulse width is adjusted according to the target voltage Vtar. Such a drive signal is individually supplied to each of four switching elements constituting a switching circuit.

The conversion circuit **25** may be a switching converter including a switching circuit (for example, a full-bridge circuit with four field-effect transistors), a transformer, a rectifier circuit (for example, a diode bridge), a smoothing circuit (for example, an electrolytic capacitor), and the like. The CPU **28** executes various processes in accordance with a control program stored in a memory **29**. For example, the CPU **28** may obtain power consumption Pin in the DC-DC converter **20** based on the detection result of the input voltage Vdc_in and the detection result of the output voltage Vdc_out, and calculate a primary correction value α of the target voltage Vtar based on the power consumption Pin. Further, the CPU **28** may calculate overall efficiency based on the detection result of the battery voltage Vbat, the detection result of the battery current Ibat, the detection result of the alternating current output voltage Vac_out transmitted from the inverter **30**, and a detection result of an output alternating current Iac_out. The overall efficiency refers to the overall efficiency Ef of the direct current power supply **10**, the DC-DC converter **20**, and the inverter **30**.

$$Ef=(Vac\_\text{out}\times Iac\_\text{out})/(Vbat\times Ibat) \tag{1}$$

The CPU **28** determines or updates the target voltage Vtar so that the efficiency Ef is improved. The CPU **28** receives the detection result of the alternating current output voltage Vac_out and the detection result of the output alternating current Iac_out from the inverter **30** via a communication circuit **27***b*. A voltage detection circuit **22***b* detects the output voltage Vdc_out and feeds back the detection result to the conversion circuit **25**. As a result, the output voltage Vdc_out is controlled to approach the target voltage Vtar corresponding to the voltage command value Vref.

The CPU **28**, the memory **29**, a communication circuit **27***a*, and the communication circuit **27***b* form a controller. Note that illustration of an auxiliary power supply that supplies an operating voltage to the CPU **28**, the memory **29**, and the communication circuits **27***a* and **27***b* is omitted. The auxiliary power supply converts the input voltage Vdc_in to generate the operating voltage. The auxiliary power supply may include, for example, a high-voltage regulator, a three-terminal regulator, an insulated power supply, and the like.

Inverter **30**

In the inverter **30**, a conversion circuit **35** is a circuit that converts the output voltage Vdc_out from the DC-DC converter **20** into the alternating current output voltage Vac_out. The conversion circuit **35** includes a bridge circuit formed by a plurality of switching elements. A voltage detection circuit **32** detects the output voltage Vac_out and outputs the detection result to a CPU **38**. A current detection circuit **33** detects the output current Iac_out and outputs the detection result to the CPU **38**. The CPU **38** controls the inverter **30** according to a control program stored in a memory **39**. The CPU **38** transmits the detection result of the alternating current output voltage Vac_out and the detection result of the output alternating current Iac_out to the DC-DC converter **20** via a communication circuit **37**.

[Functions of CPU]

FIG. **2** illustrates functions involved in determination of the voltage command value Vref. The CPU **28** implements the functions described below by executing the control program. Here, some or all of the functions described below may be implemented by a hardware circuit such as an application specific integrated circuit (ASIC) or a field programmable gate array (FPGA). Furthermore, the CPU **28** may include one or a plurality of processor circuits. As described above, each of the functions may be implemented by a logic circuit or a program module.

The power calculation unit **201** calculates the power consumption Pin of the DC-DC converter **20** based on the input voltage Vdc_in and the input current Idc_in. For example, the power calculation unit **201** calculates the power consumption Pin of the DC-DC converter **20** by multiplying the input voltage Vdc_in by the input current Idc_in (Pin=Vdc_in×Idc_in). The correction value determination unit **202** determines the correction value X of the target voltage Vtar according to the power consumption Pin. Here, the new target voltage Vtar may be expressed as a sum of the old target voltage Vtar' held in the memory **29** and the correction value X (Vtar=Vtar'+X).

For example, when the rated power of the power supply device **1** is 1500 W and the power consumption Pin is less than the first power P1 (for example, P1=500 W), it is expected that the load **40** will increase from now. In general, this is due to the fact that the user may use the load **40** with power consumption close to the rated power. Therefore, when the power consumption Pin is less than the first power P1, the correction value determination unit **202** determines the correction value X so that the output voltage Vdc_out becomes higher than the current target voltage Vtar by +α(X=+α). By increasing the output voltage Vdc_out in advance, the power supply device **1** can satisfactorily follow a rapid increase in the load **40**. For example, when the target voltage Vtar is 180 V and a is 20 V, the output voltage Vdc_out is increased to 200 V.

On the other hand, when the power consumption Pin exceeds the second power P2 (for example, P2=1000 W), it is expected that the load **40** will rapidly decrease from now. When the load **40** rapidly decreases, the output current Idc_out of the DC-DC converter **20** rapidly decreases, and the output voltage Vac_out rapidly increases. When the output voltage Vac_out rapidly increases, the output voltage Vac_out may exceed the withstand voltage of the inverter **30**. Therefore, when the power consumption Pin exceeds the second power P2, the correction value determination unit **202** determines the correction value X so that the output voltage Vdc_out becomes lower than the current target voltage Vtar by −β(X=−β). By reducing the output voltage Vdc_out in advance, the power supply device **1** can satisfactorily follow a rapid decrease in the load **40**. For example, when the target voltage Vtar is 180 V and β is 15 V, the output voltage Vdc_out decreases to 165 V. By reducing the output voltage Vdc_out in this manner, a margin is secured for the withstand voltage of the inverter **30**.

A command value determination unit **203** reads the target voltage Vtar from the memory **29**, adds the correction value X acquired from the correction value determination unit **202** to the target voltage Vtar to obtain a sum of the target voltage Vtar plus the correction value X, determines the voltage command value Vref corresponding to the sum, and sets the voltage command value Vref in the conversion circuit **25**.

FIG. **3** illustrates a function of improving the overall efficiency of the power supply device **1**. As described above, the CPU **28** implements the functions described below by executing the control program. After the output voltage Vdc_out is corrected or adjusted according to the power consumption Pin, the CPU **28** acquires the detection result of the battery voltage Vbat and the detection result of the battery current Ibat from the direct current power supply **10**, acquires the detection result of the output voltage Vac_out and the detection result of the output current Iac_out from the inverter **30**, and inputs the results to an efficiency calculation unit **211**. The efficiency calculation unit **211** calculates the efficiency Ef based on Equation (1). Here, the current efficiency Ef is expressed as Ef_new. The previous efficiency Ef obtained by the previous calculation and held in the memory **29** is expressed as Ef_old. An efficiency determination unit **212** determines whether the current efficiency Ef_new is equal to or higher than the previous efficiency Ef_old, and outputs the determination result to a target voltage determination unit **213**.

The target voltage determination unit **213** determines a new target voltage Vtar based on the determination result. For example, when the current efficiency Ef_new is equal to or higher than the previous efficiency Ef_old, the target voltage determination unit **213** increases the target voltage Vtar. For example, the target voltage determination unit **213** adds a predetermined value Y to the target voltage Vtar and stores the addition result to the memory **29**. On the other hand, when the current efficiency Ef_new is lower than the previous efficiency Ef_old, the target voltage determination unit **213** decreases the target voltage Vtar. For example, the target voltage determination unit **213** subtracts the predetermined value Y from the target voltage Vtar and stores the subtraction result to the memory **29**. Thereafter, an efficiency update unit **214** updates the previous efficiency Ef_old stored in the memory **29** by overwriting the previous efficiency Ef_old with the current efficiency Ef_new.

<Flowchart>

FIG. **4** illustrates a series of processes executed by the CPU **28** according to the control program.

In step **S401**, the CPU **28** sets an initial value Vtar_ini to the target voltage Vtar. The initial value Vtar_ini is a value determined based on the design of the power supply device **1**, and is stored in a ROM area of the memory **29**. The target voltage Vtar is stored as a variable in a RAM area of the memory **29**. In step **S402**, the CPU **28** sets an initial value Ef_ini to the previous efficiency Ef_old. The initial value Ef_ini is a value determined based on the design of the power supply device **1**, and is stored in the ROM area of the memory **29**. The previous efficiency Ef_old is stored as a variable in the RAM area of the memory **29**.

In step **S403**, the CPU **28** determines the voltage command value Vref based on the target voltage Vtar read from the memory **29** and outputs the voltage command value Vref to the conversion circuit **25**. As a result, the conversion circuit **25** starts voltage conversion processing. The conversion circuit **25** controls the output voltage Vdc_out so that the output voltage Vdc_out approaches the target voltage Vtar corresponding to the voltage command value Vref.

In step **S404**, the CPU **28** determines whether the output voltage Vdc_out has reached the target voltage Vtar based on the detection result of the output voltage Vdc_out. The detection result of the output voltage Vdc_out is a voltage (detection voltage) obtained by dividing the output voltage Vdc_out by a voltage dividing circuit. When the output voltage Vdc_out reaches the target voltage Vtar, the CPU **28** proceeds to step **S405**.

In step **S405**, the CPU **28** calculates the power consumption Pin of the DC-DC converter **20**. As described above, the CPU **28** may calculate the power consumption Pin of the DC-DC converter **20** by multiplying the input voltage Vdc_in by the input current Idc_in.

In step **S406**, the CPU **28** determines whether the power consumption Pin is less than the predetermined value P1. That is, it is determined whether the power consumption Pin is such that a rapid increase in the output voltage Vdc_out is expected. When the power consumption Pin is less than the predetermined value P1, the CPU **28** proceeds to step **S407**. In step **S407**, the CPU **28** increases the output voltage Vdc_out to the target voltage Vtar+α by setting +α to the correction value X. On the other hand, when the power consumption Pin is not less than the predetermined value P1, the CPU **28** proceeds to step **S420**. In step **S420**, the CPU **28** determines whether the power consumption Pin exceeds the predetermined value P2 (P1<P2). That is, it is determined whether the power consumption Pin is such that a rapid decrease in the output voltage Vdc_out is expected. When the power consumption Pin exceeds the predetermined value P2, the CPU **28** proceeds to step **S421**. In step **S421**, the CPU **28** decreases the output voltage Vdc_out to the target voltage Vtar−β by setting −β to the correction value X. On the other hand, when the power consumption Pin does not exceed the predetermined value P2 (P1≤Pin≤P2), the CPU **28** sets the correction value X to 0 to maintain the output voltage Vdc_out at the target voltage Vtar.

In step **S408**, the CPU **28** calculates the overall efficiency Ef. Here, the current efficiency Ef_new is calculated based on the detection result of the battery voltage Vbat, the detection result of the battery current Ibat, the detection result of the alternating current output voltage Vac_out transmitted from the inverter **30**, and the detection result of the output alternating current Iac_out. Equation (1) is merely an example, and a certain coefficient may be added to or multiplied by any one of the four variables included in Equation (1).

In step **S409**, the CPU **28** determines whether the current efficiency Ef_new is equal to or higher than the previous efficiency Ef_old. The previous efficiency Ef_old is stored in the memory **29**. When the current efficiency Ef_new is equal to or higher than the previous efficiency Ef_old, the CPU **28** proceeds to step **S410**. In step **S410**, the CPU **28** updates the previous efficiency Ef_old by overwriting the previous efficiency Ef_old with the current efficiency Ef_new. In step **S411**, the CPU **28** increases the target voltage Vtar. For example, the CPU **28** may add the predetermined value Y to the target voltage Vtar. Thereafter, the CPU **28** returns to step **S404**.

On the other hand, when the current efficiency Ef_new is not equal to or higher than the previous efficiency Ef_old, the CPU **28** proceeds to step **S430**. In step **S430**, the CPU **28** updates the previous efficiency Ef_old by overwriting the previous efficiency Ef_old with the current efficiency Ef_new. In step **S431**, the CPU **28** decreases the target voltage Vtar. For example, the CPU **28** may subtract the predetermined value Y from the target voltage Vtar. Thereafter, the CPU **28** returns to step **S404**.

Summary

First Aspect

The DC-DC converter **20** is an example of a DC-DC converter that converts a first direct current voltage supplied from a direct current power supply to generate a second direct current voltage. The inverter **30** is an example of an inverter that is supplied with the second direct current voltage from the DC-DC converter and outputs an alternating current and an alternating current voltage. The CPU **28** is an example of a controller that controls the DC-DC converter so that the second direct current voltage becomes a target voltage. The CPU **28** may have power calculation unit for calculating power consumption of the DC-DC converter. When the power consumption is less than first power, the CPU **28** may control the DC-DC converter so that the second direct current voltage output from the DC-DC converter becomes higher than the target voltage. When the power consumption (for example, Pin) exceeds second power (for example, P2) greater than the first power (for example, P1), the CPU **28** may control the DC-DC converter so that the second direct current voltage output from the DC-DC converter becomes lower than the target voltage. The power consumption changes according to the load. Therefore, in the present embodiment, the target voltage is variably controlled according to the load. By controlling the output voltage according to the power consumption in this manner, the response performance of the output voltage is improved. For example, an instantaneous drop and an instantaneous rise of the direct current output voltage may be suppressed. As a result, an instantaneous fluctuation in the output voltage of the inverter is also suppressed.

Second Aspect

When the power consumption is less than the first power, the CPU **28** may control the DC-DC converter so that the second direct current voltage output from the DC-DC converter becomes equal to a sum of the target voltage (for example, Vtar) and a predetermined value (for example, α). When the power consumption exceeds the second power, the CPU **28** may control the DC-DC converter so that the second direct current voltage output from the DC-DC converter becomes equal to a difference between the target voltage and a predetermined value (for example, β). For example, when the power consumption is less than 500 W, the target voltage is set to 200 V. When the power consumption is 500 W or greater and 1000 W or less, the target voltage is set to 180 V. When the power consumption exceeds 1000 W, the target voltage is set to 165 V. These numerical values are merely examples. In addition, in general, when the load rapidly decreases, the output voltage from the DC-DC converter rapidly increases, and thus a capacitor having a high withstand voltage is required for the inverter. In the present embodiment, in a state where the output voltage can rise rapidly, the target voltage is controlled to be low in advance. Therefore, the input withstand voltage of the inverter can be reduced.

Third Aspect

The voltage detection circuit **22***a* functions as a voltage detection circuit that detects a first direct current voltage (for example, Vdc_in) input from the direct current power supply to the DC-DC converter. The current detection circuit **23** functions as a current detection circuit that detects an input direct current (for example, Vdc_in) input from the direct current power supply to the DC-DC converter. The power calculation unit (for example, the CPU **28**) may calculate power consumption (for example, Pin) of the DC-DC converter based on the value of the first direct current voltage detected by the voltage detection circuit and the value of the input direct current detected by the current detection circuit.

Fourth and Ninth Aspects

The CPU **28** may include efficiency calculation unit (for example, the efficiency calculation unit **211**) for calculating overall efficiency (for example, Ef) of the direct current power supply, the DC-DC converter, and the inverter. The CPU **28** may have setting unit (example: efficiency determination unit **212**, target voltage determination unit **213**) for setting the target voltage according to the efficiency. This allows the target voltage to be adjusted to improve the efficiency. In general, the target voltage is set to a fixed value, but in the present embodiment, the target voltage is variably controlled so as to improve the efficiency. This will improve the overall efficiency of the power supply device including the DC-DC converter and the inverter. In this way, when the efficiency is improved, a time period when the battery included in the direct current power supply can supply power will be increased. Alternatively, the operable time of the engine-driven generator mounted on the direct current power supply will be increased. When the efficiency is improved, a heat radiation amount of the power supply device **1** decreases, so that a cooling fan can be omitted or the cooling performance of the cooling fan can be lowered. As a result, noise reduction may be achieved.

Fifth Aspect

The CPU **28** may acquire, from the inverter, a value of the alternating current output from the inverter and a value of the alternating current voltage output from the inverter. Further, the CPU **28** may acquire, from the direct current power supply, a value of the output voltage of the direct current power supply and a value of the output current of the direct current power supply. The efficiency calculation unit **211** may be configured to calculate the efficiency based on the value of the alternating current, the value of the alternating current voltage, the value of the output voltage, and the value of the output current.

Sixth Aspect

As indicated by Equation (1), the efficiency calculation unit **211** may acquire a first product by multiplying the value of the alternating current by the value of the alternating current voltage, acquire a second product by multiplying the value of the output voltage by the value of the output current, and acquire the efficiency by dividing the first product by the second product.

Seventh Aspect

The memory **29** functions as storage unit for storing first efficiency (for example, Ef_old) obtained by the efficiency calculation unit. The CPU **28** may increase the target voltage when second efficiency (for example, Ef_new) obtained by the efficiency calculation unit after the first efficiency is obtained is higher than or equal to the first efficiency. The CPU **28** may decrease the target voltage when the second efficiency is not equal to or higher than the first efficiency. This will maintain a highly efficient operating state.

Eighth Aspect

The CPU **28** may calculate the efficiency based on the value of the alternating current, the value of the alternating current voltage, the value of the output voltage, and the value of the output current, which are acquired after the second direct current voltage is controlled based on the power consumption of the DC-DC converter.

The invention is not limited to the foregoing embodiments, and various variations/changes are possible within the spirit of the invention.

What is claimed is:

1. A power supply device comprising:

a DC-DC converter that converts a first direct current voltage supplied from a direct current power supply to generate a second direct current voltage;

an inverter that is supplied with the second direct current voltage from the DC-DC converter and outputs an alternating current and an alternating current voltage; and

a controller that controls the DC-DC converter so that the second direct current voltage becomes a target voltage, wherein

the controller is configured to:

obtain a power consumption of the DC-DC converter;

control the DC-DC converter so that the second direct current voltage output from the DC-DC converter becomes higher than the target voltage when the power consumption is less than a first power; and

control the DC-DC converter so that the second direct current voltage output from the DC-DC converter becomes lower than the target voltage when the power consumption exceeds a second power greater than the first power.

2. The power supply device according to claim **1**, wherein the controller is further configured to

control the DC-DC converter so that the second direct current voltage output from the DC-DC converter becomes equal to a sum of the target voltage and a predetermined value when the power consumption is less than the first power, and

control the DC-DC converter so that the second direct current voltage output from the DC-DC converter becomes equal to a difference between the target voltage and the predetermined value when the power consumption exceeds the second power.

3. The power supply device according to claim **2**, wherein the controller is further configured to

calculate an overall efficiency of the direct current power supply, the DC-DC converter, and the inverter, and

set the target voltage according to the overall efficiency.

4. The power supply device according to claim **3**, wherein the controller is further configured to:

acquire, from the inverter, a value of the alternating current output from the inverter and a value of the alternating current voltage;

acquire, from the direct current power supply, a value of an output voltage of the direct current power supply and a value of an output current; and

calculate the overall efficiency based on the value of the alternating current, the value of the alternating current voltage, the value of the output voltage, and the value of the output current.

5. The power supply device according to claim **4**, wherein the controller is further configured to:

obtain a first product by multiplying the value of the alternating current by the value of the alternating current voltage;

obtain a second product by multiplying the value of the output voltage by the value of the output current; and

obtain the overall efficiency by dividing the first product by the second product.

6. The power supply device according to claim **4**, further comprising:

a storage that stores a first efficiency obtained by the controller, wherein the controller is further configured to:

increase the target voltage when a second efficiency obtained by the controller after the first efficiency is obtained is equal to or higher than the first efficiency; and

decrease the target voltage when the second efficiency is not equal to or higher than the first efficiency.

7. The power supply device according to claim **4**, wherein the controller is further configured to calculate the overall efficiency based on the value of the alternating current, the value of the alternating current voltage, the value of the output voltage, and the value of the output current, which are acquired after the second direct current voltage is controlled based on the power consumption of the DC-DC converter.

8. The power supply device according to claim **1**, further comprising:

a voltage detection circuit that detects the first direct current voltage input from the direct current power supply to the DC-DC converter; and

a current detection circuit that detects an input direct current input from the direct current power supply to the DC-DC converter, wherein

the controller is further configured to calculate the power consumption of the DC-DC converter based on a value of the first direct current voltage detected by the voltage detection circuit and a value of the input direct current detected by the current detection circuit.

9. A method executed by a controller in a power supply device including a direct current power supply, a DC-DC converter, an inverter, and the controller, the method comprising:

calculating a power consumption of the DC-DC converter;

controlling the DC-DC converter so that an output direct current voltage output from the DC-DC converter becomes higher than a target voltage preset in the DC-DC converter when the power consumption is less than a first power; and

controlling the DC-DC converter so that the output direct current voltage output from the DC-DC converter becomes lower than the target voltage when the power consumption exceeds a second power greater than the first power.

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