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(54) **GAS TURBINE LOWER HEATING VALUE METHODS AND SYSTEMS**

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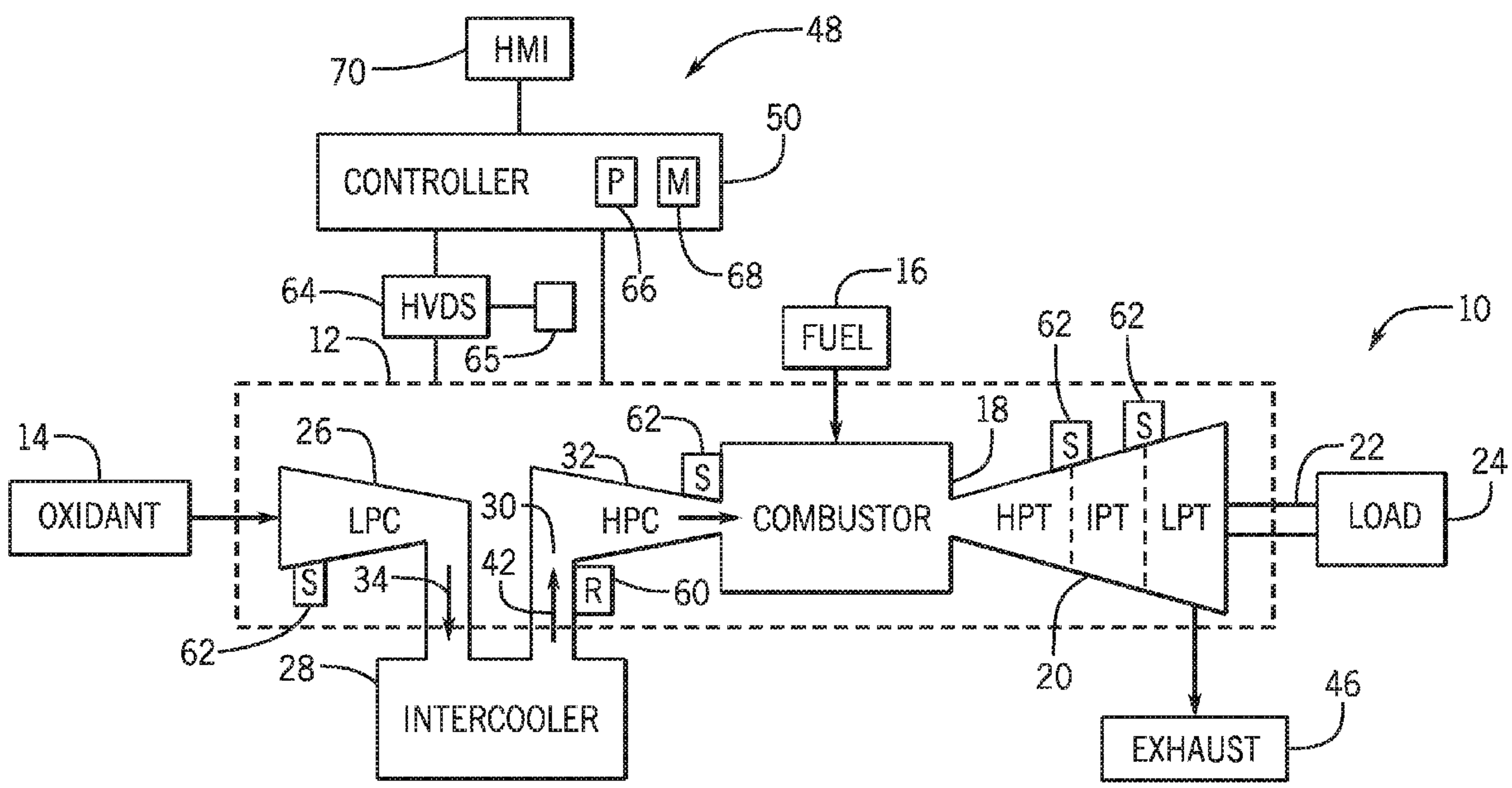
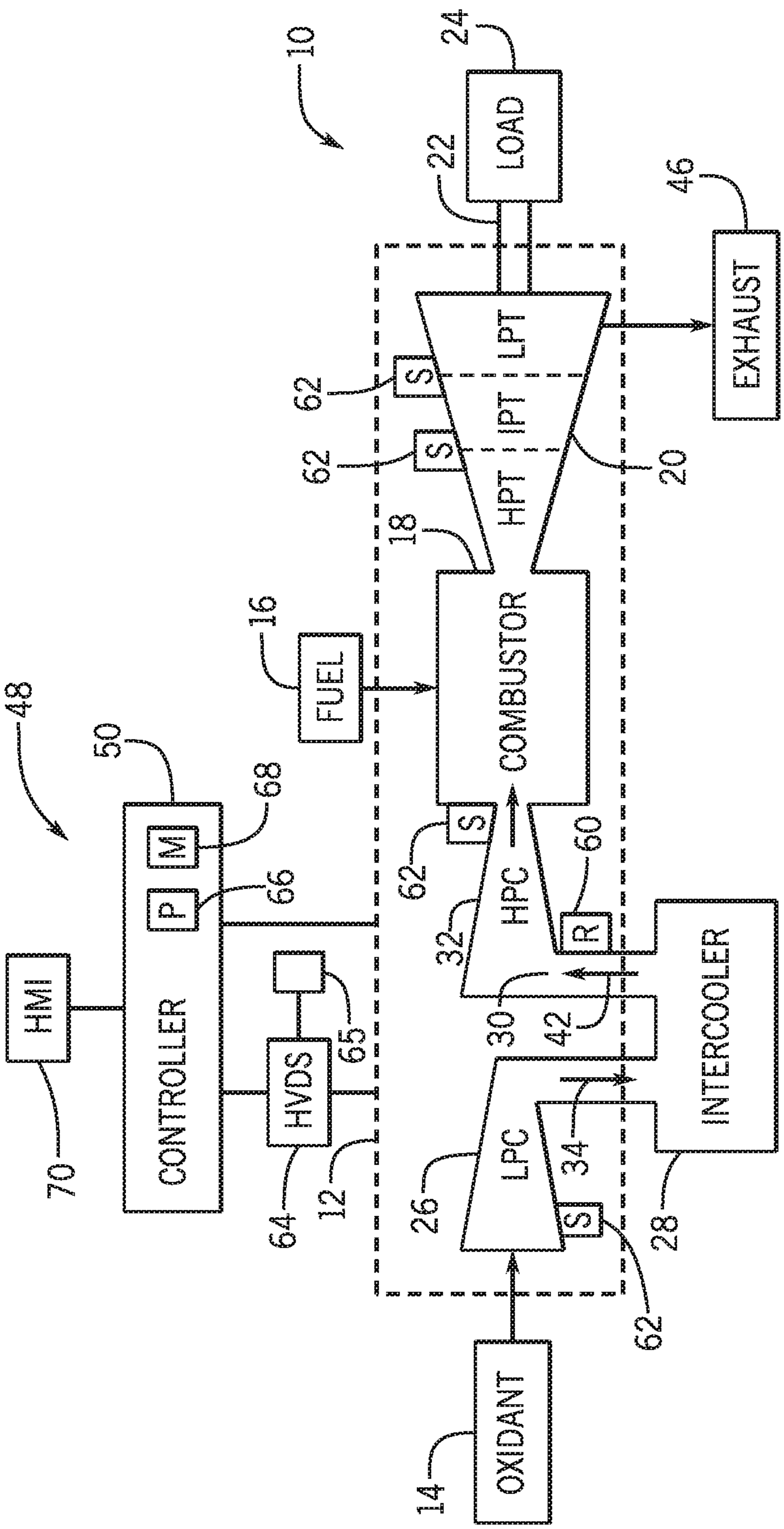
(57) **ABSTRACT**

A control system for a gas turbine includes a controller. The controller includes a processor configured to receive a plurality of signals comprising a temperature signal, a pressure signal, a speed signal, a mass flow signal, or a combination thereof, from sensors disposed in the gas turbine system. The processor is further configured to apply the plurality of signals as input to a heating value model. The processor is also configured to execute the heating value model to derive a heating value for a fuel combusted by the gas turbine system. The processor is additionally configured to control operations of the gas turbine system based on the heating value for the fuel.





10
LOAD
24
22
EXHAUST
46
LPT
IPT
HPT
S
S
62
62
20
18
16
FUEL
COMBUSTOR
48
50
M
68
P
66
S
62
60
HPC
R
32
HMI
CONTROLLER
HVDS
65
30
42
INTERCOOLER
LPC
34
S
70
64
12
26
28
62
OXIDANT
14


FIG. 1

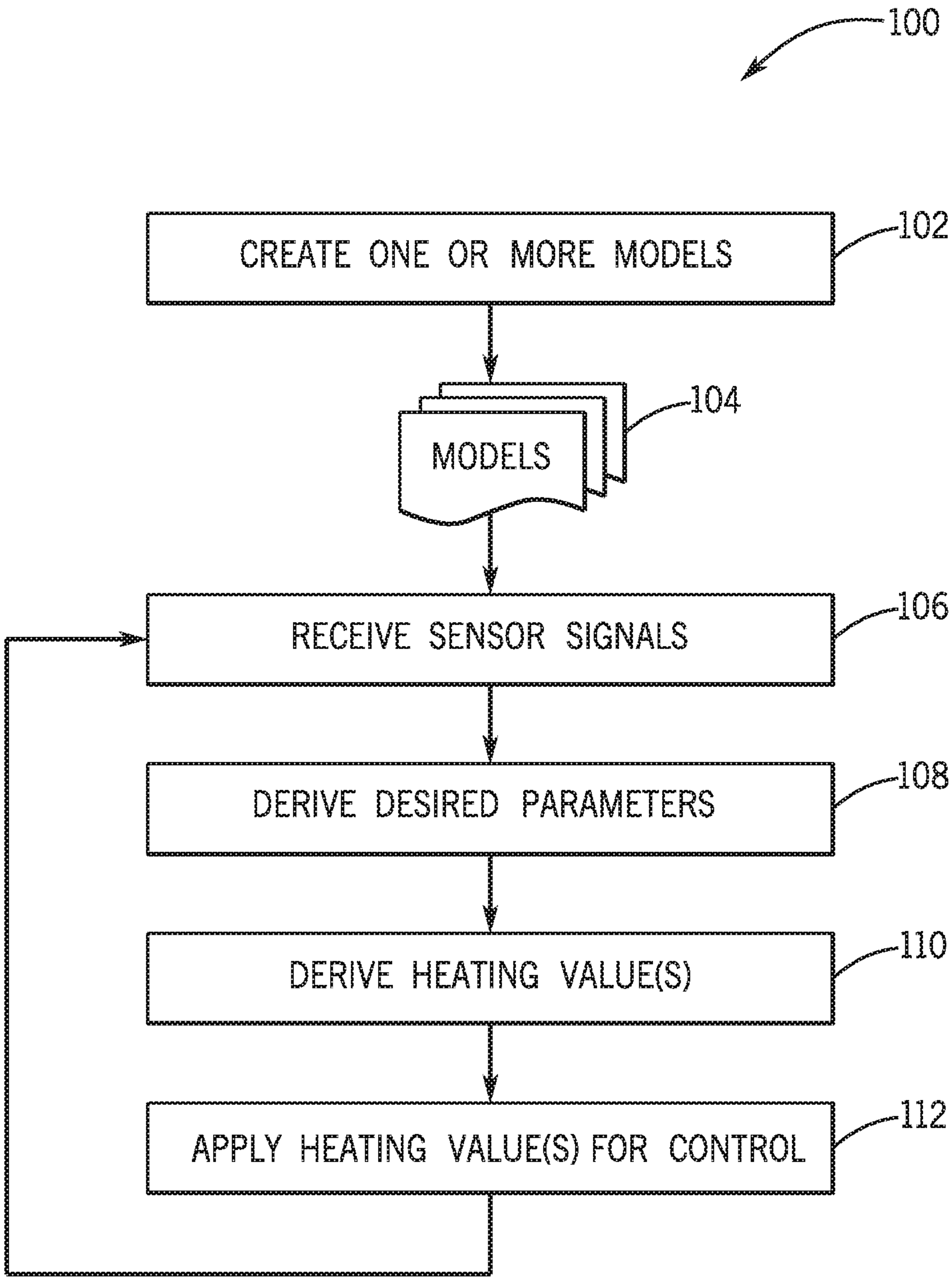

100
CREATE ONE OR MORE MODELS
102
MODELS
104
RECEIVE SENSOR SIGNALS
106
DERIVE DESIRED PARAMETERS
108
DERIVE HEATING VALUE(S)
110
APPLY HEATING VALUE(S) FOR CONTROL
112

FIG. 2

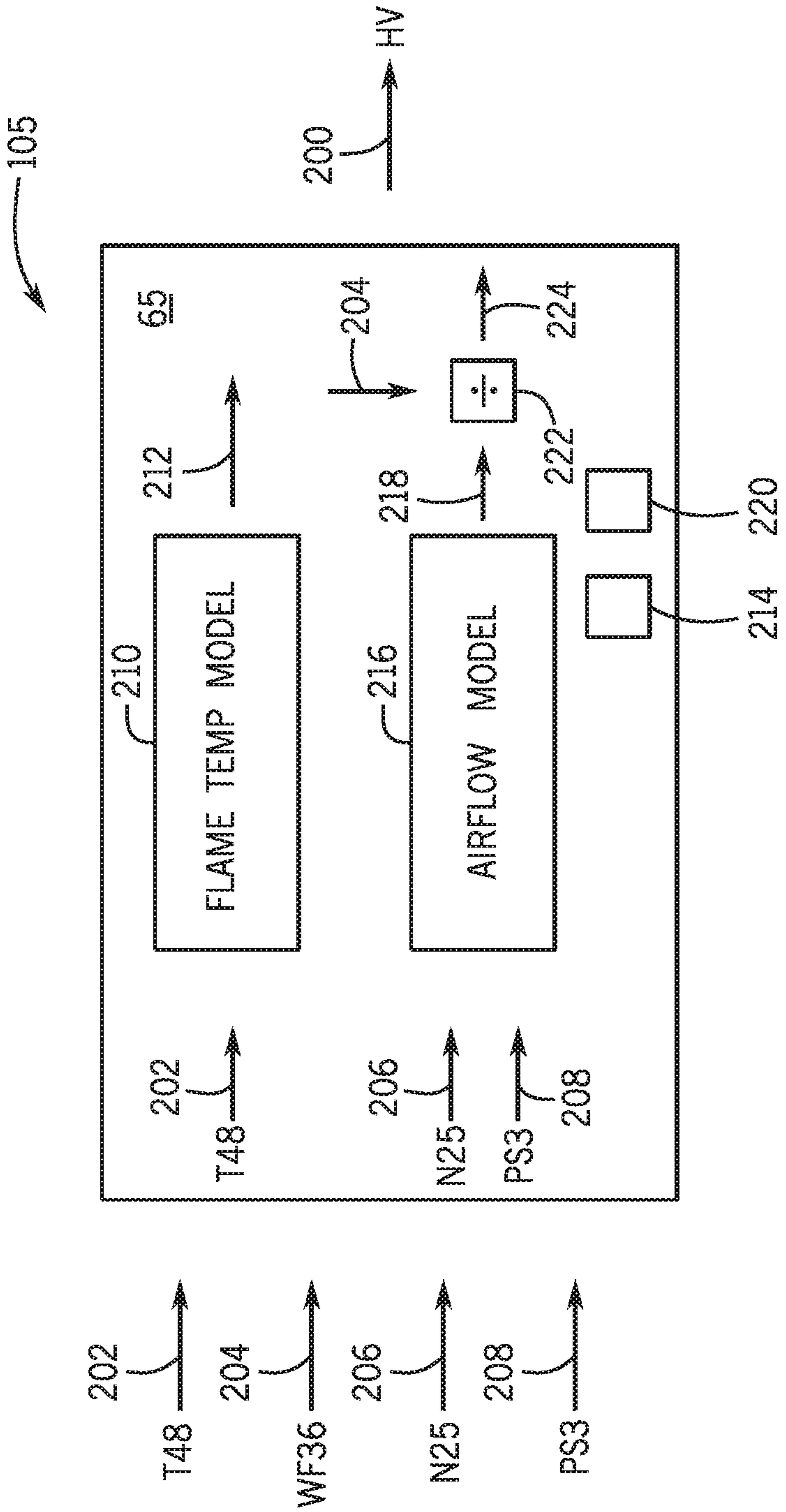

105
65
200
HV
FLAME TEMP MODEL
210
AIRFLOW MODEL
216
212
218
204
222
224
220
214
T48
202
WF36
204
N25
206
PS3
208

FIG. 3

# GAS TURBINE LOWER HEATING VALUE METHODS AND SYSTEMS

## BACKGROUND

**[0001]** The subject matter disclosed herein relates to gas turbines, and more particularly, to lower heating value methods and systems.

**[0002]** A gas turbine engine combusts a mixture of fuel and air to generate hot combustion gases, which in turn drive one or more turbines. In particular, the hot combustion gases force turbine blades to rotate, thereby driving a shaft to rotate one or more loads, e.g., electrical generator. The fuel used in combustion may be a carbonaceous fuel, such as diesel, natural gas, syngas, biogas, and the like. Accordingly, the fuel may have a variation in heating values. Lower heating value fuels may contain higher levels of inert compounds, thus leading to challenges in combustion. There is a desire, therefore, for a methods and systems that provide for more effective use of lower heating value fuels.

## BRIEF DESCRIPTION

**[0003]** Certain embodiments commensurate in scope with the originally claimed disclosure are summarized below. These embodiments are not intended to limit the scope of the claimed disclosure, but rather these embodiments are intended only to provide a brief summary of possible forms of the disclosure. Indeed, the disclosure may encompass a variety of forms that may be similar to or different from the embodiments set forth below.

**[0004]** In a first embodiment, a system includes a control system for a gas turbine including a controller having a processor. The processor is configured to receive a plurality of signals comprising a temperature signal, a pressure signal, a speed signal, a mass flow signal, or a combination thereof, from sensors disposed in the gas turbine system. The processor is further configured to apply the plurality of signals as input to a heating value model. The processor is also configured to execute the heating value model to derive a heating value for a fuel combusted by the gas turbine system. The processor is additionally configured to control operations of the gas turbine system based on the heating value for the fuel.

**[0005]** A second embodiment includes a non-transitory computer-readable medium having computer executable code stored thereon, the code having instructions to receive a plurality of signals comprising a temperature signal, a pressure signal, a speed signal, a mass flow signal, or a combination thereof, from sensors disposed in the gas turbine system. The instructions are further configured to apply the plurality of signals as input to a heating value model. The instructions are also configured to execute the heating value model to derive a heating value for a fuel combusted by the gas turbine system. The instructions are additionally configured to control operations of the gas turbine system based on the heating value for the fuel.

**[0006]** In a third embodiment, a method for a gas turbine system includes receiving a plurality of signals comprising a temperature signal, a pressure signal, a speed signal, a mass flow signal, or a combination thereof, from sensors disposed in the gas turbine system. The method also includes applying the plurality of signals as input to a heating value model. The method further includes executing the heating value model to derive a heating value for a fuel combusted by the gas turbine system. The method additionally includes controlling operations of the gas turbine system based on the heating value for the fuel.

## BRIEF DESCRIPTION OF THE DRAWINGS

**[0007]** These and other features, aspects, and advantages of the present disclosure will become better understood when the following detailed description is read with reference to the accompanying drawings in which like characters represent like parts throughout the drawings, wherein:

**[0008]** FIG. **1** is a schematic diagram of an embodiment of a power generation system having a low heating value derivation system;

**[0009]** FIG. **2** is a flowchart of a process suitable for deriving certain heating values; and

**[0010]** FIG. **3** is a block diagram illustrating certain information flows into and heating value model.

## DETAILED DESCRIPTION

**[0011]** One or more specific embodiments of the present disclosure will be described below. In an effort to provide a concise description of these embodiments, all features of an actual implementation may not be described in the specification. It should be appreciated that in the development of any such actual implementation, as in any engineering or design project, numerous implementation-specific decisions must be made to achieve the developers' specific goals, such as compliance with system-related and business-related constraints, which may vary from one implementation to another. Moreover, it should be appreciated that such a development effort might be complex and time consuming, but would nevertheless be a routine undertaking of design, fabrication, and manufacture for those of ordinary skill having the benefit of this disclosure.

**[0012]** When introducing elements of various embodiments of the present disclosure, the articles "a," "an," "the," and "said" are intended to mean that there are one or more of the elements. The terms "comprising," "including," and "having" are intended to be inclusive and mean that there may be additional elements other than the listed elements.

**[0013]** The present disclosure is directed towards a system and method to derive heating values of, for example, fuel delivered to a gas turbine system, and then apply the derived heating values to improve control of the gas turbine system. In certain embodiments, a gas turbine controller may include a heating value derivation system (HVDS) suitable for receiving certain inputs, such as temperature, pressure, speed (e.g., revolutions per minute [RPM]), clearances (e.g., distance between a moving and a stationary component), flows, mass flows, and the like, to derive, for example, a heating value of fuel used for combustion by the gas turbine. In one embodiment, a heating value model, such as a low heating value (LHV) model, may be used by the HVDS to model certain turbine parameters and to derive a heating value for low heating value fuels, as described in more detail below. The derivations provided by the LHV model may then be used, for example by the controller, to derive certain control actions suitable for improving efficiency, power production, and/or lowering emissions of the gas turbine system.

**[0014]** Turning to the figures, FIG. **1** is a schematic diagram of an embodiment of a power generation system **10** that includes a gas turbine system **12**. The gas turbine system

**12** may receive an oxidant **14** (e.g., air, oxygen, oxygen-enriched air, or oxygen-reduced air) and a fuel **16** (e.g., gaseous or liquid fuel), such as natural gas, syngas, or petroleum distillates. The oxidant **14** may be pressurized and combined with the fuel **16** to be combusted in a combustor **18**. The combusted oxidant may then be used to apply forces to blades of a turbine **20** to rotate a shaft **22** that provides power to a load **24** (e.g., electric generator). In one embodiment, the power generation system **10** may be a dry low emission (DLE) that includes the gas turbine **12** suitable for reducing nitrogen oxide (NOx) emissions, for example, by combusting the fuel **16** at lower temperatures. In DLE embodiments, the gas turbine **16** may use a lean premixed combustion as opposed to water or steam to reduce combustion temperature. Accordingly, power generation may occur with less fuel and oxidant (e.g., air), resulting in lower temperatures and lower NOx emissions.

**[0015]** The gas turbine system **12** may include one or more compressors that increase the pressure of the oxidant **14**. As depicted in FIG. **1**, the gas turbine system **12** includes a lower pressure compressor (LPC) **26** connected to an intercooler **28** to couple the lower pressure compressor **26** to an inlet **30** of a high pressure compressor (HPC) **32**. The oxidant **14** enters the low pressure compressor **26** and is compressed into a compressed oxidant **34** (e.g., gas, liquid, or both). The compressed oxidant **34** may include a compressed gas (e.g., air, oxygen, oxygen-enriched air, or oxygen-reduced air), a lubricant (e.g., oil), a coolant fluid, or any combination thereof. In certain embodiments, the compressed oxidant **34** may include gas from exhaust gas recirculation (EGR). The compressed oxidant **34** then enters the intercooler **28**. It is to be noted that, in some embodiments of the system **10**, no intercooler **28** is used.

**[0016]** The intercooler **28** may be any intercooler **28** suitable for cooling the compressed oxidant **34**, such as a spray intercooler (SPRINT) or an efficient spray intercooler (ESPRINT). The intercooler **28** may cool the compressed oxidant **34** by using a fluid to increase the efficiency of the gas turbine system **12**. The compressed and cooled oxidant **42** is further compressed in the high pressure compressor **32** and combined with the fuel **16** into an oxidant-fuel mixture to be combusted in the combustor **18**. As the oxidant-fuel mixture is combusted (e.g., burned and/or ignited), the oxidant-fuel mixture expands through one or more turbines **20**. For example, embodiments may include a high pressure turbine (HPT), intermediate pressure turbine (IPT), and a low pressure turbine (LPT) as depicted in FIG. **1**. In some embodiments, the system **10** may include HPT and LPT turbines. In other embodiments, there may be a single turbine, four, five, or more turbines.

**[0017]** The turbine **20** may be coupled to a shaft **22** that is coupled to one or more loads **24**. The turbine **20** may include one or more turbine blades that rotate causing the shaft **22** to provide rotational energy to the load **24**. For example, the load **24** may include an electrical generator or a mechanical device in an industrial facility or power plant. The rotational energy of the shaft **22** may be used by the load **24** to generate electrical power. As the gas turbine system **12** generates power, the combusted oxidant-fuel mixture is expelled as an exhaust **46**. The exhaust **46** may include one or more emissions, such as nitrogen oxides (NOx), hydrocarbons (HC), carbon monoxide (CO) and/or other pollutants. The exhaust **46** may be treated in a variety of ways, such as with a catalyst system.

**[0018]** The power generation system **10** may also include a control system **48** to monitor and/or control various aspects of the gas turbine system **12**, the load **24**, and/or the intercooler **28**. The control system **48** may include a controller **50** having inputs and/or outputs to receive and/or transmit signals to one or more actuators **60**, sensors **62**, or other controls to control the gas turbine system **12** and/or the intercooler **28**. While some examples are illustrated in FIG. **1** and described below, these are merely examples and any suitable sensors and/or signals may be positioned on the gas turbine system **12**, the load **24**, and/or the intercooler **28** to detect operational parameters to control the power generation system **10** with the controller **50**. For example, the controller **50** may send and/or receive a signal from one or more actuators **60** and sensors **62** to control any number of aspects of the system **10**, including fuel supply, speed, oxidant delivery, power production, and so forth. For example, actuators **60** may include valves, positioners, pumps, and the like. The sensors **62** may sense temperature, pressure, speed, clearances (e.g., distance between a stationary and a moving component), flows, mass flows, and the like.

**[0019]** Further, the controller **50** may include and/or communicate with a heating value derivation system **64**. The heating value derivation system **64** may calculate a heating value of the fuel **16** being used, for example, during power production. The heating value derivation system **64** may be used as an alternative to or in addition to certain systems, such as gas chromatographs and/or Wobbe meters. For example, when used as an alternative to gas chromatographs and/or Wobbe meters, the heating value derivation system **64** may provide for faster derivations of heating values useful in real-time control of the power production system **10**. When used in addition to gas chromatographs and/or Wobbe meters, the heating value derivation system **64** may provide for additional system robustness and increased accuracy. For example, redundancy may be provided by having an additional source of heating values such as the system **64**, and checks may be carried out by the system **64** to insure the accuracy of the gas chromatographs and/or Wobbe meters.

**[0020]** The heating value derivation system **64** may additionally execute a low heating value (LHV) model **65** suitable for determining low heating values of certain fuels **16**. For example, the DLE gas turbine **12** may combust certain fuels **16** having lower heating values, such as fuels having Wobbe numbers in a range between **30-60**. Indeed, the heating value derivation system **64** may apply the model **65** to derive the heating values of a variety of fuels **16**, including lower heating values fuel **16**, during operation of the gas turbine **12**. Thus, the control system **48** may be suitable for controlling gas turbine **12** operations with a variety of fuels **16**, including lower heating value fuels **16**, thus providing for enhanced fuel flexibility. It is to be understood that the heating value derivation system **64** may be a software and/or hardware component of the controller **50**, or may be a standalone system. For example, a computing device separate from the controller **50** may host the heating value derivation system **64**.

**[0021]** The controller **50** may include a processor **66** or multiple processors, memory **68**, and inputs and/or outputs to send and/or receive signals from the one or more sensors **62** and/or actuators **60**. The processor **66** may be operatively coupled to the memory **68** to execute instructions for carrying out the presently disclosed techniques. These instructions may be encoded in programs or code stored in a tangible non-transitory computer-readable medium, such as the memory **68** and/or other storage. The processor **66** may be a general purpose processor, system-on-chip (SoC) device, or application-specific integrated circuit, or some other processor configuration. For example, the processor **66** may be part of an engine control unit that controls various aspects of the turbine system **12**.

**[0022]** Memory **68** may include a computer readable medium, such as, without limitation, a hard disk drive, a solid state drive, a diskette, a flash drive, a compact disc, a digital video disc, random access memory (RAM), and/or any suitable storage device that enables processor **66** to store, retrieve, and/or execute instructions and/or data. Memory **68** may further include one or more local and/or remote storage devices. Further, the controller **50** may be operably connected to a human machine interface (HMI) **70** to allow an operator to read measurements, perform analysis, and/or adjust set points of operation. In one embodiment, the controller **50** may include a triple modular redundant (TMR) controller having three cores, R, S, T, such that each core votes on control actions. By voting, the controller **50** may provide for increased redundancy of control operations.

**[0023]** Turning now to FIG. **2**, the figure illustrates and example of a process **100** suitable for deriving certain heating values of the fuel **16** and for controlling operations of the power generation system **10** based on the derived heating values. The process **100** may be implemented as computer code or instructions executable by the processor **66** and stored in memory **68**. In the depicted embodiment, the process **100** create (block **102**) certain models **104**, such as heating values models that include the low heating value model **65**. For example, the LHV model **65** may be created by combining one or more of the submodels **104**. In one embodiment, the LHV model **65** may include the following equation:

$$LHV=(HFL*(WAR36+FAR+1.0)-H3/FAR)-C \quad \text{Equation (1):}$$

**[0024]** In one embodiment, the constant C may be, for example, 283.575. HFL may include an enthalpy value of fuel, for example, derived by using an enthalpy lookup table. Likewise, H3 is an enthalpy value that may be derived by using an enthalpy lookup table. WAR36 is a value representative of mass air flow into the combustor **18**, which may be calculated by air flow sensor(s) **62** disposed in a compressor manifold. Fuel-air-ratio (FAR) may be derived based on the equation:

$$FAR=(WF36DMD/3600)/WA4Model. \quad \text{Equation (2):}$$

**[0025]** WF36DMD represents a current fuel **16** and/or oxidant (e.g., air) demand. WA4Model is a model that derives an expected air flow at the combustor **18**. In one embodiment, the WA4Model derives the expected air flow at the combustor **18** by using an airflow lookup table. PS3 is pressure at exhaust of the HPC **32**. N25 is speed of the HPC **32** (e.g., in revolutions per minute [RPM]). T48 is temperature at an inlet of the low pressure turbine (LPT). A temperature lookup table maps T48 to combustor temperature TFLAME. Using another table you can map TFLAME to enthalpy.

**[0026]** The process **100** may receive (block **106**) signals or data from the sensors **62** representative of pressures, temperatures, flows, mass flows, and the like. The process **100** may then derive (block **108**) certain desired parameters, such as HFL, WF36, FAR, and H3. The process **100** may then use the derived parameter to derive (block **110**) a heating value or values, such as by using the LHV equation above. In embodiments without the gas chromatographs and Wobbe meters, the LHV may be used as further described below, for control of the power generation system **10**. In power generation system **10** embodiments that include systems such as gas chromatographs and/or Wobbe meters, the process **100** may derive multiple heating values, for example, one based on the LHV equation above, one based on the gas chromatographs, and one based on the Wobbe meter. The multiple heating values may then be compared to each other, and/or averaged to provide for redundant operations.

**[0027]** The process **100** may then apply (block **112**) the heating values derived in block **110**, for example, to control operations of the power generation system **10**. For example, based on the derived LHV, the fuel **16** flow may be increased or decreased to maintain a desired combustion temperature. For example, fuels with a lower LHV may be combusted at a higher fuel flow when compared to fuels with a higher LHV. By deriving the fuel's heating value, an improved combustion may be produced, resulting in lower NOx emissions.

**[0028]** Turning now to FIG. **3**, the figure is a block diagram illustrating certain information flows into the models **104**. The models **104** may use the information flow to derive heating values **200** for the fuel **16**. In the depicted embodiment, input parameters **202**, **204**, **206**, and **208** representative of temperature (e.g., T48), fuel flow (e.g., WF36) at combustor **18**, speed (e.g., N25), and pressure (e.g., PS3) may be provided to the models **104**. In the depicted embodiment, a flame temperature model **210** may be used to derive a combustor **18** flame temperature **212**. In one embodiment, a temperature lookup table **214** may be used to map the temperature parameter **202** (e.g., T48) to the combustor **18** flame temperature **212**. In other embodiments, a physics-based model suitable for modeling the combustor **18**, for example, via thermodynamic techniques, may be used as an alternative or additional to the table **214** to derive the combustor **18** flame temperature **212**.

**[0029]** The models **104** may additionally include an airflow model **216** suitable for converting speed **206** (e.g., N25) and pressure **208** (e.g., PS3) into an expected combustor **18** airflow **218**. In one embodiment, the airflow model **216** may apply an airflow lookup table **220** to map both the speed **206** and the pressure **208** to the expected airflow **218**. In other embodiments, a physics-based model suitable for modeling the combustor **18**, for example, via thermodynamic techniques, may be used as an alternative or additional to the table **220** to derive the combustor **18** airflow **218**.

**[0030]** In the depicted embodiment, the model **65** may then derive a difference (e.g., percent difference) between the expected airflow **218** and the measured airflow **204**, for example, via a division block **222**. An adjusted fuel-air-ratio (FAR) **224** may thus be derived. The model **65** may then apply the adjusted fuel-air-ratio **224** and the combustor **18** flame temperature **212** to derive the heating value **200** (e.g., LHV). In one embodiment, Equations 1 and 2 above described with respect to FIG. **2** may be may be used to derive the heating value **200**. More specifically, FAR of Equation (1) may be equivalent to the fuel-air-ratio **224**, WA4Model may be equivalent to the airflow **218**, and the enthalpies HFL and H3 may be calculated by using the flame temperature **212**. Accordingly, the LHV **200**, in this embodiment, may be derived.

**[0031]** Technical effects of the present embodiments may include executing a control for a gas turbine combusting a low heating value fuel by using a low heating value model in lieu of or as alternative to using a heating value sensor such as a Wobbe meter or a gas chromatograph. The low heating value model may take as input certain gas turbine properties such as temperature, mass flow, speed, and/or pressure, and provide for a derivation of a heating value of a low heating value fuel. The model may execute in real-time, thus improving control and efficiency for the gas turbine.

**[0032]** This written description uses examples to disclose the embodiments, including the best mode, and also to enable any person skilled in the art to practice the embodiments, including making and using any devices or systems and performing any incorporated methods. The patentable scope of the present disclosure is defined by the claims, and may include other examples that occur to those skilled in the art. Such other examples are intended to be within the scope of the claims if they have structural elements that do not differ from the literal language of the claims, or if they include equivalent structural elements with insubstantial differences from the literal language of the claims.

**1**. A control system for a gas turbine system, comprising:
a controller comprising a processor, wherein the processor is configured to:
receive a plurality of signals comprising a temperature signal, a pressure signal, a speed signal, a mass flow signal, or a combination thereof, from sensors disposed in the gas turbine system;
apply the plurality of signals as input to a heating value model;
execute the heating value model to derive a heating value for a fuel combusted by the gas turbine system;
control operations of the gas turbine system based on the heating value for the fuel.

**2**. The control system of claim **1**, wherein the heating value model comprises a Lower Heating Value (LHV) model configured to derive the heating value for the fuel in a range of between 30 to 60 Wobbe numbers.

**3**. The control system of claim **2**, wherein the LHV model comprises LHV=(HFL*(WAR36+FAR+1.0)−H3/FAR)−C, wherein HFL comprises a first enthalpy, FAR comprises a fuel-to-air ratio, H3 comprises a second enthalpy, and C comprises a constant.

**4**. The control system of claim **3**, wherein the LHV model comprises a flame temperature model configured to derive a combustion flame temperature, and wherein the LHV model is configured to use a first lookup table and the combustion flame temperature to derive HFL and a second lookup table and the combustion flame temperature to derive H3.

**5**. The control system of claim **2**, wherein FAR is derived via FAR=(WF36DMD/3600)/WA4Model, wherein WF36DMD comprises a current demand for fuel, for air, or for a combination thereof, and wherein WA4Model comprises an airflow model configured to receive the speed signal and the pressure signal to derive an expected airflow.

**6**. The control system of claim **1**, wherein the fuel comprises a LHV fuel and wherein the controller is configured to control operations of the gas turbine system by comparing the heating value to a heating value range, and by increasing fuel flow when the heating value is below the range, and by decreasing fuel flow when the heating value is above the range.

**7**. The control system of claim **1**, wherein the plurality of signals comprises a fuel heating value signal derived via a gas chromatograph or a Wobbe meter, and wherein the heating value is compared to a second heating value derived from the fuel heating value signal to provide for redundant operations.

**8**. The control system of claim **1**, wherein the gas turbine comprises a spray intercooler (SPRINT) or an efficient spay intercooler (ESPRINT) configured to cool a compressed oxidant using a fluid, and wherein the controller is configured to control the SPRINT or the ESPRINT.

**9**. A non-transitory computer-readable medium having computer executable code stored thereon, the code comprising instructions to:
receive a plurality of signals comprising a temperature signal, a pressure signal, a speed signal, a mass flow signal, or a combination thereof, from sensors disposed in the gas turbine system;
apply the plurality of signals as input to a heating value model;
execute the heating value model to derive a heating value for a fuel combusted by the gas turbine system;
control operations of the gas turbine system based on the heating value for the fuel.

**10**. The non-transitory computer-readable medium of claim **9**, wherein the heating value model comprises a Lower Heating Value (LHV) model configured to derive the heating value for the fuel in a range of between 30 to 60 Wobbe numbers.

**11**. The non-transitory computer-readable medium of claim **10**, wherein the LHV model comprises LHV=(HFL*(WAR36+FAR+1.0)−H3/FAR)−C, wherein HFL comprises a first enthalpy, FAR comprises a fuel-to-air ratio, H3 comprises a second enthalpy, and C comprises a constant.

**12**. The non-transitory computer-readable medium of claim **11**, wherein the LHV model comprises a flame temperature model configured to derive a combustion flame temperature, and wherein the LHV model is configured to use a first lookup table and the combustion flame temperature to derive HFL and a second lookup table and the combustion flame temperature to derive H3.

**13**. The non-transitory computer-readable medium of claim **11**, wherein FAR is derived via FAR=(WF36DMD/3600)/WA4Model, wherein WF36DMD comprises a current demand for fuel, for air, or for a combination thereof, and wherein WA4Model comprises an airflow model configured to receive the speed signal and the pressure signal to derive an expected airflow.

**14**. The non-transitory computer-readable medium of claim **9**, wherein the fuel comprises a LHV fuel and wherein the controller is configured to control operations of the gas turbine system by comparing the heating value to a heating value range, and by increasing fuel flow when the heating value is below the range, and by decreasing fuel flow when the heating value is above the range.

**15**. The non-transitory computer-readable medium of claim **9**, wherein the plurality of signals comprises a fuel heating value signal derived via a gas chromatograph or a Wobbe meter, and wherein the heating value is compared to a second heating value derived from the fuel heating value signal to provide for redundant operations.

**16**. A method for a gas turbine system, comprising:

receiving a plurality of signals comprising a temperature signal, a pressure signal, a speed signal, a mass flow signal, or a combination thereof, from sensors disposed in the gas turbine system;

applying the plurality of signals as input to a heating value model;

executing the heating value model to derive a heating value for a fuel combusted by the gas turbine system;

controlling operations of the gas turbine system based on the heating value for the fuel.

**17**. The method of claim **16**, wherein the heating value model comprises a Lower Heating Value (LHV) model configured to derive the heating value for the fuel in a range of between 30 to 60 Wobbe numbers.

**18**. The method of claim **17**, wherein the LHV model comprises LHV=(HFL*(WAR36+FAR+1.0)−H3/FAR)−C, wherein HFL comprises a first enthalpy, FAR comprises a fuel-to-air ratio, H3 comprises a second enthalpy, and C comprises a constant.

**19**. The method of claim **18**, wherein the LHV model comprises a flame temperature model configured to derive a combustion flame temperature, and wherein the LHV model is configured to use a first lookup table and the combustion flame temperature to derive HFL and a second lookup table and the combustion flame temperature to derive H3.

**20**. The method of claim **18**, wherein FAR is derived via FAR=(WF36DMD/3600)/WA4Model, wherein WF36DMD comprises a current demand for fuel, for air, or for a combination thereof, and wherein WA4Model comprises an airflow model configured to receive the speed signal and the pressure signal to derive an expected airflow.

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