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(54) **METHOD AND SYSTEM FOR RUB DETECTION IN A STEAM TURBINE**

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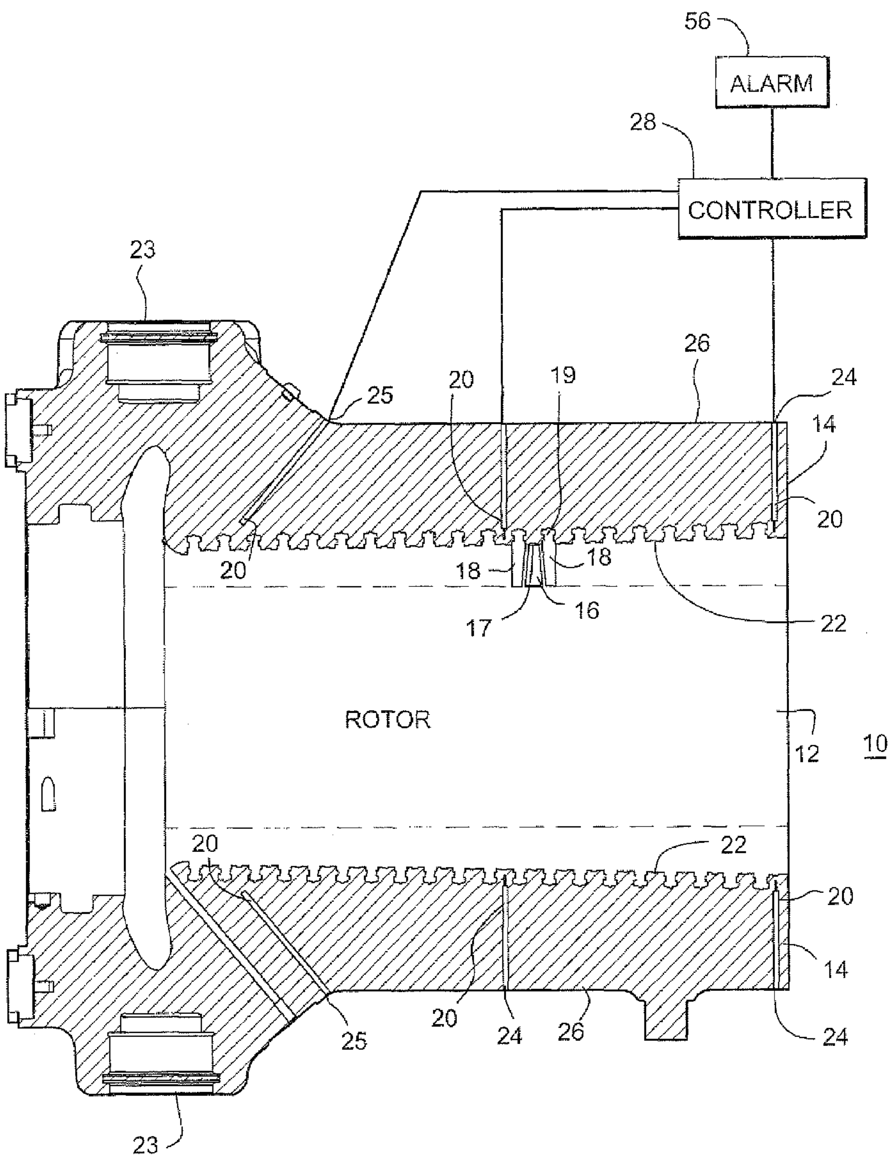
(57) **ABSTRACT**

A method for detecting rubbing between components in a steam turbine, the method includes: sensing a temperature at a plurality of locations on a casing of the steam turbine; comparing the sensed temperatures of the plurality of locations; detecting the rubbing between the components if one of the plurality of locations has a higher sensed temperature than the sensed temperature at the other plurality of locations, and reporting the rub as being at a location near the one of the plurality of locations having the higher sensed temperature.



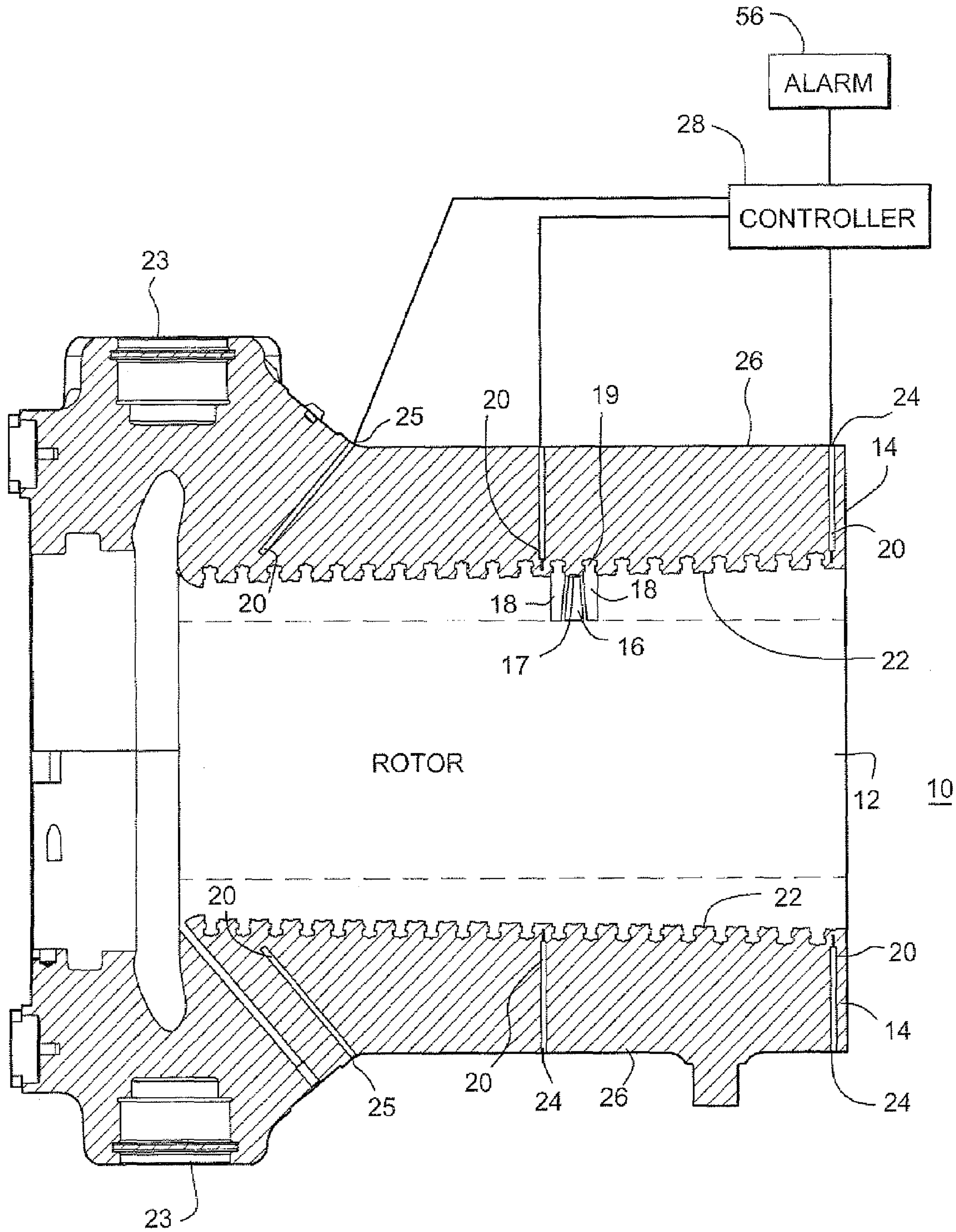

56
ALARM
28
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FIG. 1

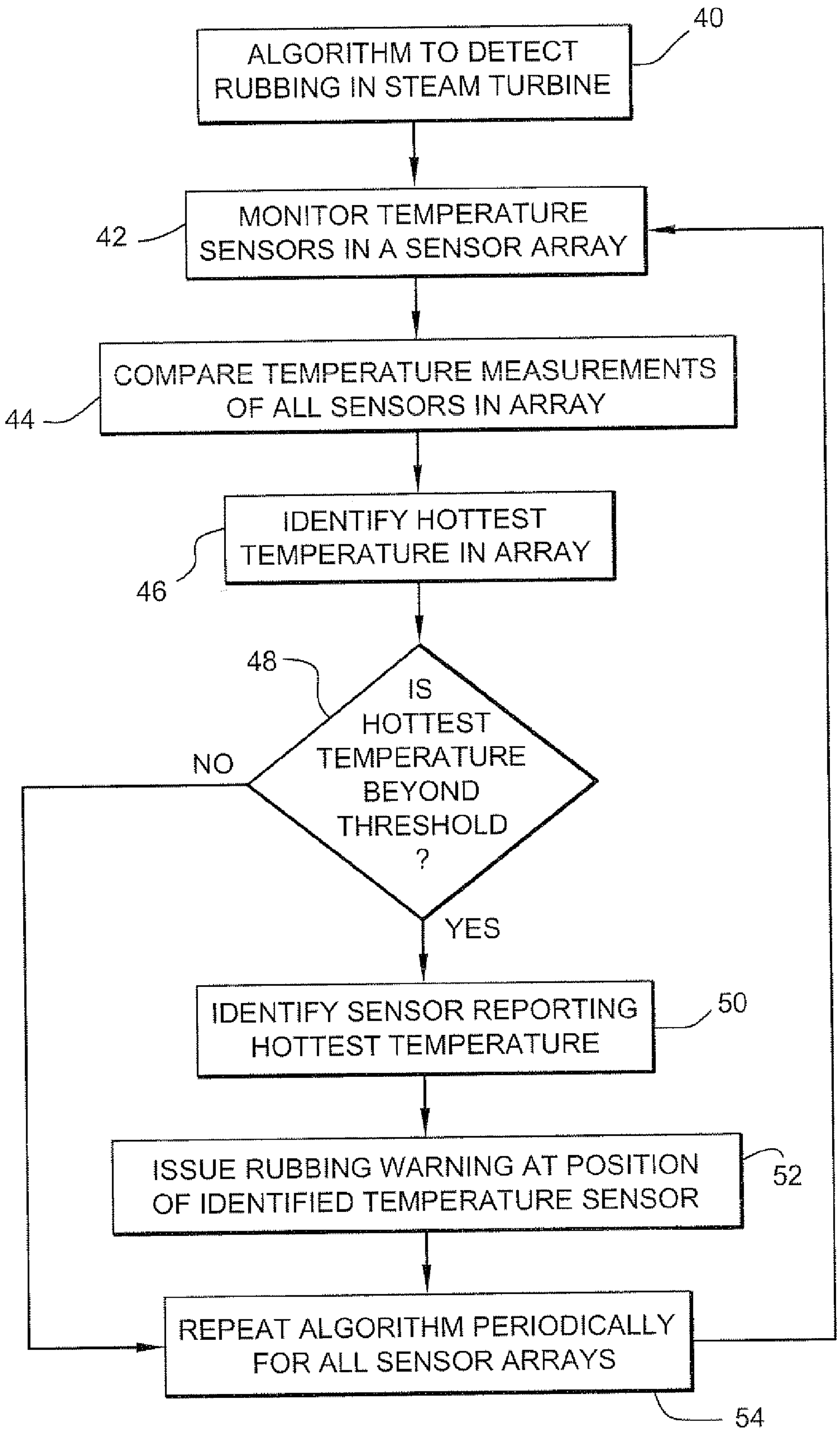
40
ALGORITHM TO DETECT RUBBING IN STEAM TURBINE
42
MONITOR TEMPERATURE SENSORS IN A SENSOR ARRAY
44
COMPARE TEMPERATURE MEASUREMENTS OF ALL SENSORS IN ARRAY
46
IDENTIFY HOTTEST TEMPERATURE IN ARRAY
48
IS HOTTEST TEMPERATURE BEYOND THRESHOLD ?
NO
YES
50
IDENTIFY SENSOR REPORTING HOTTEST TEMPERATURE
52
ISSUE RUBBING WARNING AT POSITION OF IDENTIFIED TEMPERATURE SENSOR
54
REPEAT ALGORITHM PERIODICALLY FOR ALL SENSOR ARRAYS

FIG. 2

METHOD AND SYSTEM FOR RUB DETECTION IN A STEAM TURBINE

BACKGROUND OF THE INVENTION

[0001] The present invention relates to instruments for monitoring steam turbines. In particular, the invention relates to detecting rubbing between rotating and stationary components in a steam turbine.

[0002] Steam turbines include a rotor with rows of turbine blades (buckets) that rotate between rows of stator blades (nozzles). The tips of the turbine buckets are adjacent an inside surface of the casing for the turbine. During normal operation, the turbine buckets do not rub against the casing. A slight deformity in the turbine casing, rotor shaft, inner casing or other component can cause the turbine blades to rub against a stationary casing of the turbine. The rub is typically at one rotational position, such as when the turbine tip passes through a top position on the casing.

[0003] A rub between a turbine bucket and a stationary component in a steam turbine can damage the turbine components. The clearances between the turbine buckets and stator casing may increase due to rubbing. The increased clearances, change the flow paths through the turbine and thereby reduce the efficiency of the turbine.

[0004] Severe rubbing may cause turbine buckets to fail, break off and damage downstream blades. Rubbing in a steam turbine is not easily detected. The wear resulting from rubbing is often first detected by visually inspecting the turbine components. To visually inspect components, the turbine is stopped and, at least partially, disassembled. There is a need for detecting rubbing without stopping a steam turbine. Vibration sensors have been used to sense rubbing in a steam turbine. However, vibration in a turbine is not necessarily indicative of rubbing and vibration sensors have difficulty in determining a rotational position of the rubbing. There is a long felt need for systems and method to reliably detect rubbing in a steam turbine and determine the location of the rubbing while the steam turbine is operating.

BRIEF DESCRIPTION OF THE INVENTION

[0005] A method is disclosed for detecting rubbing between components in a steam turbine, the method includes: sensing a temperature at a plurality of locations on a casing of the steam turbine; comparing the sensed temperatures of the plurality of locations; detecting the rubbing between the components if one of the plurality of locations has a higher sensed temperature than the sensed temperature at the other plurality of locations, and reporting the rub as being at a location near the one of the plurality of locations having the higher sensed temperature. The plurality of locations may be an annular array perpendicular to a rotor axis and, in particular, may be four sensor locations arranged symmetrically around the casing in a plane perpendicular to a rotor in the turbine.

[0006] A method is also disclosed to detect rubbing in a steam turbine comprising: monitoring temperature sensors in at least one sensor array in a casing for the turbine; comparing temperature measurements of all sensors in array; identifying a hottest temperature in array from the comparison; determine if the hottest temperature is beyond a threshold level; identifying a sensor reporting the hottest temperature beyond the threshold, and issuing a warning of rubbing potentially occurring at a position near the identified temperature sensor.

[0007] A system is disclosed to detect rubbing in a steam turbine having a casing around a rotor, the system comprising: at least one array of temperature sensors mounted in the casing proximate to an inside casing surface facing the rotor, and a controller monitoring temperature signals from each of the temperature sensors in the array, wherein said controller issues a rubbing warning if one of the temperature signals reports a temperature substantially hotter than other temperatures reported by the array.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] FIG. 1 is a side view of a steam turbine casing in cross-section.

[0009] FIG. 2 is a flow chart of a method for detecting rubbing components in a steam turbine using thermocouples.

DETAILED DESCRIPTION OF THE INVENTION

[0010] A novel system and method has been developed to detect rubbing in a steam turbine using temperature sensors on the turbine casing. The friction of rubbing creates heat at the rubbing location. The heating is localized in the metallic casing. Temperature sensors, e.g., thermocouples, embedded in the casing report the temperature increase in the casing due to the rubbing. The sensor reporting a high temperature is determined by comparing the temperature signal reports from an array of thermocouples. A rub is detected when the temperature report from one sensor in the array is sufficiently above the temperature reports from other sensors in the array. The location of the rub is determined to be proximate to the temperature sensor that reported the high temperature.

[0011] FIG. 1 is a side view showing in cross-section a steam turbine **10** having a rotor **12** and a turbine casing **14**. The rotor includes rows of turbine rotor buckets **16** (turbine blades) that are each arranged between rows of stator blades (nozzles) **18**. For purposes of illustration, the rotor is shown schematically by dotted lines and a single bucket on the shaft. A pair of stator blades is shown on both sides of the bucket. The tips of each row of the buckets move in a circle that is adjacent an inner surface of the casing.

[0012] Rows of stator blades **18** extend radially inward from the casing towards the rotor shaft. The stator blades are fitted to dovetail mounts **19** on an inside surface of the casing. A row of turbine buckets extends radially outward from the rotor, between adjacent rows of stator blades. An annular steam flow path is formed through the rows of turbine buckets and stator blades. The steam turns the rotor buckets and rotor. As the buckets turn, the tips of the bucket should not rub against the inside surface of the stator casing.

[0013] Rubbing can damage the surfaces of the turbine and create inefficiencies in the steam path. Rubbing typically happens as the turbine bucket tips **17** rub against a surface of the casing. The rubbing is most often localized in the casing at one surface location on the inside of the casing where the bucket tips rub as they pass over the surface location.

[0014] Temperature sensors **20** are embedded in the turbine casing **14** near the inner surface **22** of the casing which is adjacent the tips of a row of turbine buckets. The temperature sensors may be thermocouples that generate electrical signals indicative of the temperature of the casing adjacent the thermocouple. The temperature sensors may be mounted in holes **24** drilled into the casing. The holes may extend from an outer surface **26** of the casing near to the inner surface **22**, such as within an inch of the inner surface. The holes may be positioned along the casing where rubbing most often occurs. For example, the holes **22** may be at locations in the casing between bearings **23** in the casing that support the rotor shaft. An angled hole **25** for a temperature sensor may be used to position the sensor near the steam inlet to the first row of turbine buckets.

[0015] The temperature sensors **20** may be arranged in an annular array around the rotor and in a plane perpendicular to the rotational axis of the rotor. The temperature sensors in each plane may be, for example, arranged along vertical and horizontal lines through the plane. In other words, four temperature sensors may be arranged at angular positions of 0 degrees, 90 degrees, 180 degrees and 270 degrees angular positions. The arrangement of temperature sensors may be selected such that the sensors are aligned with radial locations in the casing were rubbing most often occurs. For example, if rubbing most often occurs at 0, 90, 180 and/or 270 degrees on the casing, orienting the temperature sensors at these angular positions may be used to more reliably detect rubbing.

[0016] The arrangement of each array of temperature sensors in plane perpendicular to the rotor axis and the angular orientation of the sensors may be selected based on the size of the steam turbine (the larger the size of the casing the greater the number of temperature sensors may be needed), and the angular locations at which rubbing is considered to most likely to occur (temperature sensors are preferably placed proximate to potential rubbing locations). Preferably the angular orientation of the sensors is symmetrical around the rotor casing, such as four sensors **20** each arranged 90 degrees apart. Similarly, the number and position of each array of temperature sensors along the length of the steam turbine casing depends on the size of the steam turbine (the longer the distance between the front and rear bucket rows the greater the number of sensor arrays), and the lateral locations along the length of the casing where rubbing is consider to most likely to occur (for example, arrays of temperature sensors should be positioned near the first turbine bucket row at the steam inlet and between the rotor support bearings).

[0017] The temperature sensor **20** is placed at a distal end of the hole **24**, **25** to be near the inner surface **22**. Electrical wires or other electrical communication means are provided to transmit signals from the temperature sensor to a controller instrument, e.g., a computer **28**. The wires extend from the temperature sensor, through the holes **24**, **25** and beyond the casing to the controller. The controller converts the signals from each of the temperature sensors to a temperature reading, which may be an actual temperature measurement or a reading of a relative temperature with respect to other thermocouples in the array. For example, the controller **28** may measure the voltage output of each thermocouple sensor in an array of temperature sensors. The voltage output of each thermocouple is a relative temperature measurement with respect to the voltage outputs of the other thermocouples in the array and with respect to thermocouples in other arrays monitoring the turbine casing.

[0018] FIG. **2** is an exemplary flow chart of an algorithm executed by the controller to detect rubbing in a steam turbine. The controller includes a controller **28**, e.g., microprocessor that executes instructions, e.g., software, stored in a memory accessible to the processor. The computer receives as data inputs signals from temperature sensors, such as data signals from a voltage measuring device that monitors the voltage output of each of the thermocouples in the casing.

[0019] The algorithm **40** executed by the controller detects possible rubbing in a steam turbine, such as between a bucket tip and an inside surface of the casing. In step **42**, the controller monitors the temperature signals in each of the temperature sensors **20** in each sensor array. The controller may temporarily store in memory the temperature signals and may use filtering and averaging techniques to remove noise and other artifacts from the signals.

[0020] The controller compares the temperature signals of all sensors in an array, in step **44**. Comparing the temperature signals to other temperature signals from the same array of temperature sensors identifies the sensor reporting the hottest temperature, step **46**. In an array of sensors **20** arranged in a plane perpendicular to the rotor, the sensors should measure substantially the same casing temperatures if no rubbing is occurring. A substantial hotter temperature measured by one sensor as compared to the other sensors in the array indicates that rubbing is occurring. Rubbing creates heat due to friction between the rotor blade tip and the casing against which the tip rubs. The frictional heat is conducted through the metallic casing. The casing regions nearest the rubbing are heated the most. The temperature sensor in the casing nearest the rubbing reports the hottest temperature.

[0021] To identify the hottest temperature, the controller may simply identify the hottest temperature of all temperatures reported by the sensors in an array. The controller may also determine an average (mean) or median temperature of all temperatures reported by the array. For each temperature reported by a sensor in the array, the controller may determine the difference between the reported temperature and the average or median temperature. A threshold difference value may be preprogrammed into the controller, e.g. a threshold in a range of 10 to 50 degrees Celsius. The controller may determine if the difference between the hottest temperature reported in the array and the average or mean exceeds the threshold difference value, in step **48**. Alternatively, the controller may determine if any sensor in the array is reporting a temperature greater than a predetermined threshold value than the next hottest temperature reported in the array. If the hottest temperature being measured in the array is beyond the threshold value, the controller make a determination (step **48**) that one of the sensors in the array is reporting a temperature sufficiently higher than the temperatures being reported by the other sensors to warrant a determination that rubbing is occurring in the steam turbine.

[0022] When the controller **28** determines that a temperature measurement in an array is sufficiently hot to indicate that rubbing is occurring, the controller identifies the lateral and angular position of the sensor **20** reporting the hot temperature, step **50**. The location of the sensor is used to identify the probable location of the rubbing in the casing. The rubbing is assumed to occur at the casing inner surface facing the tips of the buckets and nearest the sensor reporting the hottest temperature.

[0023] The controller issues a warning that rubbing may be occurring near the position of identified temperature sensor, in step **52**. The warning may include a visual and audible alarm **56** (FIG. **1**) and a report of the data regarding the sensor array with the sensor identified as being near the rubbing. The data may include current temperature readings from the array and historical temperature readings from the sensor array. The data enables a technician or engineer to diagnosis whether it is likely that rubbing is occurring.

[0024] The controller repeats the algorithm periodically for all sensor arrays, in step **54**. The rate at which the algorithm is repeated may vary from turbine to turbine. An exemplary rate is that the temperatures from all sensors measured every one to five minutes.

[0025] A technical effect of the disclosed invention is that it provides a means for identifying and locating rubbing in a steam turbine. The technical effect includes monitoring temperatures in the casing and identifying a temperature hot spot as a potential rubbing occurrence.

[0026] While the invention has been described in connection with what is presently considered to be the most practical and preferred embodiment, it is to be understood that the invention is not to be limited to the disclosed embodiment, but on the contrary, is intended to cover various modifications and equivalent arrangements included within the spirit and scope of the appended claims.

What is claimed is:

1. A method for detecting rubbing between components in a steam turbine, the method comprising:

sensing a temperature at a plurality of locations on a casing of the steam turbine;

comparing the sensed temperatures of the plurality of locations;

detecting the rubbing between the components if one of the plurality of locations has a higher sensed temperature than the sensed temperature at the other plurality of locations, and

reporting the rub as being at a location near the one of the plurality of locations having the higher sensed temperature.

2. A method as in claim **1** wherein the plurality of locations are in an annular array perpendicular to a rotor axis.

3. A method as in claim **1** wherein the plurality of locations are four locations arranged symmetrically around the casing in a plane perpendicular to a rotor in the turbine.

4. A method as in claim **3** wherein the four locations arranged along vertical and horizontal lines extending through the plane.

5. A method as in claim **1** wherein the detection of the rubbing includes comparing each of the sensed temperatures to at least one of an average of sensed temperatures, a mean of sensed temperatures and to each of the other sensed temperatures in the array.

6. A method as in claim **1** wherein the plurality of locations are arranged in an annular array in the casing and around a row of steam turbine buckets on a rotor of the turbine.

7. A method as in claim **1** wherein the plurality of locations are near an inlet to the turbine.

8. A method as in claim **1** wherein the plurality of locations are in a middle of the turbine and substantially mid-way between rotor bearings supporting a rotor to the turbine.

9. A method to detect rubbing in a steam turbine comprising:

monitoring temperature sensors in at least one sensor array in a casing for the turbine;

comparing temperature measurements of all sensors in array;

identifying a hottest temperature in array from the comparison;

determine if the hottest temperature is beyond a threshold level;

identifying a sensor reporting the hottest temperature beyond the threshold, and

issuing a warning of rubbing potentially occurring at a position near the identified temperature sensor.

10. The method of claim **9** further comprising periodically repeating the steps of the method.

11. A method as in claim **9** wherein the sensor array includes a plurality of sensors arranged in a plane perpendicular to an axis of a rotor in the turbine.

12. A method as in claim **9** wherein the array of plurality of locations are four locations arranged symmetrically around the casing in a plane perpendicular to a rotor in the turbine.

13. A method as in claim **12** wherein the array includes four sensors arranged along vertical and horizontal lines extending through the plane.

14. A method as in claim **9** wherein the comparison includes comparing the measurements of each of the sensors to at least one of an average of sensed temperatures, a mean of sensed temperatures and each of the other temperature measurements in the array.

15. A method as in claim **9** wherein the sensors include sensors arranged in an annular array in the casing and around a row of steam turbine blades on a rotor of the turbine.

16. A system to detect rubbing in a steam turbine having a casing around a rotor, the system comprising:

at least one array of temperature sensors mounted in the casing proximate to an inside casing surface facing the rotor, and

a controller monitoring temperature signals from each of the temperature sensors in the array, wherein said controller issues a rubbing warning if one of the temperature signals reports a temperature substantially hotter than other temperatures reported by the array.

17. A system as in claim **16** wherein the at least one array is arranged in a plane perpendicular to a rotational axis of the rotor.

18. A system as in claim **17** wherein the at least one array includes four sensors arranged along vertical and horizontal lines extending through the plane.

19. A system as in claim **16** wherein the controller compares each of the sensed temperatures to at least one of an average of sensed temperatures, a mean of sensed temperatures and to each of the other sensed temperatures in the array.

20. A system as in claim **16** wherein the at least one array is positioned at least at one of proximate to a row of turbine buckets at an inlet to the turbine and a row of turbine buckets between a pair of bearings supporting a rotor of the turbine.

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