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A future possibility of vibration based condition monitoring of rotating machines

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A B S T R A C T

Adopted conventional practice uses a number of vibration sensors at a bearing pedestal of a rotating machine for the vibration based condition monitoring. The number of bearings in a machine, say a Turbo-Generator (TG) set, is likely to be very high hence increasing sensors to a large number. Therefore results in huge data sets to analyse to track any fault(s) which often depends on the experience and the engineering judgments in fault detection process. The effort of the present study is to reduce the number of sensors per bearing pedestals by enhancing the computational effort in signal processing. The concept used was fusion of the data from all sensors in the frequency domain to get a composite spectrum for a machine and then the computation of the higher order spectra (HOS) so that the vibration data is managed efficiently and able to detect fault uniquely. The results of the suggested approach are discussed here.

1. Introduction

Rotating machines in general consist of three major parts—a rotor, journal bearings (fluid or anti-friction bearings) and a foundation. Turbogenerator (TG) set is one such major rotating machine. It consists of a High Pressure (HP) turbine, a Low Pressure (LP) turbine and an Electric Generator. A simplified block diagram of a TG set is shown in Fig. 1. In some high capacity power plants the TG sets also have a few Intermediate Pressure (IP) turbines between the HP and LP turbines. The shafts of the individual systems are joined together by means of couplings, and the complete shaft is known as the rotor of the TG set. The shafts of each turbine are designed to have a number of rows of turbine blades along the shaft length. Each rotor of an individual system is normally supported by its own journal bearings. These bearings are supported on foundation structures which are often flexible.

Experience shows that faults develop in rotating machines during normal operation and hence the detection of fault(s) at the early stage is important. Vibration based condition monitoring is most popular and well-accepted in plants to meet this requirement because the machine vibration response is sensitive to any small structural or process parameter change [1]. However, the accepted and the conventional practice generally requires four sensors at each bearing—two accelerometers on the bearing pedestals and two proximitors to measure shaft relative vibration. So if a TG set has eight bearings, a total of 32 sensors are needed. A tacho sensor is also required for the phase reference of the rotor with respect to the stationary part (bearing pedestal) and for the rotor speed measurement [1]. To aid understanding, Fig. 2 gives the different kinds of instrumentation used at a bearing. Then a number of signal processing methods are commonly used for the vibration data collected from all sensors during normal and/or transient machine operation to track down a number of

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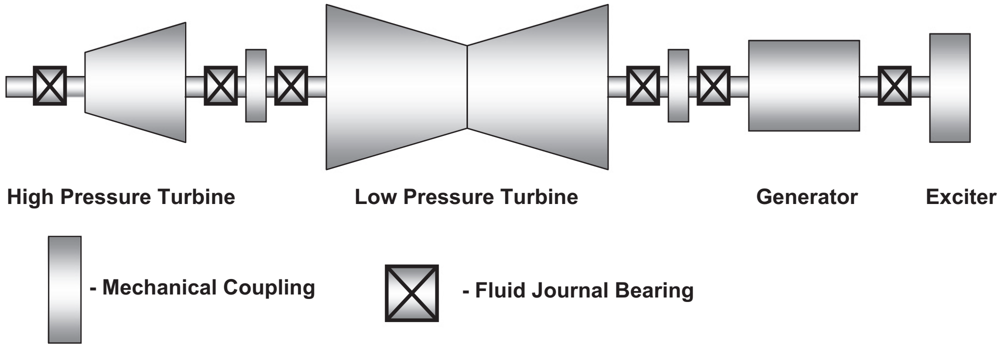

Fig. 1. Schematic of a simple layout of a TG set.

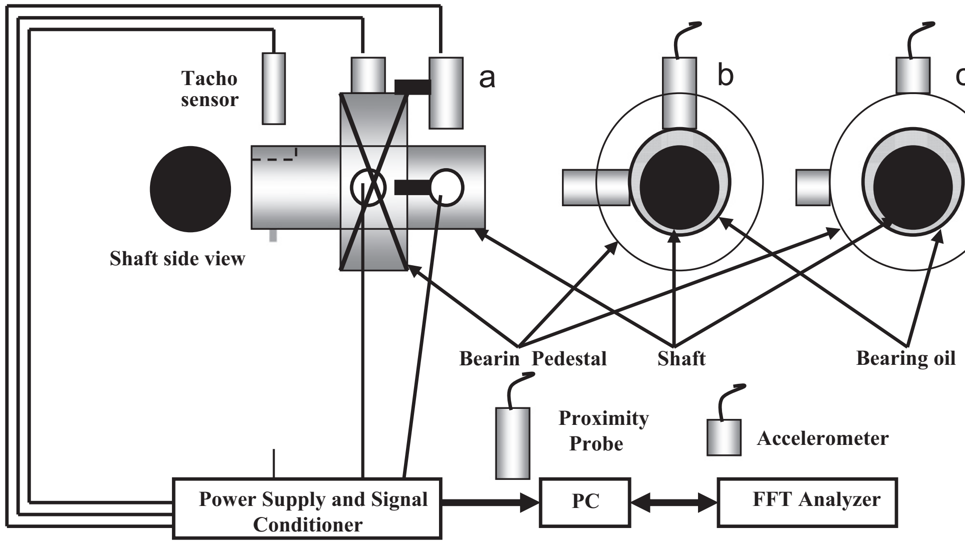

Fig. 2. Mounting of different types of vibration transducers: (a) front view of bearings and shaft, (b) side view – accelerometers not shown for clarity, and (c) side view – proximity probes not shown for clarity.

well recognized faults (Mass Unbalance, Shaft bent or bow, Misalignment and Preloads, Crack, Shaft Rub, Fluid induced instability, Mechanical Looseness/Bearing Assembly Looseness). Often these analyses include (a) overall vibration (bearing pedestal and/or shaft relative vibration), (b) spectrum analysis, (c) orbit plot, (d) 3-D waterfall spectra plot, (e) bode plot, (f) shaft centre line plot and (g) polar plot or amplitude-phase versus time plot. Goldman and Muszynska [2], and Bosmans [3] gave the summary of such vibration based techniques for identifying different faults, and Sinha [1] gave a detailed spectrum of the vibration based condition monitoring till year 2002. It is often observed that tracking a fault requires significant experience and engineering judgment. Several methods [4–20] have also been developed to enhance the fault diagnosis that include the wavelet analysis, full spectrum analysis, statistical analysis, principal component analysis, pattern recognition with a set of data for training, model based diagnosis, etc. using the measured vibration signals. Peng and Chu gave a review of the wavelet based method for the fault diagnosis in a machine [21]. A review of the fault diagnosis methods for the induction motor only is given by Mehrjou et al. [22]. Heng et al. [23] mainly gave the review of the machine prognosis methods for the prediction of remaining life based on the condition monitoring data. Lees et al. [24] gave a review of the model based fault diagnosis (MFD) methods. An excellent overview and summary of the current practices in the machine diagnosis and prognosis was given by Jardine et al. [25] where the authors have also discussed the possible future trends.

However, observations and experience show that even with these advances, the accepted practice in most of industries is still the conventional approach because the method is well-accepted for the rotor related faults diagnosis but tracking a fault often requires significant experience and engineering judgment. Hence the present objectives are concerned with the following:

(1) Reducing the number of sensors on a bearing pedestal to one which is definitely welcomed by any industry.
(2) Utilisation of computational power in signal processing to compensate the effect of a reduction in number of sensors.