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- (71) **Applicant (for all designated States except US):**
SIEMENS AKTIENGESELLSCHAFT [DE/DE]; Wiltelsbacherplatz 2, 80333 München (DE).
- (72) **Inventors; and**
- (75) **Inventors/Applicants (for US only):** SHI, Wen, Gang [CN/CN]; Room 401, Building No.1 52, Jiaoda Donglu, Haidian District, Beijing, Beijing, 100044 (CN). XING, Jian, Hui [CN/CN]; Room 1-403, Building 12 Yang Qiao Bei Li, Feng Tai District, Beijing, Beijing, 100077 (CN).
- (74) **Common Representative:** SIEMENS AKTIENGESELLSCHAFT; Postfach 22 16 34, 80506 München (DE).

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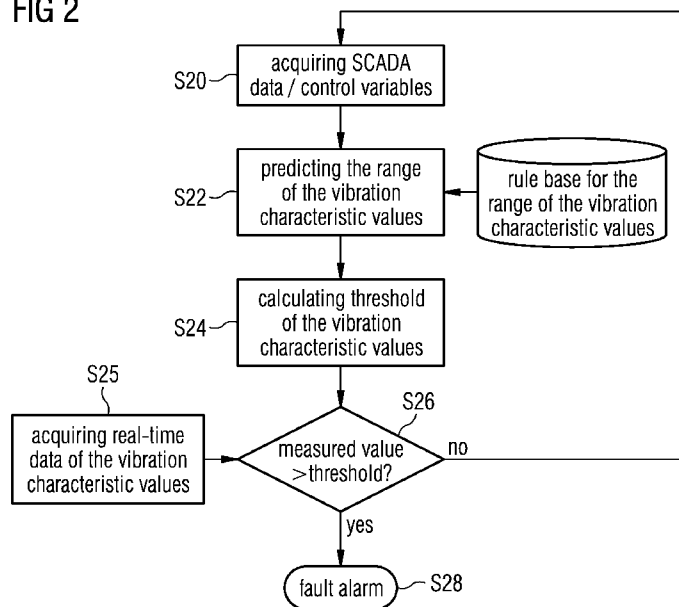
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(54) **Title:** METHOD AND SYSTEM FOR MONITORING WIND TURBINE GENERATOR VIBRATION

FIG 2



(57) **Abstract:** The present invention provides a method and system for monitoring vibrations in a wind turbine generator, and in the method a rule base for the range of vibration characteristic values is established on the basis of a large quantity of historical data by a data mining method based on a rough set, then the range of vibration characteristic values is predicted (S22) from the real-time operation data of the wind turbine generator according to the rules extracted from the rule base, the threshold of the vibration characteristic values is calculated (S24), and finally a judgment for a false alarm is made by comparing the real-time data of the wind turbine generator's operation characteristic values with the above-mentioned threshold of the vibration characteristic values (S26).

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Description

Method and System for Monitoring Wind Turbine Generator
Vibration

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Technical field

The present invention relates to a method and system for monitoring vibration and, particularly, to a method and system for monitoring vibrations in a wind turbine generator.

10

Background art

Condition monitoring and fault diagnosis of wind turbine generators (WTG) are generally focused on transmission systems, and such a transmission system comprises a main shaft, a main gearbox and a generator and so on, with such components being assembled by corresponding bearings, and faults in the mechanical transmission components being mainly caused by inadequate lubrication, contamination, overload or inherent defects. The vibration signals obtained from the transmission system are very useful in determining the condition changes of a wind turbine generator, while the traditional vibration monitoring systems in wind turbine generators produce too many false alarms, the main reason is that the behavior pattern of a wind turbine generator is extremely unstable in comparison with gas/steam turbines, centrifugal compressors, fans and other rotary machines, and therefore it leads to questions of the reliability of the vibration monitoring systems for wind turbine generators currently available.

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Since aerodynamic forces are highly nonlinear and unstable, the dynamic characteristics of a wind turbine generator vary significantly under different operation conditions. As for gearboxes in an unstable environment, the rotary speed, the torque and the forces acting on the gears are always changing, particularly in cases of wind turbulence. A more complicated issue is that even in the case

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of controlled stable power generation the rotary speed and the torque of the rotor still change significantly. In addition, there are differences in the kinetic characteristics of the various components of the rotor, the tower and the control system, which can produce significant influences on the transmission system, and these problems further affect the accuracy of the vibration monitoring. In actual operation, the statistical analysis of the vibration monitoring data shows significant unstable characteristics, and when a traditional vibration monitoring system is applied to a wind turbine generator, the above-mentioned unstable characteristics are highly likely to cause false alarms.

In operation, the rotary speed of the wind turbine generator rotor and the load of the transmission system are both unstable, and in terms of the rotary speed of the rotor, the pneumatic torque on the transmission system is related to the blade's tip-speed ratio, blade design, wind speed, blade pitch angle, yaw errors and any additional resistance on the blades, whereas the loads on the traditional system are also affected by many factors, for example random factors such as the stator/rotor currents, the wind turbulence, etc. In addition, some peculiar conditions, such as braking events, can generate random extra-large torques within a short time. In this way, even if the wind turbine generator is operating under the same wind speed and power, its normal vibration values will change when other operation data (such as wind deviation or the generator's stator current) change. Therefore, the definition of the vibration threshold will still lead to high false alarm rate in vibration monitoring if various possible combinations of operation data are not taken into consideration.

Each false alarm from the vibration monitoring system will bring with it high costs, the wind turbine generator's

operation has to be stopped for it to have a thorough inspection or even for it to be disassembled, and the loss in power generation and the costs of inspection during this period are both huge; furthermore, if a vibration monitoring system regularly sends out false alarms, the system will soon be shut down or neglected. These factors make it very difficult to accurately monitor the vibrations in a wind turbine generator, not to mention to accurately diagnose faults.

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The object of the present invention is to provide a method and system for monitoring vibrations in a wind turbine generator, which can determine adaptively the thresholds of the monitored parameters by taking into consideration various possible combinations of operation data, so as to reduce the false alarm rate, and at the same time to improve their operability and interpretability, and reduce the difficulty of maintenance.

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Another object of the present invention is to provide a vibration monitoring system for realizing the method of the present invention for monitoring vibrations in a wind turbine generator, which system is capable of comprehensively taking the influences of various factors on the wind turbine generator's vibrations into consideration, so as to reduce the false alarm rate and the maintenance costs.

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In order to achieve the above objects, the present invention proposes a method for monitoring vibrations in a wind turbine generator, which method comprises:

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establishing a rule base for the range of vibration characteristic values;

acquiring real-time operation data of various operation parameters of the wind turbine generator;

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predicting the range of the vibration characteristic values of the wind turbine generator according to the

measured real-time operation data;

calculating the threshold of a corresponding vibration characteristic value according to the predicted range of the vibration characteristic values;

5 comparing said real-time operation data of said corresponding vibration characteristic value with said threshold of the vibration characteristic value; and

10 sending out an alarm signal when said real-time operation data of said corresponding vibration characteristic value is larger than said threshold of the vibration characteristic value;

wherein said rule base for the range of the vibration characteristic values is established by a method as follows:

15 acquiring historical data of the various operation parameters and the vibration characteristic values of the wind turbine generator under normal operation, and storing the same in a database;

20 discretizing the data stored in the database; carrying out data mining to said discretized data based on a rough set, so as to constitute a knowledge system; since there are a large number of wind turbine generator parameters, and each set of data has uncertainty and inaccuracy to some extent, a rough set can solve the problems well; and

25 extracting rules for the range of the vibration characteristic values of the wind turbine generator under normal operation so as to establish the rule base for the range of the vibration characteristic values.

30 According to another method for monitoring vibrations in a wind turbine generator, in this case the above historical data of the various operation parameters include the supervisory control and data acquisition (SCADA) data of the wind turbine generator and the operation data with the
35 control variables under known normal conditions.

According to another method of the present invention for

monitoring vibrations in a wind turbine generator, in this case the method for carrying out data mining based on the rough set is applied to carry out attribute reduction to a attribute set constituted by the various operation parameters
5 of the wind turbine generator, so as to determine the minimum attribute set, thus simplifying the knowledge presentation and increasing the system processing efficiency and facilitating a user's decisions.

10 The present invention also proposes a system for using the method of the present invention for monitoring vibrations in a wind turbine generator, which system comprises:

a rule base for the range of the vibration characteristic values comprising rules for the range of the vibration
15 characteristic values;

a real-time data acquiring unit for acquiring the SCADA data and control variables of the wind turbine generator in operation;

a vibration characteristic value range predicting unit
20 for predicting a range of the vibration characteristic values according to the rules in the rule base for the range of the vibration characteristic values and the data acquired in real-time operation;

a vibration characteristic threshold calculating unit for
25 calculating the threshold of the vibration characteristic values of the wind turbine generator according to the predicted range of the vibration characteristic values;

a vibration characteristic value monitoring unit for
30 monitoring the corresponding vibration characteristic value of the wind turbine generator and acquiring the real-time data of the vibration characteristic value;

a comparison unit for comparing the threshold of said vibration characteristic value and the real-time data of said vibration characteristic value; and

35 an alarm unit for sending out a corresponding alarm signal when said real-time data of said vibration characteristic value are larger than said threshold of said

vibration characteristic value.

In the method and system of the present invention for monitoring vibrations in a wind turbine generator, on one
5 hand, since the threshold of the vibration characteristic values of the wind turbine generator is calculated on the basis of the mutual relationships of the automatically selected operation data, which can greatly reduce the false alarms under various normal operation conditions. On the
10 other hand, since in the present invention the rule base for the range of the vibration characteristic values is established on the basis of the historical data of the wind turbine generator by way of data mining based on the rough set, these rules are represented as a compact set of the
15 automatically selected operation data, instead of the operation data of all types. By means of the rule base and taking various combinations of the operation data into consideration, the threshold of the vibration characteristic values is calculated under various normal operation
20 conditions of the wind turbine generator, thus greatly reducing the false alarm rate.

Furthermore, in the method and system of the present invention for monitoring vibrations in a wind turbine
25 generator, the rule base for the range of the vibration characteristic values is represented as explicit and interpretable multiple rules and rules derived from tests, standards or maintenance experiences of other similar type wind turbine generators, which can be easily added into an
30 existing rule base by maintenance personnel. Furthermore, by way of an automatic and periodical database knowledge discovery and upgrading mechanism, it enables "learning" continuously and automatically from the experiences in monitoring the wind turbine generator, and in this way, the
35 accuracy of the system for monitoring vibrations is further increased and the false alarm rate further reduced over time.

Description of the accompanying drawings

The following accompanying drawings are only intended for the exemplary illustrations and explanations of the present invention and are not to limit the scope of the present
5 invention. In the drawings,

Fig. 1 is a flow chart for establishing a rule base of a wind turbine generator under normal operation conditions in the present invention;

Fig. 2 is a flow chart of the method of the present
10 invention for monitoring vibrations in a wind turbine generator; and

Fig. 3 is a block diagram of the system of the present invention for monitoring vibrations in a wind turbine generator.
15

Exemplary embodiments

In order to understand the technical features, objects and effects of the present invention more clearly, particular embodiments of the present invention are described with
20 reference to the accompanying drawings.

Fig. 1 shows the process of establishing a rule base for the range of vibration characteristic values. Before monitoring vibrations, step S10 is carried out within a
25 particular normal operation period of a wind turbine generator (generally at least for six months or a year) to collect various relevant data and store the same in a database and then discretize them. Such data include the data of normal vibration characteristic values, the historical
30 data of supervisory control and data acquisition (SCADA), known normal operation conditions and control variables of the wind turbine generator and so on, and such data are historical data for data mining of the operating conditions of the wind turbine generator.

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The data of vibration characteristic values can be statistical parameters of vibration signals in the time

domain, frequency domain or other domains, such as the virtual values of the vibration speed and time signals (10-1000Hz) acquired at the high-speed end of the main gearbox. Generally speaking, the more historical data for data mining there are, the lower the possibility of false alarms in the established vibration monitoring system. Table 1 shows a set of attributes of the collected historical data, and of course this attribute set is also the set of attributes of the conditional data to be mentioned below. Table 2 shows a set of decision attributes of the range of the vibration characteristic values for data mining, and this attribute set includes the data of the normal operating conditions of the wind turbine generator. As decision attributes, the ranges of the vibration characteristic values can be determined by current standards (such as German Standard VDI 3834) or by the operation experience of the wind turbine generator, for example, each normal vibration speed range in the standard VDI 3834 can be equally divided into 5 sections, and each section can be defined as a decision attribute in Table 2.

20

Table 1 Set of conditional attributes

Conditional attribute	Data type
C1	Wind speed
C2	Rotor speed
C3	Generator rotational speed
C4	Wind deviation per second
C5	Power
C6	Nacelle position
C7	Actual pitch angle of the first blade
C8	Actual pitch angle of the second blade
C9	Actual pitch angle of the third blade
C10	Set pitch angle of the first blade
C11	Set pitch angle of the second blade
C12	Set pitch angle of the third blade

C13	Actual speed of the pitch motor of the first blade
C14	Actual speed of the pitch motor of the second blade
C15	Actual speed of the pitch motor of the third blade
C16	Difference between rated speed and actual speed of the pitch motor of the first blade
C17	Difference between rated speed and actual speed of the pitch motor of the second blade
C18	Difference between rated speed and actual speed of the pitch motor of the third blade
C19	Pitch motor torque of the first blade
C20	Pitch motor torque of the second blade
C21	Pitch motor torque of the third blade
C22	Rotor position (when the first blade is vertically upwards, the rotor position is 0 degree, and the rotor angle range is -180.00 to +180.00)
C23	Gearbox oil temperature
C24	Gearbox bearing temperature
C25	Gearbox oil pump pressure
C26	Cooling temperature (low temperature side)
C27	Cooling temperature (high temperature side)
C28	Wind deviation every 10 seconds
C29	Power consumption
C30	Reactive power
C31	Generator speed measured by convertor
C32	DC bus voltage
C33	Line frequency
C34	Current at the generator's rotor side of the convertor
C35	Current at the line side of the convertor
C36	Total current into grid
C37	Stator current
C38	Virtual value of grid voltage L1-L2
C39	Virtual value of grid voltage L2-L3

C40	Virtual value of grid voltage L3-L1
C41	Phase of grid current L1
C42	Phase of grid current L2
C43	Phase of grid current L3
C44	Temperature of U-winding of generator stator
C45	Temperature of V-winding of generator stator
C46	Temperature of W-winding of generator stator
C47	Generator bearing temperature (driving end)
C48	Generator bearing temperature (non-driving end)
C49	Grid current at an interval of 5 seconds
C50	Line side current of convertor at an interval of 5 seconds
C51	Current of generator's rotor side of the convertor at an interval of 5 seconds
C52	Stator current at an interval of 5 seconds
C53	Active power required by convertor
C54	Ambient temperature
C55	Nacelle temperature
C56	Tower temperature (measured at the tower base)
C57	External temperature (measured at the tower base)
C58	Braking status (at high-speed end of gearbox)
C59	Pinch status
C60	Yaw status

Table 2 Set of decision attributes

Decision attribute	Vibration characteristic value (10-1000 Hz)	Unit	Range
D1	Virtual value of rotor main shaft bearing vibration speed	mm/s	[0 0.4)
D2	Virtual value of main gearbox low gear vibration speed	mm/s	[0 0.7)
D3	Virtual value of main gearbox intermediate gear vibration	mm/s	[0 0.7)

D4	Virtual value of main gearbox high gear vibration speed	mm/s	[0 0.7)
D5	Virtual value of generator driving end vibration speed	mm/s	[0 1.2)
D6	Virtual value of generator non-driving end vibration	mm/s	[0 1.2)
D7	Virtual value of rotor main shaft bearing vibration speed	mm/s	[0.4 0.8)
D8	Virtual value of main gearbox	mm/s	[0.7 1.4)
D9	Virtual value of main gearbox intermediate gear vibration	mm/s	[0.7 1.4)
D10	Virtual value of main gearbox high gear vibration speed	mm/s	[0.7 1.4)
D11	Virtual value of generator driving end vibration speed	mm/s	[1.2 2.4)
D12	Virtual value of generator non-driving end vibration	mm/s	[1.2 2.4)
D13	Virtual value of rotor main shaft bearing vibration speed	mm/s	[0.8 1.2)
D14	Virtual value of main gearbox low gear vibration speed	mm/s	[1.4 2.1)
D15	Virtual value of main gearbox intermediate gear vibration	mm/s	[1.4 2.1)
D16	Virtual value of main gearbox high gear vibration speed	mm/s	[1.4 2.1)
D17	Virtual value of generator driving end vibration speed	mm/s	[2.4 3.6)
D18	Virtual value of generator non-driving end vibration	mm/s	[2.4 3.6)
D19	Virtual value of rotor main shaft bearing vibration speed	mm/s	[1.2 1.6)
D20	Virtual value of main gearbox low gear vibration speed	mm/s	[2.1 2.8)
D21	Virtual value of main gearbox intermediate gear vibration	mm/s	[2.1 2.8)
D22	Virtual value of main gearbox high gear vibration speed	mm/s	[2.1 2.8)

D23	Virtual value of generator driving end vibration speed	mm/s	[3.6 4.8)
D24	Virtual value of generator non-driving end vibration	mm/s	[3.6 4.8)
D25	Virtual value of rotor main shaft bearing vibration speed	mm/s	[1.6 2.0)
D26	Virtual value of main gearbox low gear vibration speed	mm/s	[2.8 3.5)
D27	Virtual value of main gearbox intermediate gear vibration	mm/s	[2.8 3.5)
D28	Virtual value of main gearbox high gear vibration speed	mm/s	[2.8 3.5)
D29	Virtual value of generator driving end vibration speed	mm/s	[4.8 6.0)
D30	Virtual value of generator non-driving end vibration	mm/s	[4.8 6.0)

At step S12, data mining based on a rough set is carried out on the data collected at step S10 in the data mining unit in Fig. 1 to construct a knowledge system. From the wind turbine generator's operation data and the vibration characteristic values measured during normal operation of the wind turbine generator, the knowledge system is defined as follows, i.e. the knowledge system is the decision table, which can be used for rule extraction:

$$DT = \langle U, C \cup D, V, f \rangle \tag{1}$$

in which, DT is the knowledge system;

U is a finite set of N objects, e.g. the sample data obtained for N times from the wind turbine generator;

C is a conditional attribute set, e.g. the various wind turbine generator operation data as shown in Table 1;

D is a decision attribute set, e.g. the ranges of the vibration characteristic values as shown in Table 2;

V is defined as follows:

$$V = \cup_{q \in C \cup D} V_q \tag{2}$$

wherein V_q is the domain set of the attribute q ,

$q \in (C \cup D)$;

f is defined as follows:

$$f : U \times (C \cup D) \rightarrow V \tag{3}$$

wherein f represents all of the decision functions, and
 5 for each $q \in (C \cup D)$ and $x \in U$,

$$f(x, q) \in V_q \tag{4}$$

There are many data types in the operation parameters of
 a wind turbine generator, and each type of data has
 inaccuracy and uncertainty to some extent, so the rough set
 10 method can solve the problem quite well.

Part of the attributes in a knowledge system can be
 redundant and reducible, and the reduction of the redundant
 attributes shall not lose necessary information. As one of
 15 the key contents of the rough set theory, attribute reduction
 can determine a smaller attribute set for a knowledge system,
 and the reduced attribute set contains the knowledge which is
 the same as or similar to the original attribute set.

Accordingly, a reduced set ($RED(A)$) of an original attribute
 20 set A can be defined as:

$$E = RED(A) \Leftrightarrow (E \subset A, IND(E) = IND(A))$$

in which, E is the reduced attribute set of A ;

$IND()$ represents the irresolvable relationship generated
 by the attribute set.

25

In the knowledge system DT (referring to equation (1)),
 if the reduced attribute set E can distinguish all objects
 distinguishable in the original attribute set A and E cannot
 be further reduced, then E is called the minimum attribute
 30 set. Hence it can be seen that after the attribute reduction,
 the minimum attribute set as the key part of the knowledge
 system has simplified the knowledge representation while it
 can still distinguish all the objects distinguishable in the
 original attribute set, so that the system processing
 35 efficiency is increased and user decision facilitated.

On the basis of the data in Tables 1 and 2, a decision table for monitoring vibrations in a wind turbine generator can be established by data mining, as shown in Table 3.

5

Table 3 Decision table

No.	Conditional attributes								Decision attributes
	C1	C2	C3	C4	C5	C6	C7	...	
1	11.48	19.89	1796.43	-	1535.4	104.36	6.91	...	D22
2	11.53	19.86	1794.59	-2.7	1525.54	104.4	6.83	...	D28
3	11.17	19.84	1792.43	-	1510.92	108.68	5.99	...	D22
4	9.73	19.46	1757.94	4.95	1251.82	108.96	2	...	D16
5	10.02	19.56	1766.55	-2.2	1345.76	114.01	2.24	...	D16
6	10.5	19.64	1774.39	-	1447.8	107.95	2.89	...	D22
7	10.6	19.71	1780.17	6.22	1479.73	108.8	3.25	...	D22
8	10	19.53	1764.6	4.09	1322.41	113.01	2.65	...	D22
9	9.22	19.31	1744.16	-	1125.06	113.64	1.97	...	D16
10	9.8	19.56	1767.48	-	1294.13	113	2.37	...	D16
11	9.7	19.45	1757.57	5.58	1236.64	113	1.92	...	D16
12	9.93	19.52	1762.81	3.13	1338.67	113.95	1.96	...	D16
13	10.15	19.57	1768.23	3.52	1374.91	115	2.34	...	D16
14	10.77	19.74	1783.13	-	1484.68	116.8	3.58	...	D22
15	11.06	19.83	1791.84	-	1524.09	117.01	4.72	...	D22

At step S14, the rules for the range of the vibration characteristic values of the wind turbine generator under normal conditions are extracted from the knowledge system according to Table 3, and, with reference to Table 4, these rules provide conditions for monitoring vibrations in a wind turbine generator.

15 Table 4 Rules for the range of vibration characteristic

values

No.	Rule description
1	IF C3 ([1118.03, 1118.65)) AND C5 ([223.81, 226.06)) AND C6 ([272.08, 272.69)) THEN D4
2	IF C3 ([1338.90, 1357.26)) AND C5 ([412.03, 427.51)) AND C6 ([268.58, 271.10)) THEN D10
3	IF C3 ([1519.88, 1523.31)) AND C5 ([602.81, 613.37)) AND C6 ([272.69, 273.98)) THEN D16
4	IF C3 ([1439.89, 1459.66)) AND C5 ([505.78, 534.61)) AND C6 ([271.10, 272.08)) THEN D16
5	IF C3 ([1534.49, 1543.31)) AND C5 ([625.34, 629.58)) AND C6 ([263.91, 265.38)) THEN D16
6	IF C3 ([1793.51, 1795.51)) AND C4 ([-2.80, -2.69)) THEN D28
7	IF C3 ([1786.84, 1793.51)) AND C4 ([-0.79, -0.69)) THEN D22
8	IF C3 ([1757.24, 1760.11)) AND C4 ([4.94, 4.96)) THEN D16
9	IF C3 ([1765.58, 1772.01)) AND C4 ([-2.20, -2.19)) THEN D16
10	IF C3 ([1772.01, 1775.25)) AND C4 ([-2.68, -2.60)) THEN D22
11	IF C3 ([1779.25, 1784.55)) AND C4 ([6.22, 6.23)) THEN D22
12	IF C3 ([1763.71, 1765.58)) AND C4 ([4.03, 4.26)) THEN D22
13	IF C3 ([1711.05, 1754.33)) AND C4 ([-7.06, -6.89)) THEN D16
14	IF C3 ([1765.58, 1772.01)) AND C4 ([-0.12, -0.11)) THEN D16
15	IF C3 ([1523.31, 1526.46)) AND C4 ([-7.10, -7.08)) THEN D10
16	IF C3 ([1393.17, 1398.10)) AND C4 ([-2.69, -2.68)) THEN D10
17	IF C3 ([1276.83, 1277.75)) AND C4 ([2.07, 2.15)) THEN D10
18	IF C3 ([1142.49, 1147.01)) AND C4 ([6.51, 6.53)) THEN D10
19	IF C3 ([1079.18, 1080.29)) AND C4 ([1.22, 1.33)) THEN D4
...	...

As shown in Table 4, after the discretization of the conditional attribute set C, the rule base for the range of the vibration characteristic values of the wind turbine generator can be established by attribute reduction, the

rules are represented as a compact set of the automatically selected conditional attributes, and apparently the automatically selected conditional attributes are generally a part of the original attribute set. The rule base mines the important relationships between the vibration characteristic values and the operation data of the wind turbine generator, and then the range of the vibration characteristic values can be predicted by using the rule base in combination with the real-time operation data of the wind turbine generator.

5

Once the rule base for the range of the vibration characteristic values of the wind turbine generator has been established, it can be used for monitoring vibrations. Fig. 2 shows a flow chart of the method of the present invention for monitoring vibrations.

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As shown in Fig. 2, at step S20, various real-time data representing the performance of the wind turbine generator are acquired, which data mainly include the supervisory control and data acquisition data and the control variables used in the data mining step S12 shown in Fig. 1;

20

at step S22, corresponding rules for the range of the vibration characteristic values are extracted from the rule base for the range of the vibration characteristic values of the wind turbine generator established at step S14 shown in Fig. 1, and according to the rules, real-time operation data are used to predict the range of the vibration characteristic values of the wind turbine generator;

25

at step S24, the corresponding threshold of the vibration characteristic values is calculated from the predicted range of the vibration characteristic values, and, for example, the alarm threshold can be defined as the predicted virtual value of the vibration speed upper limit multiplied by various weight factors;

30

at step S25, the corresponding vibration characteristic values of the actual operating wind turbine generator are monitored and the real-time data acquired;

35

at step S26, the threshold of the vibration characteristic values calculated at step S24 is compared with the real-time data of the vibration characteristic values measured at step S25. If the real-time data of the vibration characteristic values are within a normal range, the monitoring process continues; and if the real-time data of the vibration characteristic values exceed the threshold of the vibration characteristics values, a corresponding fault alarm is sent out at step S28.

5

Fig. 3 shows a block diagram of a system of the present invention for monitoring vibration in a wind turbine generator, and the vibration monitoring system comprises:

15 a real-time data acquiring unit 30 for acquiring the SCADA data and control variables of the wind turbine generator in operation;

20 a rule base of the vibration characteristic value ranges 31, which rule base 31 is the rule base for the range of the vibration characteristic values of the wind turbine generator established in the vibration monitoring method of the present invention as shown in Fig. 1, formed by rules for the vibration characteristic value ranges;

25 a vibration characteristic value range predicting unit 32 for predicting the range of the vibration characteristic values;

a vibration characteristic value threshold calculating unit 34 for calculating the threshold of the vibration characteristic values;

30 a vibration characteristic value monitoring unit 35 for monitoring the corresponding vibration characteristic values of the wind turbine generator and acquiring the real-time data of the vibration characteristic values;

35 a comparison unit 36 for comparing the threshold of the vibration characteristic values and the real-time data of the vibration characteristic value; and

an alarm unit 38 for sending out a corresponding fault alarm when the particular data of the vibration

characteristic values are larger than the threshold of the vibration characteristic values.

As shown in Fig. 3, the system for monitoring vibration in the wind turbine generator acquires various real-time data of the wind turbine generator by the real-time data acquiring unit 30, including the SCADA data and the control variables in Table 1. The system extracts the corresponding rules for the range of the vibration characteristic values from the vibration characteristic value range rule base 31, and the vibration characteristic value range predicting unit 32 predicts the range of the vibration characteristic values of the wind turbine generator according to the extracted rules and the real-time operation data. The vibration characteristic value threshold calculating unit 34 calculates the threshold of the vibration characteristic values of the wind turbine generator from the predicted range of the vibration characteristic values. The vibration characteristic value monitoring unit 35 monitors the corresponding vibration characteristic values of the wind turbine generator and acquires the real-time data of the vibration characteristic values. When the real-time data of the wind turbine generator is acquired, the comparison unit 36 compares the threshold of the vibration characteristic values and the real-time data of the vibration characteristic values. The alarm unit 38 sends out a corresponding fault alarm in a certain form if the real-time data of the vibration characteristic value exceed the threshold of the vibration characteristic values.

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In the method and system of the present invention for monitoring vibrations in a wind turbine generator, the rule base for the range of the vibration characteristic values is established by way of the data mining method (such as rough set calculation) on the basis of a large quantity of historical data, and the rules are represented as a compact

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set of the automatically selected operation data. Then the threshold of the vibration characteristic values under any operation status can be calculated by means of the rule base mentioned above by taking into consideration various combinations of the operation data. Since the threshold is calculated on the basis of the relationships between the automatically selected operation data, it can significantly reduce the false alarms in the system.

At the same time, the rule base for the range of the vibration characteristic values is represented in the form of explicit and explainable multiple rules, which is easily understandable and convenient for automatic or manual maintenance, and the rules obtained from tests, standards or maintenance experiences of other similar wind turbine generators can be easily added into the existing rule base by the maintenance personnel. Furthermore, by way of an automatic and periodical database knowledge acquiring and upgrading mechanism, the system is able to "learn" continuously and automatically from the wind turbine generator monitoring experiences, so as to increase its own prediction accuracy continuously. In this way, the accuracy of the system for monitoring vibrations will be further improved and the false alarm rate further reduced over time.

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The above descriptions are only exemplary particular embodiments of the present invention and are not to limit the scope of the present invention. Equivalent changes, modifications or combinations made by any persons skilled in the art without departing from the spirit and principle of the present invention shall belong within the protective scope of the present invention.

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Claims

1. A method for monitoring vibrations in a wind turbine generator, the method comprising:
 - 5 establishing a rule base for the range of vibration characteristic values;
acquiring real-time operation data of various operation parameters of the wind turbine generator;
predicting the range of the vibration characteristic
10 values of the wind turbine generator according to the measured real-time operation data;
calculating the threshold of a corresponding vibration characteristic value according to the predicted range of the vibration characteristic values;
15 comparing said real-time operation data of said corresponding vibration characteristic value with said threshold of the vibration characteristic value; and
sending out an alarm signal when said real-time operation data of said corresponding vibration characteristic value is
20 larger than said threshold of the vibration characteristic value;
wherein said rule base for the range of the vibration characteristic values is established by a method as follows:
 - 25 acquiring historical data of the various operation parameters and the vibration characteristic values of the wind turbine generator under normal operation, and storing the same in a database;
discretizing the data stored in the database;
carrying out data mining to said discretized data
30 based on a rough set, so as to constitute a knowledge system;
and
extracting rules for the range of the vibration characteristic values of the wind turbine generator under normal operation so as to establish the rule base for the
35 range of the vibration characteristic values.
2. The method for monitoring vibrations in a wind turbine

generator as claimed in claim 1, wherein said historical data of the various operation parameters include supervisory control and data acquisition (SCADA) data and control variables' operation data of the wind turbine generator under
5 normal operation.

3. The method for monitoring vibrations in a wind turbine generator as claimed in claim 1, wherein said method for carrying out data mining based on a rough set includes
10 carrying out attribute reduction to a attribute set constituted by said various operation parameters of the wind turbine generator, so as to determine the minimum attribute set.

15 4. A system for using the method for monitoring vibrations in a wind turbine generator as claimed in claim 1, the system comprising:

a rule base for the range of the vibration characteristic values comprising rules for the range of the vibration
20 characteristic values;

a real-time data acquiring unit for acquiring the SCADA data and control variables of the wind turbine generator in operation;

a vibration characteristic value range predicting unit
25 for predicting a range of the vibration characteristic values according to the rules in the rule base for the range of the vibration characteristic values and the data acquired in real-time operation;

a vibration characteristic threshold calculating unit for
30 calculating the threshold of the vibration characteristic values of the wind turbine generator according to the predicted range of the vibration characteristic values;

a vibration characteristic value monitoring unit for
35 monitoring the corresponding vibration characteristic value of the wind turbine generator and acquiring the real-time data of the vibration characteristic value;

a comparison unit for comparing the threshold of said

vibration characteristic value and the real-time data of said vibration characteristic value; and

an alarm unit for sending out a corresponding alarm signal when said real-time data of said vibration characteristic value are larger than said threshold of said vibration characteristic value.

FIG 1

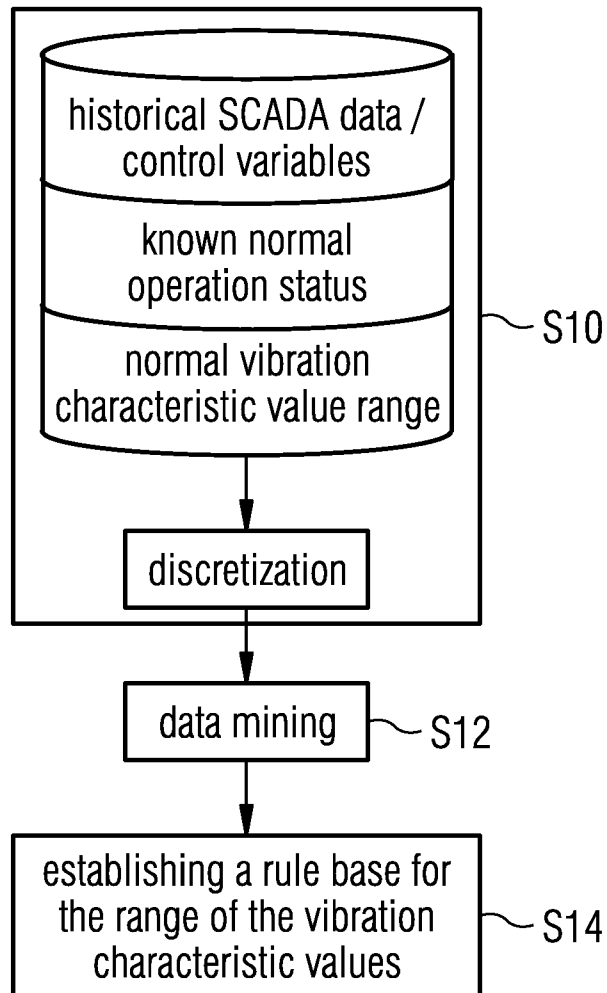


FIG 2

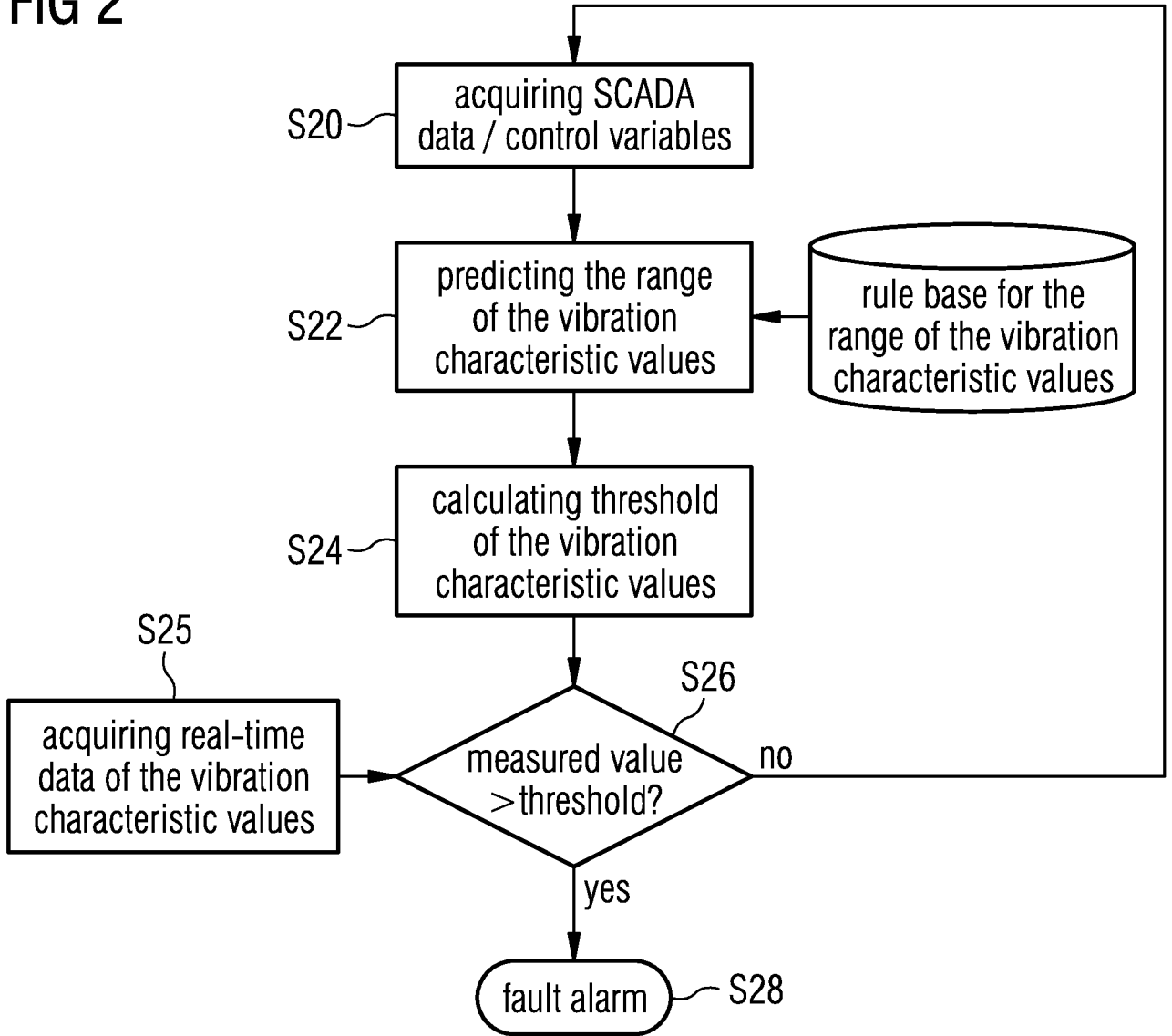
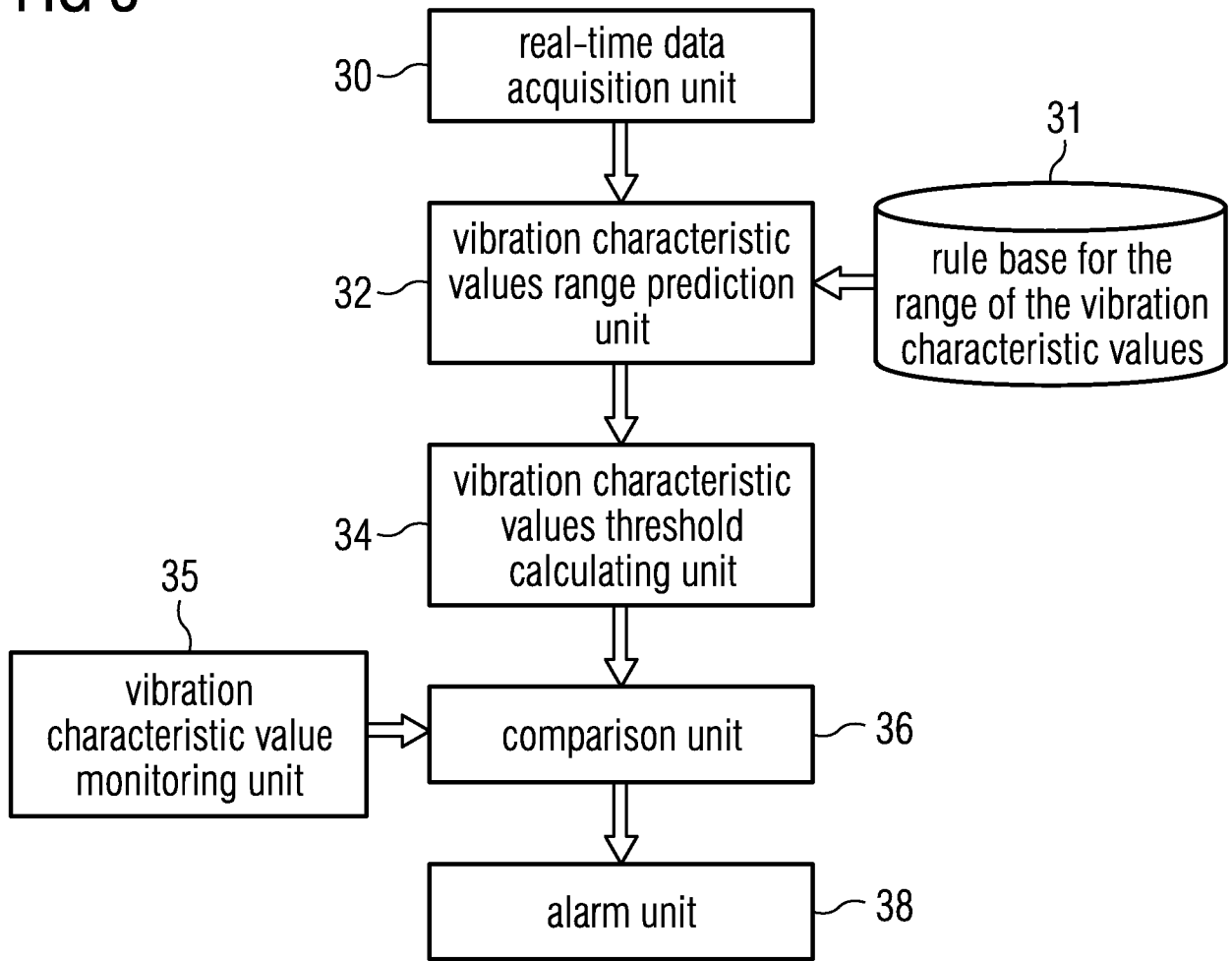


FIG 3



INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2010/061972

A. CLASSIFICATION OF SUBJECT MATTER INV. G05B23/02 G01H1/00 ADD.				
According to International Patent Classification (IPC) or to both national classification and IPC				
B. FIELDS SEARCHED				
Minimum documentation searched (classification system followed by classification symbols) G05B G01H				
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched				
Electronic data base consulted during the international search (name of data base and, where practical, search terms used) EPO-Internal				
C. DOCUMENTS CONSIDERED TO BE RELEVANT				
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.		
Y	US 2008/243344 A1 (CASEY KENT A [US] ET AL) 2 October 2008 (2008-10-02) paragraph [0029] - paragraph [0031] paragraph [0036] - paragraph [0039] paragraph [0045] paragraph [0049]	1-4		
Y	----- YANG PING ET AL: "A Fault Diagnosis System for Turbo-Generator Set by Data Mining" COMPUTATIONAL INTELLIGENCE AND SECURITY, 2006 INTERNATIONAL CONFERENCE ON, IEEE, PI, 1 November 2006 (2006-11-01), pages 801-804, XP031012908 ISBN: 978-1-4244-0604-3 page 801, right-hand column, line 27 - page 803, right-hand column, line 24 -----	1-4		
<input type="checkbox"/> Further documents are listed in the continuation of Box C.				
<input checked="" type="checkbox"/> See patent family annex.				
* Special categories of cited documents :				
<table style="width: 100%; border: none;"> <tr> <td style="width: 50%; border: none; vertical-align: top;"> "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier document but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed </td> <td style="width: 50%; border: none; vertical-align: top;"> "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art. "&" document member of the same patent family </td> </tr> </table>			"A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier document but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art. "&" document member of the same patent family
"A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier document but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art. "&" document member of the same patent family			
Date of the actual completion of the international search	Date of mailing of the international search report			
8 November 2010	23/11/2010			
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Authorized officer Kelperis, K			

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2010/061972

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2008243344	A1	NONE	