World Academy of Science, Engineering and Technology
International Journal of Electrical and Computer Engineering
Vol:13, No:08, 2019

Transducers for Measuring Displacements of Rotating Blades in Turbomachines

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Abstract : The study deals with transducers for measuring vibration displacements of rotating blade tips in turbomachines. In order to prevent major accidents with extensive economic consequences, it shows an urgent need for every low-pressure steam turbine stage being equipped with modern non-contact measuring system providing information on blade loading, damage and residual lifetime under operation. The requirement of measuring vibration and static characteristics of steam turbine blades, therefore, calls for the development and operational verification of both new types of sensors and measuring principles and methods. The task is really demanding: to measure displacements of blade tips with a resolution of the order of 10 μm by speeds up to 750 m/s, humidity 100% and temperatures up to 200 °C. While in gas turbines are used primarily capacitive and optical transducers, these transducers cannot be used in steam turbines. The reason is moisture vapor, droplets of condensing water and dirt, which disable the function of sensors. Therefore, the most feasible approach was to focus on research of electromagnetic sensors featuring promising characteristics for given blade materials in a steam environment. Following types of sensors have been developed and both experimentally and theoretically studied in the Institute of Thermodynamics, Academy of Sciences of the Czech Republic: eddy-current, Hall effect, inductive and magnetoresistive. Eddy-current transducers demand a small distance of 1 to 2 mm and change properties in the harsh environment of steam turbines. Hall effect sensors have relatively low sensitivity, high values of offset, drift, and especially noise. Induction sensors do not require any supply current and have a simple construction. The magnitude of the sensors output voltage is dependent on the velocity of the measured body and concurrently on the varying magnetic induction, and they cannot be used statically. Magnetoresistive sensors are formed by magnetoresistors arranged into a Wheatstone bridge. Supplying the sensor from a current source provides better linearity. The MR sensors can be used permanently for temperatures up to 200 °C at lower values of the supply current of about 1 mA. The frequency range of 0 to 300 kHz is by an order higher comparing to the Hall effect and induction sensors. The frequency band starts at zero frequency, which is very important because the sensors can be calibrated statically. The MR sensors feature high sensitivity and low noise. The symmetry of the bridge arrangement leads to a high common mode rejection ratio and suppressing disturbances, which is important, especially in industrial applications. The MR sensors feature high sensitivity, high common mode rejection ratio, and low noise, which is important, especially in industrial applications. Magnetoresistive transducers provide a range of excellent properties indicating their priority for displacement measurements of rotating blades in turbomachines.

Keywords : turbines, blade vibration, blade tip timing, non-contact sensors, magnetoresistive sensors
Conference Title : ICEEE 2019 : International Conference on Electrical and Electronics Engineering
Conference Location : Paris, France
Conference Dates : August 27-28, 2019