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Ichinose et al.

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(54) **COMBUSTION TURBINE POWER GENERATION SYSTEM AND METHOD OF CONTROLLING THE SAME**

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(22) Filed: **May 15, 2003**

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Related U.S. Application Data

(63) Continuation of application No. 10/246,470, filed on Sep. 19, 2002, now Pat. No. 6,684,639.

(30) **Foreign Application Priority Data**

Jul. 8, 2002 (JP) 2002-198833

(51) **Int. Cl.**^{7} **F01K 13/02**
(52) **U.S. Cl.** **60/660**; 60/645
(58) **Field of Search** 60/645, 660; 290/2, 290/12

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(57) **ABSTRACT**

A combustion turbine power generating system and method in which the system includes a permanent magnet type AC power generator, a combustion turbine that drives the AC power generator, a first converter enabling conversion between AC current and DC current and having an AC side connected to the AC power generator, a second converter enabling conversion between AC current and DC current and having a DC side connected to a DC output side of the first converter, a capacitor connected between the first and second converters, a generator-speed control unit that controls the first converter and a DC voltage control unit that controls a DC-side voltage of the second converter. The generator-speed control unit controls the first converter on the basis of a number of revolution command value.

6 Claims, 5 Drawing Sheets

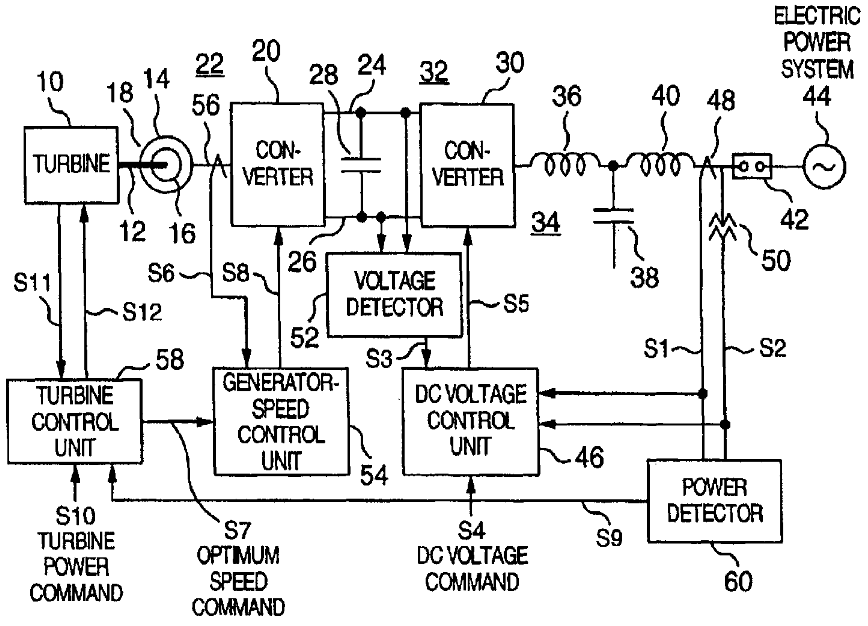


FIG. 1

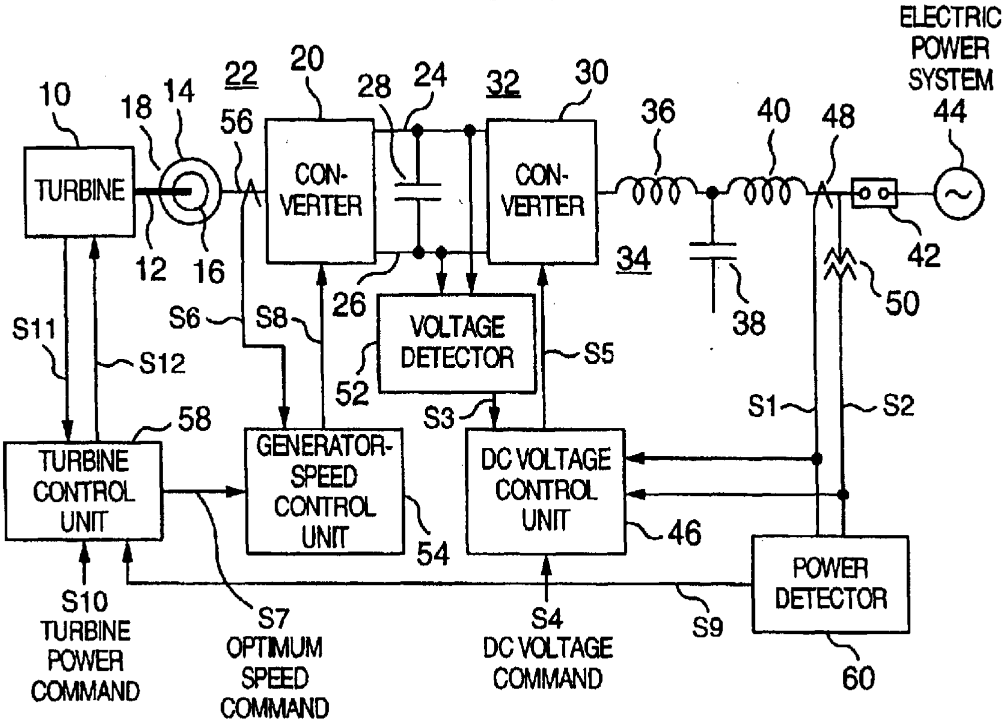

ELECTRIC POWER SYSTEM
44
10
TURBINE
18
14
22
56
20
CON-VERTER
28
24
32
30
CON-VERTER
36
40
48
12
16
26
34
38
42
50
S11
S12
S6
S8
VOLTAGE DETECTOR
52
S5
S3
S1
S2
58
TURBINE CONTROL UNIT
GENERATOR-SPEED CONTROL UNIT
54
DC VOLTAGE CONTROL UNIT
46
POWER DETECTOR
60
S10
TURBINE POWER COMMAND
S7
OPTIMUM SPEED COMMAND
S4
DC VOLTAGE COMMAND
S9

FIG. 2

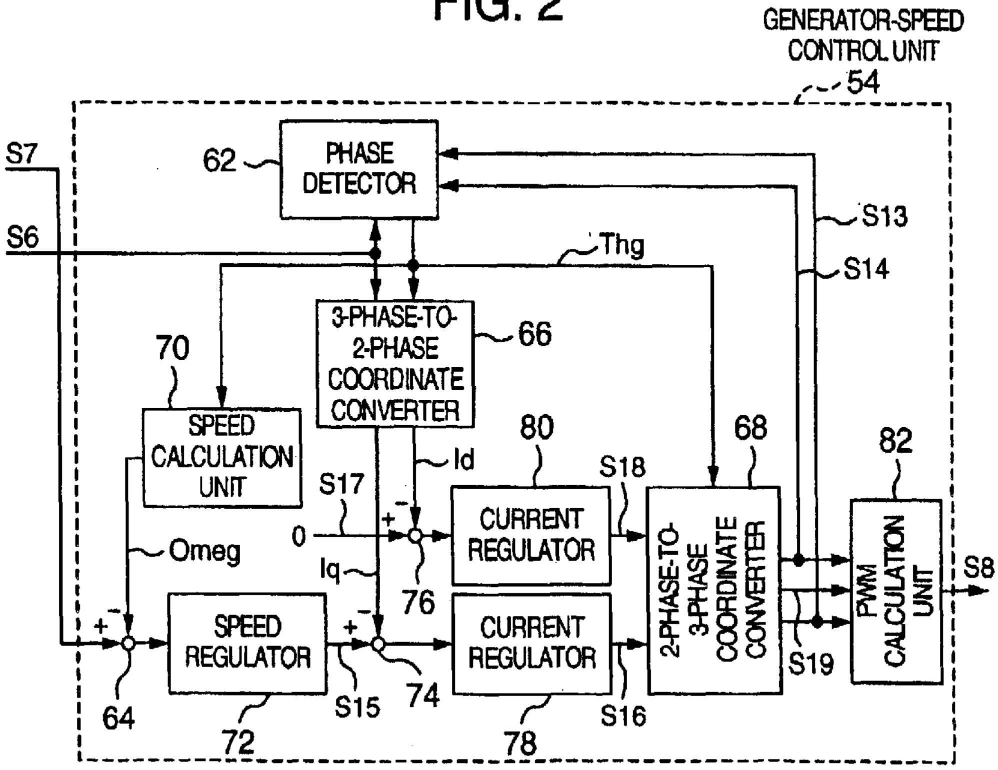

GENERATOR-SPEED CONTROL UNIT
54
S7
62
PHASE DETECTOR
S6
Thg
S13
S14
3-PHASE-TO-2-PHASE COORDINATE CONVERTER
66
70
SPEED CALCULATION UNIT
Id
80
CURRENT REGULATOR
S18
68
2-PHASE-TO-3-PHASE COORDINATE CONVERTER
82
PWM CALCULATION UNIT
S8
S17
0
+
-
Iq
76
Omeg
+
-
SPEED REGULATOR
+
-
74
CURRENT REGULATOR
S19
64
72
S15
78
S16

FIG. 3

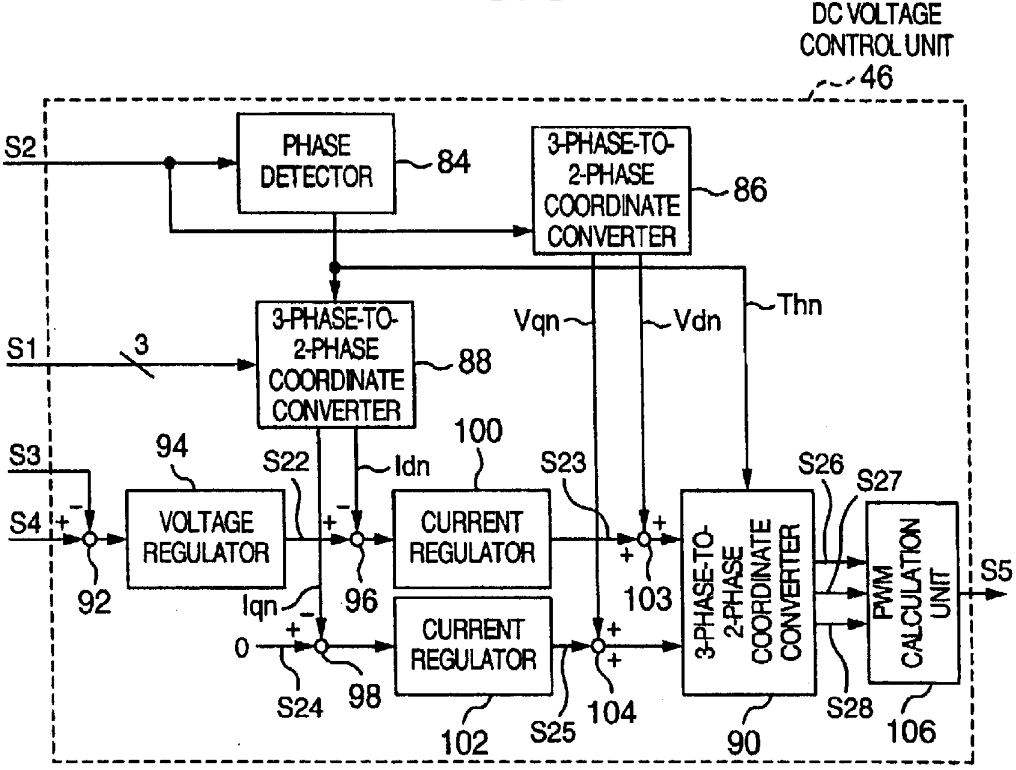

DC VOLTAGE CONTROL UNIT
46
S2
PHASE DETECTOR
84
3-PHASE-TO-2-PHASE COORDINATE CONVERTER
86
S1
3
3-PHASE-TO-2-PHASE COORDINATE CONVERTER
88
Vqn
Vdn
Thn
S3
S4
94
VOLTAGE REGULATOR
92
S22
Idn
100
CURRENT REGULATOR
96
Iqn
0
S24
98
CURRENT REGULATOR
102
S23
103
S25
104
3-PHASE-TO-2-PHASE COORDINATE CONVERTER
90
S26
S27
S28
PWM CALCULATION UNIT
106
S5

FIG. 4

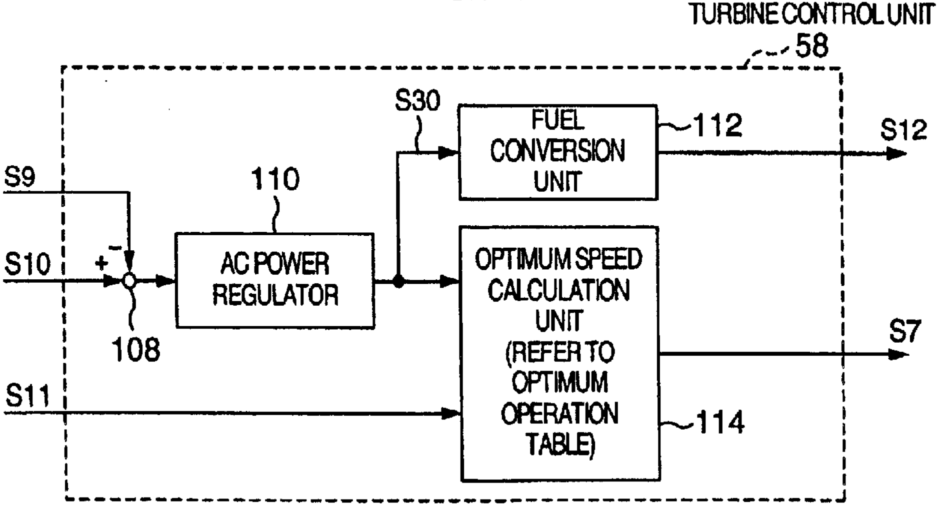

TURBINE CONTROL UNIT
58
S30
FUEL CONVERSION UNIT
112
S12
S9
110
S10
AC POWER REGULATOR
108
OPTIMUM SPEED CALCULATION UNIT (REFER TO OPTIMUM OPERATION TABLE)
114
S7
S11

FIG. 5

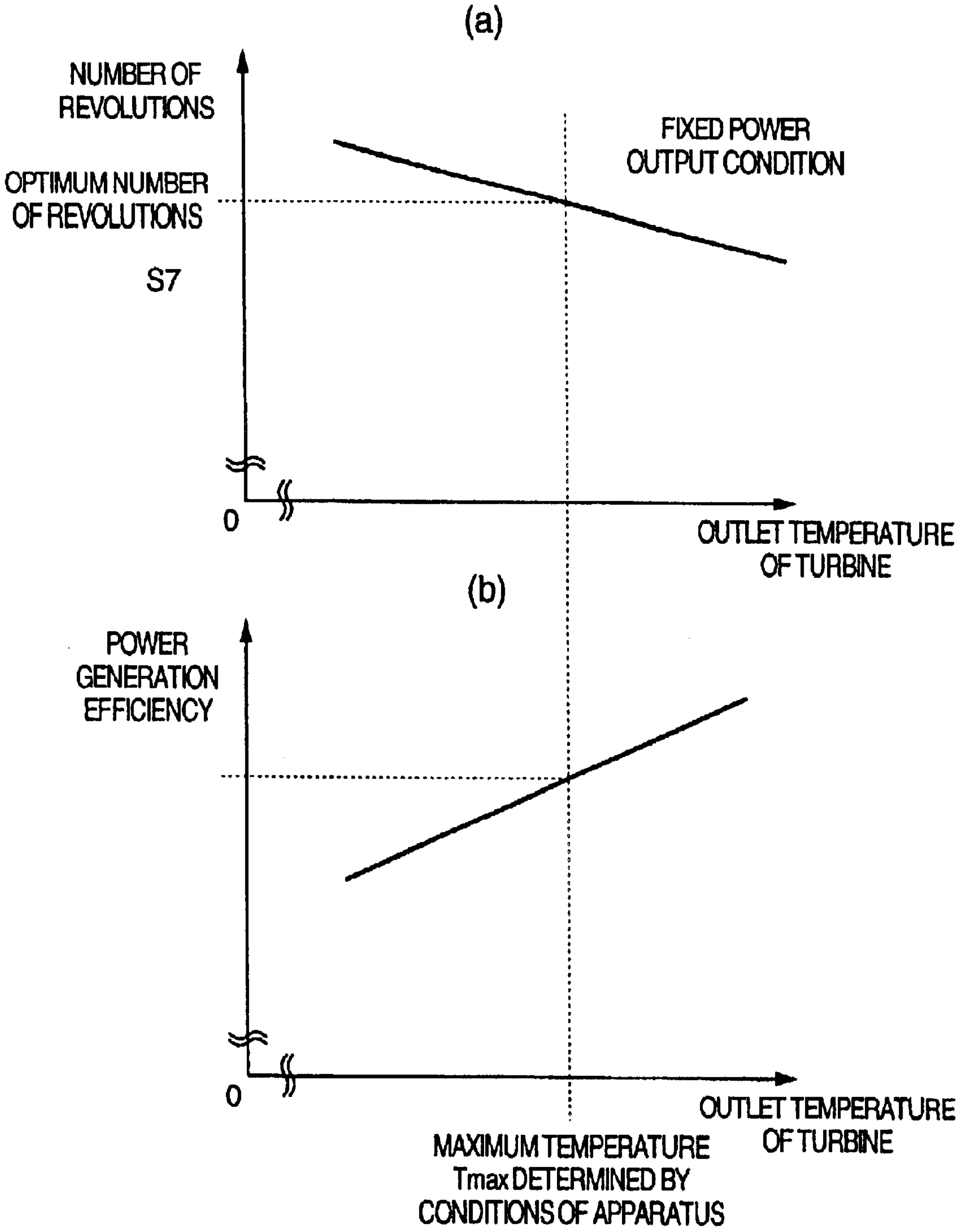

(a)
NUMBER OF REVOLUTIONS
OPTIMUM NUMBER OF REVOLUTIONS
S7
FIXED POWER OUTPUT CONDITION
0
OUTLET TEMPERATURE OF TURBINE
(b)
POWER GENERATION EFFICIENCY
0
OUTLET TEMPERATURE OF TURBINE
MAXIMUM TEMPERATURE Tmax DETERMINED BY CONDITIONS OF APPARATUS

FIG. 6

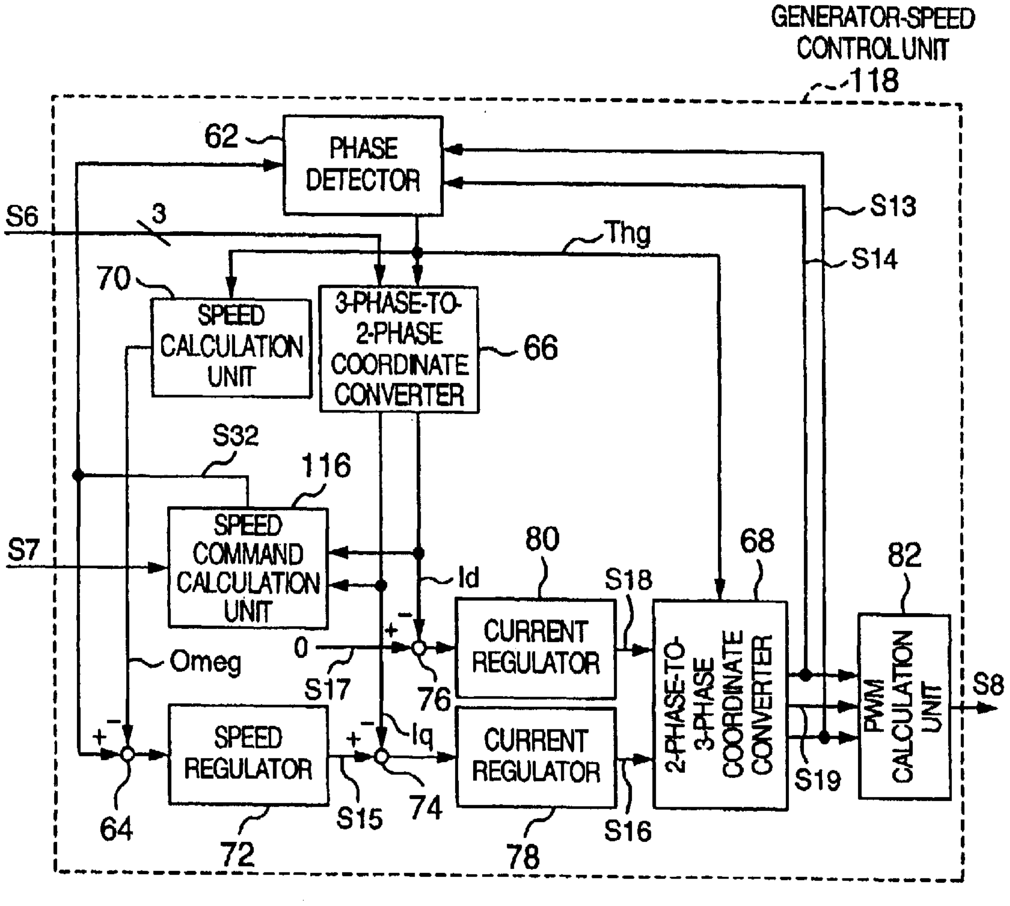

GENERATOR-SPEED
CONTROL UNIT
118
62
PHASE DETECTOR
S6
3
S13
S14
Thg
70
SPEED CALCULATION UNIT
3-PHASE-TO-2-PHASE COORDINATE CONVERTER
66
S32
116
SPEED COMMAND CALCULATION UNIT
S7
80
68
82
Id
S18
0
+
-
CURRENT REGULATOR
2-PHASE-TO-3-PHASE COORDINATE CONVERTER
PWM CALCULATION UNIT
S8
Omeg
S17
76
Iq
SPEED REGULATOR
64
72
S15
74
78
S16
S19

FIG. 7

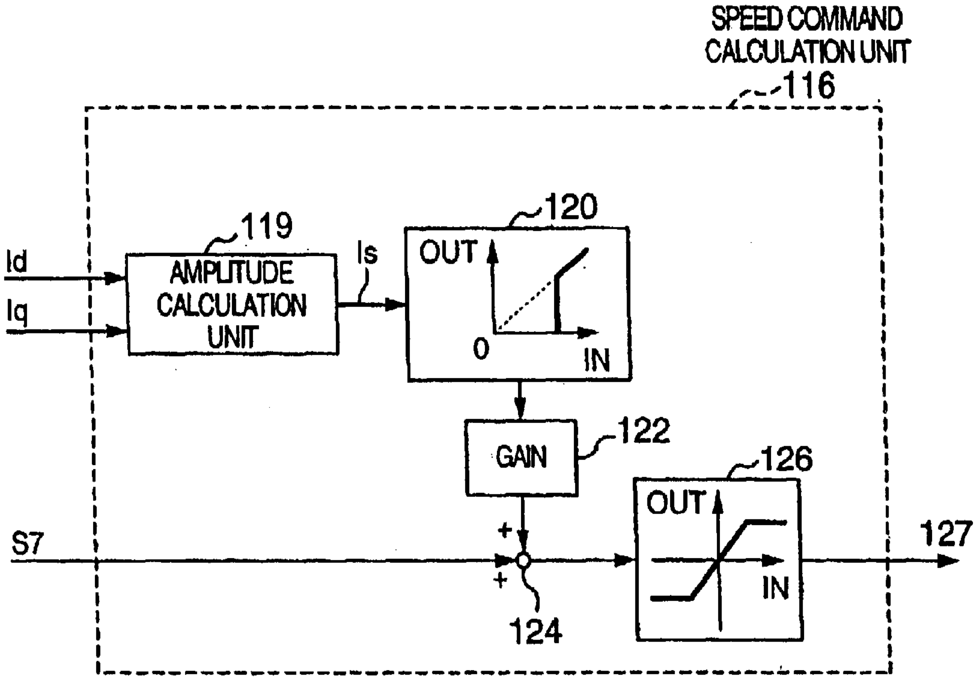
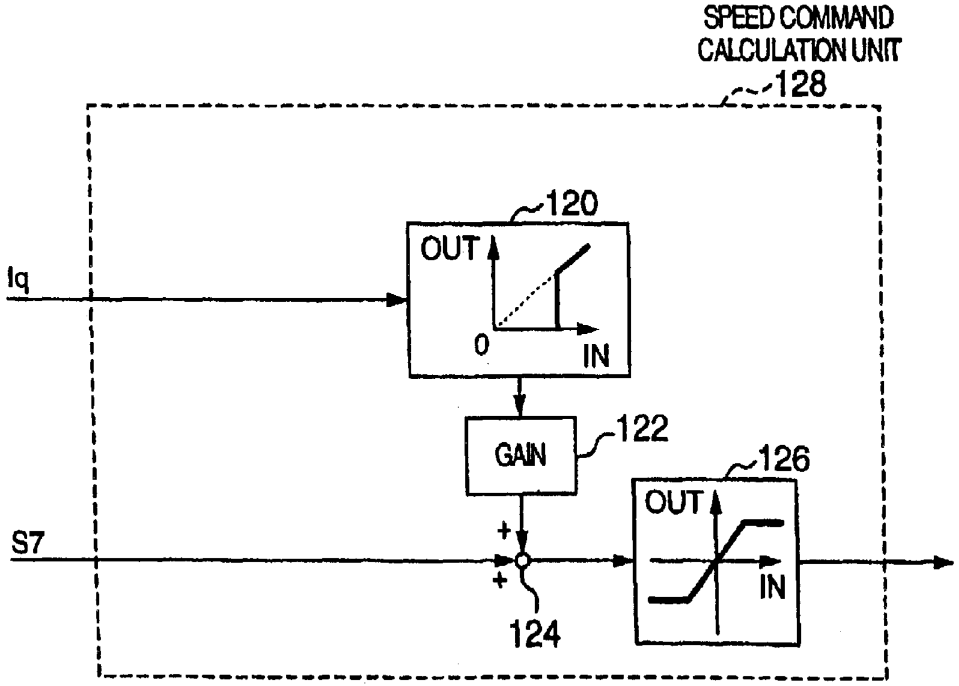

SPEED COMMAND CALCULATION UNIT
116
119
AMPLITUDE CALCULATION UNIT
Id
Iq
Is
120
OUT
0
IN
122
GAIN
126
OUT
IN
S7
+
+
124
127

FIG. 8


SPEED COMMAND CALCULATION UNIT
128
120
OUT
0
IN
Iq
122
GAIN
126
OUT
IN
S7
+
+
124

COMBUSTION TURBINE POWER GENERATION SYSTEM AND METHOD OF CONTROLLING THE SAME

CROSS REFERENCE TO RELATED APPLICATION

This is a continuation of U.S. application Ser. No. 10/246,470, filed Sep. 19, 2002, now U.S. Pat. No. 6,684,639, the subject matter of which is incorporated by reference herein.

BACKGROUND OF THE INVENTION

1. Filed of the Invention

The present invention relates to a combustion turbine power generating system that can realize high efficient and high reliable operation and method of controlling the same.

2. Description of Related Art

As disclosed in JP-A-09-289776, in a case of a conventional combustion turbine power generating system, a command value for number of revolutions is calculated from a load power to be outputted and the command value for the number of revolutions is inputted to a turbine controller to control the number of revolutions for a combustion turbine, thereby controlling the number of revolutions for a power generator.

In the above technique, the command value for the number of revolutions is calculated from the output power of the turbine on the basis of the knowledge that the output power of the turbine is proportional to its the number of revolutions.

The turbine controller adjusts a quantity of fuel to be fed on the basis of the command value for the number of revolutions calculated as above and controls the number of revolutions. However, since the efficiency of turbine is influenced by a temperature of suction air or the like, the turbine cannot be always operated at the number of revolutions that the highest efficiency and a low Nox (nitrogen oxide) are attained for a certain fuel quantity. Accordingly, it is difficult that the efficiency of the turbine is always kept to be high.

SUMMARY OF THE INVENTION

It is an object of the present invention to make power generation at high efficient state of turbine by controlling the number of revolutions of a power generator.

According to an aspect of the present invention, in a combustion turbine power generating system for supplying an output of turbine to an electric power system through a power generator and a power converter capable of converting the power between AC current and DC current, the speed of power generator is always controlled by means of the power converter connected to the power generator.

Further, an optimum speed command is produced from state quantity of the turbine and the speed of power generator is controlled on the basis of the optimum speed command by means of the power converter connected to the power generator.

Moreover, when a fuel quantity is varied by adjustment of fuel or the like and a current of the power generator is greater than a predetermined value, the speed of power generator is increased temporarily.

Other objects, features and advantages of the invention will become apparent from the following description of the embodiments of the invention taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a block diagram schematically illustrating the whole of a main circuit and a control system of a combustion turbine power conversion system according to an embodiment of the present invention;

FIG. **2** is a block diagram schematically illustrating a generator-speed control unit according to an embodiment of the present invention in detail;

FIG. **3** is a block diagram schematically illustrating a DC voltage control unit according to an embodiment of the present invention in detail;

FIG. **4** is a block diagram schematically illustrating a turbine control unit according to an embodiment of the present invention in detail;

FIG. **5** is a diagram explaining an optimum speed calculation unit of a turbine control unit according to a second embodiment of the present invention;

FIG. **6** is a block diagram schematically illustrating a generator-speed control unit according to a second embodiment of the present invention in detail;

FIG. **7** is a block diagram schematically illustrating a speed command calculation unit according to a second embodiment of the present invention in detail; and

FIG. **8** is a block diagram schematically illustrating another speed command calculation unit according to a second embodiment of the present invention in detail.

DETAILED DESCRIPTION OF THE EMBODIMENTS

An embodiment of a combustion turbine power generating system to which the present invention is applied is now described with reference to the accompanying drawings. FIG. **1** is a block diagram schematically illustrating the combustion turbine power generating system.

Referring to FIG. **1**, a rotation axis **12** of a turbine **10** is connected to a shaft that supports a rotor **16** of a permanent-magnet generator **14**. The side of a stator **18** of the permanent-magnet generator **14** is connected to an AC side **22** of a converter **20**. The permanent-magnet generator **14** supplies an output power itself to the converter **20** in power generating operation and receives electric power from the converter **20** in motor operation.

DC terminals **24** and **26** of the converter **20** are connected to a DC side **32** of a converter **30** through a capacitor **28**. An AC output side **34** of the converter **30** is connected to a reactor **36** constituting an AC filter for eliminating harmonics. The converters **20** and **30** are constituted by well-known semiconductor switching elements and make conversion between AC current and DC current by turning a gate pulse on and off.

In this embodiment, in power generating operation, the converter **20** converts AC output power of the AC power generator **14** into DC power and the converter **30** converts DC output power from the converter **20** into AC power.

Further, the converter **30** converts AC power from an electric power system **44** into DC power and supplies the DC power to the converter **20**. In motor operation, conversely, the converter **30** receives the AC power from the electric power system **44** and converts the AC power into DC power to supply the DC power to the converter **20**. The converter **20** converts the DC power into AC power and operates the AC power generator as an electric motor.

The reactor **36** is connected to a capacitor **38** and a reactor **40** constituting an AC filter. The two series-connected reactors **36** and **40** and the capacitor **38** connected to the junction thereof constitute a T-type AC filter. The reactor **40** is connected through a circuit breaker **42** to the electric power system **44**.

A DC voltage control unit **46** for the converter **30** is supplied with detection values S1 and S2, a voltage detection value S3 and a DC voltage command value S4 to supply a gate signal S5 to the converter **30**.

The detection values S1, S2 and the voltage detection value S3 are produced from a current detector **48** that detects a current flowing through the reactor **40**, a voltage detector **50** disposed on the side of the electric power system **44** of the reactor **40**, and a voltage detector **52** for the capacitor **28** disposed on the DC side of the converter **30**, respectively.

Further, a generator-speed control unit **54** connected to the converter **20** is supplied with a detection value S6 and an optimum speed command value S7 and supplies a gate signal S8 to the converter **20**. The detection value S6 and the optimum speed command value S7 are produced from a current detector **56** for detecting a current produced by the permanent-magnet generator **14** and a turbine control unit **58**, respectively.

The turbine control unit **58** is supplied with a power detection value S9, a power command S10 and state quantity S11 such as temperature and pressure from the turbine **10** and supplies a fuel adjustment command S12 to the turbine **10**.

A power detector **60** detects electric power from AC current S1 and AC voltage S2 and produces the power detection value S9. Further, the turbine control unit **58** supplies the optimum speed command value S7 to the generator-speed control unit **54** connected to the power converter **20**.

FIG. **2** is a block diagram schematically illustrating the generator-speed control unit **54** connected to the converter **20** in detail. Referring to FIG. **2**, the generator-speed control unit **54** is supplied with the optimum speed command value S7 and the generator current detection value S6. The optimum speed command value S7 is supplied to a subtracter **64**.

A phase detector **62** is supplied with output voltage command values S13 and S14 of a 2-phase/3-phase coordinate converter **68** and the generator-current detection value S6 to calculate a phase signal Thg of an induced voltage from the power generator **14** by means of a sensor-less phase detection system. The phase signal is supplied to a 3-phase-to-2-phase coordinate converter **66**, the 2-phase-to-3-phase coordinate converter **68** and a speed calculation unit **70**.

The speed calculation unit **70** calculates a speed Omeg from the phase signal Thg of the induced voltage in accordance with the expression (1):

$$\mathrm{Omeg}=\Delta\theta/\Delta t \tag{1}$$

Δθ: increment of the phase signal Thg

Δt: variation of time

The subtracter **64** calculates a deviation between the optimum speed command value S7 and the calculated speed value Omeg to supply the deviation to a speed regulator **72**. The speed regulator **72** can be constituted by, for example, a proportional integral controller. The speed regulator **72** regulates a q-axis current command value (torque current command value) **S15** so that the speed deviation is reduced to zero and supplies the command value to a subtracter **74**.

The 3-phase-to-2-phase coordinate converter **66** calculates a d-axis current (excitation current component) Id and a q-axis current (torque current component) Iq from the inputted generator-current detection value S6 and the phase signal Thg of the induced voltage in accordance with the expression (2). The d-axis current detection value Id is supplied to a subtracter **76** and the q-axis current detection value Iq is supplied to the subtracter **74**.

$$\begin{pmatrix} Id \\ Iq \end{pmatrix} = \begin{pmatrix} Iu\cdot\cos(0)+Iv\cdot\cos(2\pi/3)+Iw\cdot\cos(4\pi/3) \\ Iu\cdot\sin(0)+Iv\cdot\sin(2\pi/3)+Iw\cdot\sin(4\pi/3) \end{pmatrix} \begin{pmatrix} \cos(Thg) & \sin(Thg) \\ \sin(Thg) & -\cos(Thg) \end{pmatrix} \tag{2}$$

The subtracter **74** calculates a deviation between the q-axis current command value **S15** and the q-axis current detection value Iq and supplies it to a current regulator **78**. The current regulator **78** regulates a q-axis voltage command value **S16** so that the deviation between the command value **S15** and the detection value Iq is reduced to zero and supplies the regulated value to the 2-phase-to-3-phase coordinate converter **68**.

Further, the subtracter **76** calculates a deviation between a d-axis current command value **S17** and the d-axis current detection value Id to thereby supply the deviation to a current regulator **80**. The current regulator **80** regulates a d-axis voltage command value **S18** which is an output thereof so that a deviation between the command value S17 and the detection value Id is reduced to zero, and supplies the regulated value to the 2-phase-to-3-phase coordinate converter **68**. The current regulators **78** and **80** can be constituted by, for example, a proportional integration controller.

The 2-phase-to-3-phase coordinate converter **68** is supplied with the phase signal Thg, the d-axis voltage command value **S18** and the q-axis voltage command value **S16** to be thereby calculated voltage command values S13, **S14** and **S19** produced by the 2-phase-to-3-phase coordinate converter **68** in accordance with the expressions (3) and (4) to be supplied to a PWM calculation unit (pulse-width-modulation calculation unit) **82**.

$$\begin{pmatrix} Vagr \\ Vbgr \end{pmatrix} = \begin{pmatrix} \cos(Thg) & \sin(Thg) \\ \sin(Thg) & -\cos(Thg) \end{pmatrix} \begin{pmatrix} Vdgr \\ Vqgr \end{pmatrix}$$

$$\begin{pmatrix} Vugr \\ Vvgr \\ Vwgr \end{pmatrix} = \begin{pmatrix} \cos(0) & \sin(0) \\ \cos(2\pi/3) & \sin(2\pi/3) \\ \cos(4\pi/3) & \sin(4\pi/3) \end{pmatrix} \begin{pmatrix} Vagr \\ Vbgr \end{pmatrix}$$

The PWM calculation unit **82** calculates a gate signal **S8** on the basis of the inputted voltage commands **S13**, **S14** and **S19**. The signal **S8** is supplied to the converter **20** constituted by the pulse-width-modulation system to turn on and off semiconductor elements thereof.

An example of operation of FIG. **2** is now described. In the generator-speed control unit **54** of FIG. **2**, it is defined that a torque current in motor operation of the generator **14** is positive and a torque current in power generating operation is negative.

When the optimum speed command value **S7** of the turbine control unit **58** is now increased, the input of the speed regulator **72** is increased. Accordingly, the output (a torque current command value **S15**) of the speed regulator **72** is increased in the positive direction.

Since the torque current in power generating operation is defined to be negative, the fact that the torque current command value **S15** is increased in the positive direction means that the torque current is reduced. When the torque current command value **S15** is increased in the positive direction, the input of the current regulator **78** is increased.

In order to reduce the torque current, the current regulator **78** changes the q-axis voltage command value **S16** to delay the phase of the voltage produced by the converter **20**. Consequently, the phase difference between the voltage and the induced voltage of the generator **14** is made small and the torque current is reduced.

The reduction of the torque current corresponds to reduction of electric energy taken out from the generator **14**. The generator **14** increases rotational energy by the reduction of the taken-out energy, so that the rotational speed thereof is increased.

This can be explained from the equation of motion of the generator given by the expression (5). In the expression (5), when energy of the generator **14** received from the turbine **10** is T and energy taken out by the converter **20** from the generator **14** is Ti, T>Ti represents acceleration, T=Ti fixed speed and T<Ti deceleration.

$$T-Ti=j\cdot d\omega/dt \tag{5}$$

Conversely, when the speed command value **S7** is reduced in power generating operation, the positive-direction input of the speed regulator **72** is reduced. Accordingly, the output (torque current command value **S15**) of the speed regulator **72** is increased in the negative direction.

Since the torque current in power generating operation is defined to be negative, change of the torque current command value **S15** in the negative direction means that the torque current is increased. In order to increase the torque current, the current regulator **78** reduces the q-axis voltage command value **S16** and advances the phase of the voltage produced by the converter **20**. Thus, a phase difference between the voltage and the induced voltage of the generator **1** is increased.

The increase of the torque current corresponds to increase of electric energy taken out from the generator **14**. The generator **14** reduces the rotational energy by the increase of the taken-out energy, so that the rotational speed thereof is reduced.

In this case, the relation of the energy T inputted to the generator **14** from the turbine **10** and the energy Ti taken out from the generator **14** by the converter **20** is T<Ti, so that the generator is decelerated.

FIG. **3** is a block diagram schematically illustrating the DC voltage control unit **46** for the converter **30** in detail. In FIG. **3**, the DC voltage control unit **46** is supplied with the current detection value **S1**, the voltage detection value **S2**, the DC voltage detection value **S3** and the DC voltage command value **S4**.

The AC voltage detection value **S2** is supplied to a phase detector **84** and a 3-phase-to-2-phase coordinate converter **86**. The phase detector **84** calculates a phase signal Thn following the voltage of the electric power system **44** by means of the phase-locked loop (PLL) system, for example, and supplies the phase signal Thn to 3-phase-to-2-phase coordinate converters **88** and **86** and a 2-phase-to-3-phase coordinate converter **90**.

The DC voltage command value **S4** and the DC voltage detection value **S3** are inputted to a subtracter **92**, which supplies a deviation between the DC voltage command value **S4** and the DC voltage detection value **S3** to a voltage regulator **94**.

The voltage regulator **94** can be constituted by, for example, a proportional integration controller. The DC voltage regulator **94** regulates a d-axis current command value (effective current command value) **S22** produced therefrom so that the inputted deviation is reduced to zero and supplies the command value to a subtracter **96**.

The 3-phase-to-2-phase coordinate converter **88** calculates a d-axis current detection value Idn (effective current) and a q-axis current detection value Iqn (reactive current) from the inputted current **S1** in accordance with the conversion equation given by the expression (2) and supplies the d-axis current detection value Idn and the q-axis current detection value Iqn to the subtracter **96** and a subtracter **98**, respectively.

The subtracter **96** calculates a deviation between the d-axis current command value **S22** and the d-axis current detection value Idn and supplies the deviation to a current regulator **100**. The current regulator **100** regulates a d-axis voltage command value **S23** so that the deviation between the command value **S22** and the detection value Idn is reduced to zero and supplies the command value to an adder **103**.

Similarly, the subtracter **98** calculates a deviation between a q-axis current command value **S24** and the q-axis current detection value Iqn and supplies the deviation to a current regulator **102**. The current regulator **102** regulates a q-axis voltage command value **S25** so that a deviation between the inputted command value and the detection value is reduced to zero and supplies the command value to an adder **104**. The current regulators **100** and **102** can be constituted by, for example, a proportional integration controller.

The 3-phase-to-2-phase coordinate converter **86** calculates a d-axis voltage detection value (phase component coincident with system voltage **44**) and-a q-axis voltage detection value (component orthogonal to the d-axis voltage detection value) Vqn from the inputted voltage S2 in accordance with the conversion equation given by the equation (2) and supplies the values Vdn and Vqn to the adders **103** and **104**, respectively.

The adder **103** adds the d-axis voltage command value S**23** and the d-axis voltage detection value Vdn and supplies its sum to the 2-phase-to-3-phase coordinate converter **90**. Similarly, the adder **104** adds the q-axis voltage command value S**25** and the q-axis voltage detection value Vqn and supplies its sum to the 2-phase-to-3-phase coordinate converter **90**.

The 2-phase-to-3-phase coordinate converter **90** is supplied with the phase signal Thn and the results of the adders **104** and **103** and calculates voltage command values S**26**, S**27** and S**28** produced therefrom in accordance with the conversion expressions (3) and (4) to supplies them to the PWM calculation unit **106**.

The PWM calculation unit **106** calculates the gate signal S**5** from the inputted voltage commands S**26**, S**27** and S**28**. In order to control to turn on and off the semiconductor elements of the converter **30** constituted by the pulse width modulation system, the gate signal S**5** is supplied to the converter **30**.

FIG. **4** is a block diagram schematically illustrating the turbine control unit **58** in detail. In FIG. **4**, the turbine control unit **58** is supplied to the power command value S**10**, the power detection value S**9** and the state quantity S**11**.

A subtracter **108** calculates a deviation between the power command value S**10** and the power detection value S**9** and supplies the deviation to an AC power regulator **110**. The AC power regulator **110** can be constituted by, for example, a proportional integration controller. The AC power regulator **110** produces a power command value S**30** which is the power command value S**10** corrected so that the deviation between the command value and the detection value is reduced to zero.

The corrected power command value S**30** is supplied to a fuel conversion unit **112**. The fuel conversion unit **112** calculates the fuel adjustment command value S**12** from the power and outputs the command value.

Further, the corrected power command value **30** is also supplied to an optimum speed calculation unit **114**. The optimum speed calculation unit **114** is supplied with the corrected power command value S**30** and the state quantity S**11** and refers to optimum operation conditions in previously set states to produce the optimum speed command value S**7** for satisfactory turbine efficiency.

Referring now to FIG. **5**, operation of the optimum speed calculation unit **114** is described. The graph shown in (a) of FIG. **5** shows a relation of the number of revolutions of the generator **14** and a temperature at an outlet of the turbine **10**. Further, the graph shown in (b) of FIG. **5** shows a relation of the power generation efficiency and the temperature at the outlet of the turbine **10**.

When the temperature at the outlet of the turbine, for example, is used as the state quantity S**11** of the turbine **10**, the optimum speed command S**7** is decided from the optimum number of revolutions (shown in the graph of (a) in FIG. **5**) for operation at the highest power generation efficiency.

When the optimum number of revolutions is tabulated for each output power, for example, which is a certain power output condition from the graphs shown in FIG. **5**, the optimum speed calculation unit **114** can always produce the optimum speed command value S**7**.

Further, in addition to the tabulation, the optimum speed command value S**7** can be obtained even by reducing the speed when the outlet temperature of the turbine is low and by increasing the speed when the outlet temperature of the turbine is high so that the temperature of the turbine is equal to the permissible maximum temperature Tmax.

In the above description, the outlet temperature of the turbine is used, while even the state quantity corresponding to the outlet temperature of the turbine is used to attain the same function. Further, the efficiency of the general combustion turbine as described above is varied depending on the number of revolutions and even the combustion turbine utilizing high-humidity air can attain the same effects.

According to the embodiment, since the speed of the generator can be always controlled by the converter **20** connected to the generator **14** even in power generating operation, its control is simplified as compared with the case where control is once stopped and rectification by diodes is made.

Further, the optimum speed command S**7** is prepared from the state quantity S**11** of the turbine **10** and the speed of the generator is controlled by the converter **20** connected to the generator **14** on the basis of the optimum speed command S**7**, so that the generator **14** can be operated at the speed of the satisfactory turbine efficiency.

In the embodiment, sensor-less control is used for control of the converter of the generator **14**, while even in the case where a position detector connected to the rotation axis **12** of the generator **14** is used to detect a phase, the same effects can be attained.

Another embodiment of the present invention is now described. Like constituent elements are designated by like reference numerals throughout the drawings and detailed description thereof is omitted.

[Embodiment 2]

FIGS. **6** to **8** schematically illustrate another embodiment for realizing a combustion turbine power converting apparatus and a control method of the present invention. The generator-speed control unit **118** of FIG. **6** is different in partial configuration from the generator-speed control unit **54** of the embodiment 1.

The optimum speed command value S**7** inputted from the turbine control unit **58** is supplied to a speed command calculation unit **116** and an output of the speed command calculation unit **116** is used as the speed command value. The generator-speed control unit **54** of FIG. **1** can be replaced by the generator-speed control unit **118**. Other configuration shown in FIG. **6** is the same as FIG. **2** and accordingly detailed description thereof is omitted.

FIG. **7** is a block diagram schematically illustrating the speed command calculation unit **116** shown in FIG. **6**. The speed command calculation unit **116** is supplied with the d-axis current detection value Id (exciting current component), the q-axis current detection value Iq (torque current component) and the optimum speed command value S**7**.

The d-axis current detection value Id and the q-axis current detection value Iq are inputted to an amplitude calculation unit **119**, which calculates an amplitude Is of the current in accordance with the expression (6) and supplies it to a dead-band limiter **120**.

$$Is=\sqrt{Id^2+Iq^2} \tag{6}$$

The dead-band limiter **120** outputs the input value Is when the input value Is exceeds a set value. The output value of the dead-band limiter **120** is supplied to a gain multiplier **122**, which multiplies the output value by a predetermined gain and supplies its result to an adder **124**.

The adder **124** is supplied with the multiplication result and the optimum speed command value **S7** and supplies its addition result to a limiter **126** for preventing over-speed exceeding the command value. The limiter **126** produces a limit value when the input value exceeds the limit value and produces the input value when the input value is smaller than or equal to the limit value.

According to the embodiment, in addition to the advantages of the embodiment 1, the speed of the generator is temporarily increased to absorb or discharge energy produced by inertial energy upon transient variation that fuel is varied by adjustment of fuel fed to the turbine and the current of the converter **20** is larger than a predetermined value.

More particularly, since variation of mechanical input can be absorbed by mechanical energy of the rotating body to suppress electrical variation, there can be realized the reliable system that can prevent the over-current of the converter **20**.

Further, in the embodiment, the system using the amplitude of the current has been described, while even a speed command calculation unit **128** using the q-axis current (torque current) detection value as shown in FIG. **8** can attain the same effects.

As described above, in the embodiment, since the speed is always controlled by the converter connected to the generator even in power generating operation, the control is simplified as compared with the case where control is once stopped and rectification by diodes is made.

Further, the optimum speed command is prepared from the state quantity of the turbine and the speed of the generator is controlled by the converter connected to the generator on the basis of the optimum speed command, so that the generator can be operated at speed of the satisfactory turbine efficiency.

Moreover, since the speed of the generator is increased temporarily to absorb or discharge energy produced by inertial energy upon transient variation that fuel is varied by adjustment of fuel and the current of the converter is larger than a predetermined value, there can be realized the reliable system that can prevent the over-current of the converter.

When the current of the converter is increased, the speed is controlled to be increased temporarily and accordingly there can be realized the reliable system that can prevent the over-current of the converter.

According to the present invention, since the speed is always controlled by the converter connected to the generator even in power generating operation, the control is simplified as compared with the case where control is once stopped and rectification by diodes is made.

It should be further understood by those skilled in the art that although the foregoing description has been made on embodiments of the invention, the invention is not limited thereto and various changes and modifications may be made without departing from the spirit of the invention and the scope of the appended claims.

What is claimed is:

1. A combustion turbine power generating system comprising:

a permanent-magnet type AC power generator;

a combustion turbine that drives said permanent-magnet type AC power generator;

a first converter that enables conversion between AC current and DC current and having an AC side connected to a stator of said permanent-magnet type AC power generator;

a second converter that enables conversion between AC current and DC current and having a DC side connected to a DC output side of said first converter;

a capacitor connected between said first and second converters;

a circuit breaker connected between an AC side of said second converter and an electric power system;

generator-speed control means that controls said first converter;

a position detector connected to a rotation axis of said permanent-magnet type AC power generator; and

DC voltage control means that controls a DC-side voltage of said second converter;

wherein said generator-speed control means controls said first converter on the basis of a number of revolution command value, a detected value of an output signal from said position detector and an output voltage command value of said first converter, so that a number of revolutions of said permanent-magnet type AC power generator is controlled.

2. A combustion turbine power generating system according to claim **1**, wherein said generator-speed control means includes means that detects an output current of said permanent-magnet type AC power generator, and when a detected current value of said permanent-magnet type AC power generator exceeds a predetermined value, said optimum number of revolution command value is modified to change the number of revolutions of said permanent-magnet type AC power generator.

3. A combustion turbine power generating system according to claim **1**, wherein said generator-speed control means includes means that converts variation of mechanical energy produced by said combustion turbine into rotational energy of said permanent-magnet type AC power generator to thereby suppress electrical variation produced by said permanent-magnet type AC power generator.

4. A combustion turbine power generating system comprising:

a permanent-magnet type AC power generator;

a combustion turbine that drives said permanent-magnet type AC power generator;

a first converter that enables conversion between AC current and DC current and having an AC side connected to a stator of said permanent-magnet type AC power generator;

a second converter that enables conversion between AC current and DC current and having a DC side connected to a DC output side of said first converter;

a capacitor connected between said first and second converters;

a circuit breaker connected between an AC side of said second converter and an electric power system;

generator-speed control means that controls said first converter;

DC voltage control means that controls a DC-side voltage of said second converter; and

combustion turbine control means that controls said combustion turbine;

a position detector connected to a rotation axis of said permanent-magnet type AC power generator;

wherein said combustion turbine control means obtains a state quantity of said combustion turbine and supplies an optimum number of revolution command value of said permanent-magnet type AC power generator obtained from said state quantity to said generator-speed control means; and

wherein said generator-speed control means controls said first converter on the basis of said optimum number of revolution command value, a detected value of an output signal from said position detector and an output voltage command value of said first converter, so that a number of revolutions of said permanent-magnet type AC power generator is controlled.

5. A control method of a combustion turbine power generating system including a permanent-magnet type AC power generator, a combustion turbine that drives the permanent-magnet type AC power generator, a first converter that enables conversion between AC current and DC current and having an AC side connected to a stator of the permanent-magnet type AC power generator, a second converter that enables conversion between AC current and DC current and having a DC side connected to a DC side of the first converter, a capacitor connected between the first and second converters, a circuit breaker connected between an AC side of the second converter and an electric power system, generator-speed control means that controls the first converter, a position detector connected to a rotation axis of the permanent-magnet type AC power generator, DC voltage control means that controls a DC-side voltage of the second converter, and combustion turbine control means that controls said combustion turbine, comprising the steps of;

obtaining a state quantity of the combustion turbine by the combustion turbine control means and supplying an optimum number of a revolution command value of the permanent-magnet type AC power generator obtained from the state quantity to the generator-speed control means; and

controlling by the generator-speed control means the first converter on the basis of the optimum number of the revolution command value, an output signal from the position detector and an output voltage command value of the first converter so as to control a number of revolutions of the permanent-magnet type AC power generator.

6. A control method according to claim **5**, wherein the generator-speed control means changes the optimum number of the revolution command value so as to change the number of revolutions of the permanent-magnet type AC power generator when an output signal of the position detector exceeds a predetermined value.

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