Bharat Heavy Electricals Limited, Bhopal

EXPRESSION OF INTEREST

(Ref: TME/Condition_Monitoring/2023/01)

Dated: 31.08.2023

FOR

"Condition monitoring system for Traction motor and Gear box"

Issued by:

Traction Machines Engineering, First Floor Block#9 Annexure,

Bharat Heavy Electricals Limited, Bhopal

Madhya Pradesh-462022, INDIA

Registered office at

Bharat Heavy Electricals Limited, having registered office at

BHEL House, Siri Fort New Delhi-110049

(Hereinafter referred to as 'BHEL')

All information contained in this EOI provided / clarified are in good interest and faith. The information contained in this Expression of Interest document or subsequently provided to Applicant(s), whether verbally or in documentary or any other form, by or on behalf of BHEL, is provided on the terms and conditions set out in this EOI and such other terms and conditions subject to which such information is provided.

The purpose of this EOI is to provide interested parties with information that may be useful to them in the formulation of their application for qualification and subsequent selection pursuant to this EOI. This EOI is not an offer by BHEL to the prospective Applicant(s) or any other person. This EOI is neither intended nor shall it be construed as creating or requiring any ongoing or continuing relationship or commitment with any party or person. This is not an offer or invitation to enter into an agreement of any kind with any party.

Though adequate care has been taken in the preparation of this EOI document, the interested firms shall satisfy themselves that the document is complete in all respects. The information is not intended to be exhaustive. Interested Agencies are required to make their own enquiries and assumptions wherever required. Intimation of discrepancy, if any, should be given to the specified office immediately. If no intimation is received by this office by the date mentioned in the document, it shall be deemed that the EOI document is complete in all respects and firms submitting their interest are satisfied with the EOI document in all respects.

The issue of this EOI does not imply that BHEL is bound to select and shortlist Applicant(s) for next stage or to enter into any agreement(s) with any Applicant(s). BHEL reserves all right to reject any applications submitted in response to this EOI document at any stage without assigning any reasons thereof. BHEL also reserves the right to withhold or withdraw the process at any stage. Neither BHEL nor its employees and associates will have any liability, loss, expense or damage which may arise from or be incurred or suffered in connection with anything contained in this EOI document or any matter deemed to form part of this EOI document, the information and any other information supplied by or on behalf of BHEL. BHEL accepts no liability of any nature whether resulting from negligence or otherwise howsoever caused arising from reliance/use of any statements/information contained in this EOI by the Applicant. BHEL is not making any representation or warranty, express or implied, as to the accuracy or completeness of any information/statements made in this EOI. The Applicant shall bear all its costs associated with or relating to the preparation and submission of its Application including but not limited to preparation, copying, postage, delivery fees, expenses associated with any demonstrations or presentations which may be required by BHEL or any other costs incurred in connection with or relating to its Application. All such costs and expenses will remain with the Applicant and BHEL shall not be liable in any manner whatsoever for the same or for any other costs or other expenses incurred by an Applicant in preparation or submission of the Application, regardless of the conduct or outcome of the EOI.

(1) Key Objectives

BHEL wishes to install railway vehicle mounted, 'Condition Monitoring System for traction motor and gear box' that will monitor the health and safety of key components of the Traction motor and gear box that would finally result in improved safety, improved reliability, higher utilization, increased up-time and reduced operation cost of the railway assets by enabling Predictive Maintenance and reduction in sudden catastrophic failures of these assets.

The 'Condition Monitoring System for traction motor and gear box' will enable Predictive Maintenance of traction motor and gear box by meeting the following functionalities:

A) Improving safety by early warning of distress in or impending failures in traction motor and gearbox.

B) Improvement in reliability of these assets by detecting early signs of deterioration in traction motor and gearbox thus providing ample time for planning preventive and predictive maintenance and avoiding sudden breakdowns in service.

C) Enabling scientific decision-making for maintenance of assets based on accurate deterioration trending and quantified indices of state of health by implementing fault failure analysis of these assets to plan condition-based maintenance rather than time-based maintenance.

D) Reducing maintenance cost of the railway assets by
   i) Identifying unnecessary maintenance regimes.
   ii) Reduced replacement of "still serviceable" components.
   iii) More efficient deployment of maintenance resources.
   iv) Maintenance extension of traction motor and gear box.
   v) Future extension of Automatic analysis.

E) The proposed system should be capable of being used with existing traction motor and gear box without having to make any structural modifications in the stock.

F) Easy operation of the Condition Monitoring System by simple, automatically generated and actionable alerts.

G) Options to enhance the functionality and capability of this system in the future without requiring major replacement of the existing equipment monitoring system. That's means on-air update of firmware to enhance edge computing capability of concentrator.

H) The system should be capable to accurately & separately identify the failure modes based on the monitored trends.

I) The offered system should either be proven in service or vendor shall offer the system for trials on BHEL systems for demonstration & validation.

J) Non-interference with any of the existing electronics, electrical & mechanical systems.

K) BHEL may ask for multiple demonstrations for proving individual features of condition monitoring system in static/dynamic environment. Applicant shall agree to this condition.

(2) ABOUT BHEL

Bharat Heavy Electricals Limited (BHEL) is a Central Public Sector Enterprise, wherein Government of India is holding 63.17% of its equity. One of the largest engineering and manufacturing companies of its kind in India having a turnover of more than USD 3 billion. The company is engaged in the design, engineering, manufacture, construction, testing, commissioning and servicing of a wide range of products and services for the core sectors of the economy, viz. Power, Transmission, Industry, Transportation, Renewable Energy, Oil & Gas and Defense with over 180 product offerings to meet the needs of these sectors.

Since its inception in 1964, BHEL has been the solid bedrock of evolution of India's Heavy Electrical Equipment industry. BHEL has a mammoth 20,000 MW per annum capability for manufacturing of power generation equipment. With a widespread network of 16 manufacturing facilities, 2 repair units, 4 regional offices, 8 service centers, 1 subsidiary, 3 active joint ventures, 15 regional marketing centers, 3 overseas offices and current project execution at more than 150 project sites across India and abroad, BHEL manufactures a wide range of high quality & reliable products adhering to national and international standards.

With key focus on project execution, the worldwide installed base of power generating equipment supplied by BHEL has exceeded 185 GW. BHEL's equipment that account for about 60% of the country's total generation from thermal utility sets (coal based), stand a testimony to its valuable contribution towards nation building. BHEL's global competitiveness has established its footprint in all the inhabited continents with references in 83 countries.
The high level of quality & reliability of BHEL products is a testimony to its adherence to international standards by acquiring and adapting some of the best technologies from leading companies in the world including General Electric, Siemens AG, Mitsubishi Heavy Industries Ltd. etc., together with technologies developed in its own R&D centers. BHEL invests more than 2.5% of turnover on R&D and innovation.

BHEL has been designing and manufacturing rolling stock for rail and urban transportation. BHEL has also been manufacturing Motors, Power electronics and Controllers for various transportation applications at its various factories.

In transportation sector, BHEL is into the manufacture of complete electric and diesel electric locomotives and electrical assemblies/components including traction motors, traction transformers, power & auxiliary converters and controls, gear wheels etc. We are a regular supplier of propulsion equipment of ACEMU/MEMU. India's first air-conditioned ACEMU train operational in Mumbai is equipped with BHEL's electrics and propulsion system.
At our Jhansi plant, we manufacture complete Electric Locomotives upto 6000 HP rating for mainline application of Indian Railways, Diesel Electric Locomotives from 350 HP to 3250 BHP rating. Till date, we have supplied cumulatively more than 725 nos. of main line electric locomotives to Indian Railways and diesel electric locomotives for shunting operations to various industries.

Our Jhansi plant have an installed capacity of 75 nos. locomotives per year. At Jhansi, we have complete state-of-the-art facilities for manufacturing, fabrication and testing of bogies, loco shells, under frames and other mechanical components of locomotives. We have recently developed India's first state-of-the-art WAG7 Electric Locomotive with regenerative capabilities. Among electrical propulsion equipment, we manufacture and supply traction motors, traction transformers, power converters(IGBT) & controls, auxiliary converters(IGBT) and vehicle control units for electric locomotives, diesel electric locomotives, EMUs, DEMUs & and metros trains of Indian Railways. Our manufacturing range includes complete solution for ACEMU/MEMU, IGBT based 3-phase drive equipment up to 6000HP rating. We have also developed India's first Traction Motor for 9000HP Electric Locomotives.

BHEL has also been in the forefront of providing maintenance and spares/replacement support to Indian Railways for their locomotive fleet. We have full-fledged service department located at major centers in the country. Please visit www.bhel.com for more details on BHEL's products and operations

(3) INSTRUCTION TO APPLICANTS REALTED TO THIS EOI:

A) Reputed business entities may submit their application as per Annexure -A (along with supporting documents) by Post / e-mail so as to reach us on or before 30th Sept'2023 at the following address:

Manager, TME,
Bharat Heavy Electricals Limited
Bhopal, Madhya Pradesh-462022, India.
Email: ashishtiwari@bhel.in; abhishukla119@bhel.in
Phone: +91 755 2503793, +91 755 2505605

B) Annexure B is attached for listing out the type of faults observed in traction motor and gear box. Applicant's inputs are requested for offering solutions, available with applicant, for various faults indicated there in. Faults are not limited to the list and applicant may offer solution for other kind of failures not covered in the list. Inputs shall be used for finalizing the tender document, considering various best solutions available in the market, to meet the end requirements. Other key requirements for executing the order in listed under clause (4) below.

C) Applicant to submit clause by clause comments against requirements listed under clause (4) along with filled and signed copy of Annexure A and B.

D) The details submitted by the Applicant(s) shall be complete in all respects and BHEL may seek clarifications/ additional information as considered necessary. Such clarifications/additional information must be provided within 2 days of BHEL request.

E) The EOI process involves seeking willingness of interested party/parties and selecting party/parties amongst all who make an application in response to this EOI.

F) Any request for further information or clarification on the EOI document may be submitted to above address within 15 days from date of issue of EOI.

G) Responses to EOI are to be submitted in English only. Supporting documents, as required, should also be in English language. In case of some documents being available in languages other than English, the Applicant shall necessarily provide duly authenticated translated version of the same in English.

H) Duly authorized representative of the Applicant(s) shall sign on each page of the document. Response to EOI should be prepared in such a way so as to provide a straight forward, concise description of Applicant's capabilities.

I) Notwithstanding anything contained in this EOI, BHEL reserves the right to accept or reject any Application and to annul the EOI Process in whole or part, at any time without any liability or any obligation for such acceptance, rejection or annulment, and without assigning any reasons thereof.

J) BHEL reserves the right to verify all statements, information and documents submitted by the Applicant in response to the EOI. Any such verification or lack of such verification by BHEL shall not relieve the Applicant of his obligations or liabilities hereunder nor will it affect any rights of BHEL.

K) The EOI process shall be governed by, and construed in accordance with, the laws of India and the Courts at New Delhi shall have exclusive jurisdiction over all disputes arising under, pursuant to and/ or in connection with the EOI process.

L) All costs incurred for participation in the EOI shall be borne by the Applicant(s).

(4) KEY REQUIRMENTS:

A) Vendors Experience:

i) The vendors should have proven experience of delivering these systems to the rail/other industry.

ii) Shall have installed the condition monitoring system in any rotating equipment for industry application, across globe, in the past 5 years.

iii) Installed system shall be already monitoring the faults as per the applicant's claim.

iv) Ability to demonstrate in the form of references/published case studies the successful detection of faults with more than three months of the remaining service life of component on in-service train.

B) System Configuration expected from the vendor:

i) The 'Condition Monitoring System for traction motor and gear box' shall have the following elements:

a) Sensors or other modes of collecting data.
b) Data collector/concentrator: Collector shall be designed in a manner that in the event of cellular network not being available, the data shall be held for the entire required time until cellular network coverage becomes available and then data must be transmitted at the earliest.
c) Analysis Software.
d) Communications network to get the sensor data to BHEL`s network, passing through data collector and analysis software.
e) Information Display to BHEL using web access.

C) Deliverables expected from the System elements:

i) System shall be capable of operating effectively with 3G cellular data network coverage. System must be scalable to upgrade to 4G and 5G as and when needed in future without having to replace any element of the system. The collector/concentrator must have Wifi module to use onboard concentrator cellular network for the transfer of data. The supplier shall be responsible for 3G, 4G and 5G data service and shall accommodate the same in the package.

ii) All data shall be captured and transmitted to a central server for inspection and analysis from the data collector/concentrator. The analysis software shall be smart enough to do sensor health self-diagnosis. The recheck shall be done for the sensors detected by software to avoid false positive.

iii) Data, if required, should be held in buffer on board the collector/concentrator and then transmitted to a central database for processing, analysis and alert. In the event of cellular network not being available, the data shall be held for the entire required time until cellular network coverage becomes available and then data must be transmitted at the earliest. The data holding buffer must be designed accordingly.

iv) The condition monitoring system shall not be specific to any particular type of traction motor equipment or to any specific traction motor equipment's supplier but should function with multiple types of traction motor that are running on BHEL.

v) Different type of collector/concentrators should not be used to collect data from traction motors and gearbox on the same coach.

vi) The system shall have proven capability of detecting damages before an equipment change is required, allowing ample time for the activity to be planned in with other maintenance activities.

vii) The equipment condition scale (level of damage) shall, after appropriate configuration and calibration, enable the operator to distinguish between equipment with none or low level of damage and those that required increased attention and finally those requiring replacement to allow continued reliable operation of the train without a line-failure of the equipment.

viii) All parameters of all assets should be possible to be plotted and trended over time/distance to identify the deterioration rate/trend. This should enable prioritization of maintenance activities, thus enabling reducing damage and maximizing useful traction motor and gearbox life.

ix) The condition monitoring system must be able to identify various individual faults of traction motor and gear box as mentioned in Annexure B.

x) In the event of sensor damage a warning shall be generated to enable safe replacement at the next inspection interval.

xi) Alert levels shall be configurable and set by the operator to enable simple, actionable responses. However, the vendor shall take the responsibility of identifying the values and setting the limits and alarm thresholds. A time period shall be given to the supplier to understand the operations and maintenance scenario and practices for setting such thresholds. The supplier shall be obligated to assist BHEL personnel in understanding the logics of the thresholds so set by him - to the full satisfaction of the BHEL personnel.

xii) All sensor data shall be time, date and location stamped. Data location shall be typically accurate to ±50m or better. Time stamp shall be taken from the GPS system.

xiii) The allocation of sensor nodes to a data collector/concentrator and train will be easily configured either through the terminal input of the data collector/concentrator using non-contact programming device Bluetooth, or by remote connection with the user website.

xiv) Sensor shall be free from any configuration of serial number. If faulty sensors are replaced by maintenance team, there should not be any need of re-programming of collector/concentrator.

xv) Only standard Industry Communication protocols and encryption algorithms shall be used in the system from data collector/concentrator to the cloud. The Onboard collector/concentrator shall have open communication platform like Modbus TCP/IP or RS485 for transfer of data to onboard systems. The collector/concentrator integration with the other controller should not be restricted. Proprietary communication protocols or data formats/information interchange formats used by the system when interfacing during system integration other sensors or while scaling up the deployment should be shared with BHEL.

xvi) BHEL should also be able to extract the raw data in usable format and communication protocols being used between sensor and data collector/concentrator.

D) Sensor:

i) The sensor shall be suitable for measurement of different parameters i.e.; temperature, current, speed, vibration etc. The same sensor shall be capable of monitoring condition data from the traction motor, gearbox wherever fitted in respective equipment.

ii) Vendor to ensure that no interference in the existing sensors shall be caused by new sensors.

iii) The sensor shall communicate to collector/concentrator reliably by wired/wireless mode of communication. For wired mode of communication, the cable from sensor to onboard collector/concentrator shall go through either connector or Junction box for easily removal of Bogie from Coach frame during maintenance period.

a) Sensor should send live data to onboard system through Modbus protocol to avoid any lag in the system.
b) Sensor shall be sealed to IP67 standard.
c) Sensor shall be generally comply with following standards

- Electric equipment's for Railway application: EN 50155/IEC 60751
- Railway application – Electromagnetic compatibility: EN 50121-3-2/IEC 62236-3-2
- Shock and Vibration – EN/IEC 61373 Cat.3
- Fire safety-EN45545-2-HL-3

d) Sensor housing shall be surface treated to protect against corrosion.
e) The bogie mounted sensor mounted on the trains shall operate satisfactorily over the range of -50°C to +120°C.

E) Data collector/Concentrator:

i) The Data collector/Concentrator shall have sufficient channels for inputs (temperature, current, speed, vibration etc.) from traction motor, gearbox etc.

ii) The data collector/concentrator shall have GPS sensor.

iii) The data collector/concentrator shall be powered by Industry Standard 24V or 110V DC on-board power supply with a maximum current capacity of 2A and 1 A slow blow fuse respectively. Amp at 110VDC. The power supply shall comply with shock and vibration EN50155/IEC 60751 – EN/IEC 61373 and EN 45545-2-HL-3.

iv) The data collector/concentrator can have Bluetooth, GSM, Wifi, Modbus TCP/IP & RS485 for the following functions:

a) Configuration of collector/Concentrator by Bluetooth. The configuration shall be done by Mobile device both IOS and Android. For any trouble shooting the same application shall be used.
b) GSM shall be used for continuous data streaming to cloud.
c) Wifi shall be used for continuous streaming to cloud in case coach has its own internet enabled Wifi system.
d) All the remote configuration shall be handled by Bluetooth, GSM & Wifi.
e) Data Concentrator should accept industry standard protocols like MODBUS. This will be used for reading the sensor data from "third-party" devices whenever they are fitted on the existing system. Data concentrator should be able to configure and transmit the field data from such devices.
f) All the component like GSM router, Wifi Module, GSM antenna should be inside the concentrator. Only GPS module shall be installed outside the Concentrator.

g) The data concentrator shall be IP67 certified to comply with under the coach installation.

v) The data concentrator shall comply with following standards.

- EMC: EN/IEC 61000-6-4, EN 50121-3-2/IEC 62236-3-2
- Railway standards Compliant: with EN 50155:2017/IEC 60751 and EN 50121-3-2/IEC 62236-3-2
- Vibration and shock: EN/IEC 61373 Cat II
- Fire & Smoke: EN 45545-2:2013 + A1:2015
- Temperature range: 0 – 65 degree C

F) Software and Algorithms:

i) The software shall receive filtered data to analyze the received raw sensor data and produce simple actionable alerts (monitoring display, automatic generated email and SMS) to BHEL. The actionable alert should include the recommendation to BHEL.

ii) The output from the software algorithms shall be a simple numerical value to quantify the seriousness of any emerging problem depicting:

a) Normal Health of equipment being monitored.
b) Beginning of deterioration but degradation does not warrant intervention.
c) Deterioration in the health of equipment being monitored that requires intervention within three months.
d) Deterioration in the health equipment being monitored that requires immediate pull out from service at the next available attention point.
e) Reason for deterioration in the health of equipment.

G) Installation:

i) Installation on one coach shall not take more than 8 working hours.

ii) Condition monitoring system shall be:

a) Capable of being fitted to the existing in-service traction motor and gear box at any time in the lifecycle of the traction motor and gear box.
b) Capable of being fitted to both legacy and new rolling stock.
c) Not require any change to the existing equipment. The sensor fitment shall be non-intrusive i.e. no requirement to modify the equipment.
d) Capable to install on bogie, under the coach frame or inside the coach frame. In either case no rewiring or changes in existing installations shall be necessary.

iii) Condition monitoring collector/concentrator shall be facilitated by a wireless communication/Bluetooth that can be read using a handheld reader and then downloaded directly to the system.

iv) Data collector/concentrator should be designed as vandal proof to international standards and should be mounted on metro cars in a position and using means so as to minimize possibility of theft.

H) Environmental Conditions:

- Relative Humidity: Upto 100% saturation during monsoon season.
- Maximum altitude: 1600 m
- Operating temperature range: –40 to +70 °C
- Storage temperature range –50 to +85 °C

I) Communications:

i) Communications to and from the sensor shall be wired/wireless.

ii) 3G/4G/5G Cellular or satellite communications shall be used to send data to and from the train.

iii) Data compression and filtering will be part of the “on train” systems so that communications can be achieved effectively with 3G/4G/5G cellular data communications.

iv) The communication from the sensors shall be free from interference by passenger communication systems such as Wi-Fi, Bluetooth and cellular radio.

v) The communication from onboard concentrator shall be open communication platform and shall have Modbus TCP/IP and RS485.

J) Front-end presentation:

i) A user website shall be provided to display the current status of all monitored rail assets.

ii) The user website shall be used for remote access & to configure sensor to monitored rail assets.

iii) All raw data acquired from each sensors shall also be available to BHEL.

K) Server:

i) Information about the monitored rail assets on the user website shall be compatible of accessibility with common mobile devices (iPhone, Android, Windows phone, tablets) as well as standard desktop computers running a web browser.

ii) Sensor information shall be available as simple colored status diagrams, tables of numerical values indicating alert, equipment health and diagnostic information with reason for deterioration, and graphical display of historical condition information allowing comparison of on all common Internet browsers, including mobile platforms.

iii) The information for monitored rail assets with sensors shall include but not be limited to:

a) Location (shown on a map and available as a downloaded data file).
b) Speed.
c) Direction.
d) Health state (including state of the sensors and data concentrator).
e) Condition as indicated by sensor/algorithm

Necessary APIs (Application Program Interface) with for this, along with the mapping software, should be developed by the supplier of the system - including obtaining any authorization for use of Geo-mapping data and software.

iv) The website shall be hosted on a non-proprietary cloud computing system with scalability, and geographical resilience with adequate redundancy and with mirrored redundant servers at each geographical location. The preferred platform for this purpose shall be the secure ones that are hoisted by Internationally certified platform like those by Microsoft, Hewlett-Packard, etc. whose Security Audit Certificate would require to be submitted with the Technical Bid to begin with.

v) The website shall display the train sets with the correct vehicles order displayed on a single or layered webpage.

vi) The website shall have a top-level summary page displaying summary status of the fleet.

vii) The website shall have multi-level query menu as per the demands of Organizational hierarchy - relevant to that particular administrative level of person logging in.

L) Scalability and universality of the Onboard Condition monitoring system:

i) The data communications system shall be scalable to allow addition of sensor nodes in future.

ii) Data concentrator shall be modular and should be scalable to accept connection of additional sensors. For the protocol to be used for communications of the Data concentrator, kindly refer to relevant clause.

iii) Apart from the hardware connectivity, software handshaking with sensors must also be ensured.

Bharat Heavy Electricals Limited, Bhopal

Annexure-A

Information to be submitted by Applicant along with EOI

1. Name of the Company:

2. Financial / Legal status of the Company (attach latest balance sheet):

3. Brief description of the Company including details of its business groups/subsidiaries/ affiliates:

4. Date of Incorporation:

5. Date of commencement of Business:

6. Full address including Telephone nos./Fax nos.:
   Registered office:
   Head office:
   Address for communication:
   Contact Details:
   Office Address in India, if any:
   Email for correspondence:

7. Documents to be enclosed:
   a) Duly filled Annexure B.
   b) Clause by clause comment for clause no. 4 of this EOI.

(Sign & Company Seal) Authorized signatory

Bharat Heavy Electricals Limited, Bhopal

Annexure-B

Type of faults that can be identified using applicant's condition monitoring system

Sl. No.	System under supervision	Faults/Failure	Whether condition monitoring system shall be able to detect respective faults individually (√/ X)	Parameter that shall be measured/ monitored by condition monitoring system and working principle	"Actionable Alert" that shall be generated by the system	Any comment/ remarks
1	Motor, coupling and gear box as a system	Loose foundation/Soft Foot				
2	Motor, coupling and gear box as a system	Unbalance				
3	Motor, coupling and gear box as a system	Misalignment				
4	Transmission faults (gear box and coupling)	Crack or Broken teeth/gear				
5		Looseness				
6		Excessive clearance				
7		Eccentricity				
8		Unbalance				
9		Mesh quality				
10		Backlash				
11		Misalignment of coupling				
12		Hunting tooth frequency				
13	Within traction motor	Looseness of components within traction motor				

14		Unbalance of components within traction motor				
15		Misalignment of components/bearing within traction motor				
16	Traction motor and gear box Bearing	Outer & inner race pitting				
17		Ball/roller wear				
18		Cage/raceway deformation				
19		Cocked bearing				
20		Grease contamination				
21		Metal content in bearing grease				
22		Over greasing				
23		Bearing creep/skidding				
24		False & true brinelling				
25		Plain bearing oil whirl and whip				
26		Plain bearing radial preload				
27						
28		Plain bearing rotor rub				
29	Fan in traction motor	Broken fan/ Crack in Fan				
30	Electrical	Voltage unbalance				
31	Electrical	Current unbalance				
32	Rotor Faults	Unbalance (fan, shaft deformation)				
33		Rubbing				
34		Broken, damaged and loose rotor bars				
35		Overheating				

36		Rotor bar looseness				
37		Damping cage degradation				
38		Thermal bow (unbalance)				
39		Static and dynamic eccentricity				
40		Severe porosity				
41		Angular and parallel misalignment				
42		Lamination looseness				
43	Stator Faults	Interturn short circuit				
44		Phase to phase short circuit				
45		Impedance unbalance or shift				
46		Insulation degradation				
47		Soft foot (Stator deformation)				
48		Loose foot (bolt loose)				
49		Winding overheating				
50		Winding looseness				
51		Lamination looseness				
52	Any other fault					