# A MONITORING AND PROTECTION SYSTEM FOR HYDRO TURBINE AND GENERATOR SETS


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## Abstract

A system aimed at support the predictive maintenance of large vertical hydro T - G sets, turbine and pump -turbine generator sets, running up to 600 RPM is under development in the framework of the BRITE-EURAM II projects (BE7289 PROMOSHYGES). The prototype, now installed on an IBERDROLA hydro- generating unit in Villarino (Spain), allows the measurement, data processing, data analysis and correlation of static and dynamic signals, short and long term data trend.
The prototype of trend monitoring and protection systems has been developed taking into account the capability of the vibration monitoring to detect most of the mechanical, electrical mechanical related and hydraulic malfunctions; in the prototype the following measures have been implemented:

- static signals (i.e. active and reactive power, hydraulic head, temperatures, flow rate, levels,....);
- alert/alarm digital signals coming from the "Protection and Control System";
- dynamic data (relative and / or absolute displacements at the guide bearings level, acceleration of the bearings support);
- end - winding vibration (intensity modulated optical accelerometers having a bandwidth higher than 450 Hz have been developed and are under test).

The monitoring system is a hierarchical, distributed system, which is composed of several Digital Acquisition Signal Processing Unit (DASPU's) connected to the host computer by means of a communication network that follows the RS - 422 Standard. Two types of DASPU's are considered, one deals with static signals and is a commercial unit; the second one (dynamic DASPU) deals with large frequency bandwidth signals. In the dynamic DASPU several signal processing algorithms (filtering, interpolation, spectral estimation, conversion of asynchronous sampled data into equivalent synchronous, orbits,...) are implemented by means of a Digital Signal Processor (DSP).
Data acquisition is controlled by an host computer that process selected data in order to do data trend prediction based on the use of statistical kriging technique; as alternative / concurrent method a neural network approach is under development.

## Introduction

The reliability of the rotating machines such as electrical generator is critical to the overall reliability and operation of an electrical power plant. It is becoming more and more important to receive early warning of machine problem before failure and long outage occurs. The vibration monitoring is the most popular tool for its capability to detect most of the mechanical, electrical mechanical related and hydraulic malfunctions [1].
Retrofit of older hydrogenerating unit with vibration monitoring system is being done at very slow rate for different reason, among these [1]:

- most of the existing system in the market have been developed for different applications and later on have been extrapolated to hydro machines;
- the existing system are normally stand alone;
- tools for diagnosis have been developed for other purposes.

Taking into account that the operating conditions of an hydroelectric unit can vary in a large range, according to the type of service required, the monitoring system must recognise the variation of the monitored variables due to the change of the operating conditions respect to changes related to the development of faults or malfunctions. To obtain the results predictive analysis based on statistical kriging technique have been developed, checked with data coming from turbogenerator and is now under test with data taken from hydroeletric unit No. 3 of Villarino power plant; an alternative / concurrent technique based on the neural network approach is under development.

The prototype of the monitoring and protection system ( now installed in field) acquire and process the following data:
- static parameters (i.e. active and reactive power, voltages, currents, temperatures, hydraulic heads, opening of the distributor,...);
- alarm and / or alert signals coming from the field;
- vibration of the line axis with determination of the relative motion between shaft and guide bearings of the generator and turbine (for which the max. frequency of interest has been limited to 140 Hz);
- absolute motion of the bearing supports (max. frequency of interest 140 Hz);
- winding end turn vibration (for which the max. frequency of interest has been limited to 450 Hz).

For the monitoring of the absolute vibration of the bearing supports and of the winding end turn vibration intensity modulated optoelectronic accelerometers developed in the frame of the PROMOSHYGES project have been used [6,7].

## The Villarino hydroelectric unit

Villarino plant belong to Duero catchement area and is located near Villarino village, Salamanca area, close to Portugal border. The hydroelectric station is an underground cavern excavated in a granite mountain. The plant has six reversible modified Francis pump - generators (fig. 1). The monitored hydroelectric set is the unit no. 3. Each vertical unit consists of a motor - generator, having 10 poles, with rated power of 135000 kW. The pump - turbine is a 16 vanes unit, with a runner having a diameter of 2850 mm and 9 runner blades. In generating mode the nominal power of the turbine is 187500 CV with a nominal flow of 38.75 m3/s, the raw hydraulic head is in the range of 291.90 - 397.81 m; in pumping mode the max. power at the axis is 200000CV. The operating speed of the units is 600 rpm.

## Monitoring strategy and data processing

The monitoring strategy is based on:
- continuous surveillance ( automatic mode ) of the group carried out at predetermined time interval, defined by the operator, with the machine in "steady state regime";

- detection of alert / alarm signals generated by the "Protection and Control System" with subsequent acquisition of the measured data, at defined time interval, for a predetermined time duration or up to the alert / alarm signal go down.

Moreover manual mode data acquisition with the machinery under specific conditions (like machine at no load and specific speed, coast - down,...) is allowed. In manual mode the data are acquired in the time domain and are transferred to an host computer for off - line analysis; as general rule the data acquisition under specific conditions is used for diagnostics purposes and to establish the status of the monitored machinery or the interferences between machines.

## Data processing

The early detection of anomalous situations (fault detection) and the fast identification of the most probable causes (fault diagnosis) are significant aspects of the management and monitoring of hydro TG-sets.

The core of the data processing is addressed to obtain:

- the static parameters representative of the working point of the group;

- the line axis vibration considering the firsts 10 harmonics (including the sub - harmonics) of the running speed (1X) in the frequency range between the 20% of 1X and the max. frequency of 140 Hz, the data so obtained will be used for the determination of the holospectra and orbit analysis;

- the absolute vibration of the bearing supports;

- the vibration of the end winding turn;

- the prediction by statistical kriging technique of the vibration parameters (dependent variables) as a function of the parameters representative of the working point of the machine and / or the parameters influencing the vibrational behaviour (independent variables); as alternative / concurrent techniques a Neural Networks approach is under development;

- the data trend by comparison between the observed vibration and the predicted one in order to do an early detection of a possible malfunction and / or fault; short, mid and long term data trend can be performed;

- the evaluation of the defect, before to stop the machine, carried out off - line starting from orbit analysis, spectra or directly from the original time histories recovered in a host computer. The maximum number of the original time histories that can be recovered correspond to the last 720 cycles of observation. In such a way the original data are available to the experts for indeep diagnostics.

A schematic block diagram of the data processing is presented in fig. 2.
Before to proceed it is necessary to spend some words about the "dynamic" kriging technique, as implemented in the present project and on the parameters representative of the working point of the machine.

## Dynamic kriging technique [5]

The kriging technique was originally developed to estimate the distribution of ore grades within mining deposits. Up to today it has been successfully used in image analysis, cartography, studies on earthquakes; initial applications to hydro power plants [4] start to appear in literature.
The main characteristics of kriging may be summarised as follow:

- it is a modified technique of linear regression
- it estimates the value at a point assuming that the value has a spatial relationship with know values in a zone surrounding the working point (operating conditions of the monitored machine)
- the estimate is calculated by a linear sum of weighed known data values
- the weights are chosen to minimise the estimation error variance
- the kriging is an unbiased procedure
- the estimate is based on neighbourhood dynamic configuration of the working points of the machine.

The monitored variable y (i.e. vibration) is related to a series of k independent variables ($X_j$) representative of the operating conditions.

Two types of kriging models [3] have been used in this work. One is called "ordinary kriging": the mean or drift value for the vibration data is not known but it is assumed to be stationary. The relation for the model is:

$$\mathbf{y(p) = Co + \sum_{i=1}^{n} Wi * K(hip)} \tag{1}$$

In the other technique, called "universal kriging", the mean or drift is unknown but it is assumed to be non stationary:

$$\mathbf{y(p) = Co + \sum_{j=1}^{k} Cj * Xj + \sum_{i=1}^{n} Wi * K(hip)} \tag{2}$$

$C_0$, $C_j$ are the coefficients defining the mean plane, Wi are Lagrange multipliers, $K(h_{ip})$ is the generalised covariance between points i and p and n is the number of nearest neighbours considered in the estimate of the dependent variable y(p). The generalised covariance which characterises the auto correlation of the dependent variable, is only function of the distance h among the measured independent variables. It may have the following form [3]:

$$\mathbf{K(h) = \sum_{m=0}^{t} [(-1)^{m+1}] * b_m * |h|^{2m+1}} \tag{3}$$

being t the order of the trend and $b_m$ coefficients which depend on the number k of the independent variables included in the model. Taking into account that the k-dimensional domain represents an hyper plane of independent variables having different ranges of variability and different physical measuring units, in the resolution of the kriging system normalised co-ordinates are adopted. The interpolation in k-dimensional domain by kriging gives a good average accuracy, the kriging model does not require, for its creation, a reference baseline; a minimum number of data should be available at a first time (only two observations are used to estimate the third point, three to estimate the fourth point and so on up to a maximum of 40 observations to estimate the next points).
The maximum number of points to be considered in the estimation (number of nearest neighbours) has been set to 40: this not only made possible a high precision, but also made very fast the computational effort for the solution of the kriging equations; the data base will increase with time (that's why our kriging model has been called "dynamic").

The model has been implemented and tested (at the present time) on vibration signals taken from the shaft line of a turbogenerator (data from a hydrogenerator were not yet available at the time of writing this paper) just after a periodical maintenance. For this presentation, among the number of signals available, the vibration amplitude of the first horizontal harmonic of a bearing of the turbine reported in Fig. 3.a has been chosen as the dependent variable y. Fig. 3.b plots the active power curve of the generator, which is one of the signals chosen as an independent variable. Fig. 4 shows the prediction, performed through the kriging technique, of the vibration amplitude of the first horizontal harmonic of Fig. 3. Fig. 4 shows also the per cent error between the estimated and the observed value. In conclusion, the model obtained through dynamic kriging, which has been tested also on vector variables, provide good results.

Criteria to accept or reject data to build, on - line, the reference baseline for the observed variables and to discover anomalous behaviour have been defined and checked.

The advantages of the model based on the dynamic kriging can be summarised as follows:

- a reference baseline is not needed to individuate the model
- the model is immediately operational (when just the first two points have been acquired, the third one can be estimated)

- the number of points necessary to perform the estimation is reduced
- the estimates are very accurate and the measurement errors can be taken into account
- the model follows the system without adapt itself to it.

## Neural Networks approach

The prediction of the vibration parameters by statistical techniques provides a solution to the early detection of anomalous situations. An alternative solution to the detection and diagnosis problem is provided by Neural Networks: they are models composed by many nonlinear computational units called neurons or nodes. These nodes are connected via weighted links that are typically adapted during a training stage to increase performance. A network is trained to perform a specific task by modifying the weights: this represents the process of learning, while the weights represents the information stored in the network.
The advantages of Neural Networks (NNs) over classical techniques are the following:

- to solve a problem with NNs it is not necessary to know the set of rules on which the problem is based: they can be applied without any statistical knowledge about the signals or the noise;

- they can extract linear or nonlinear relations among the dependent variables;

- they have other interesting properties such as: failure tolerance, robusteness, etc.

On the other hand, the main drawbach of these techniques is that usually they require a large amount of data for training.

A Neural Network software is currently under development. This software allows to train different NNs: each NN topology has different input variables while the variable to be predicted is the root mean square value of one of the signals coming from the accelerometers or the displacement sensors. The difference between the prediction and the measurement is used for data trend and to determine anomalous conditions.

## Integration of the kriging and neural network techniques

At the actual stage of the development the neural network allows to manage only scalar quantity; the kriging allows the management of vectorial quantity (i.e. the generating vector related to the holospectra). The envisaged integration between the two techniques will consist in the:

- adoption of kriging models to obtain the main shape dependent forms between the inputs (independent) and the output (dependent) variables;

- realization of a multiple parallel outputs neural network structure to obtain a little error between the observed and predicted variables;

- collection of a consistent data base (validates by kriging) in the time to satisfy the requirements for the learning of the neural network without the introduction of delays in the execution of the predictive analysis due to the lack of training data for the neural network.

## Parameters representative of the working point of the machine

Doing the selection of the parameters representative of the working point it is necessary to take into account that the behaviour of different types of observed (dependent) variables should be predicted and that the selection of the working point parameters should be done taking into consideration what are the independent variables that have higher influence on the variation of the vibration with the operating conditions. The following selection has been carried out:
- shaft line vibration: - active and reactive power, hydraulic head, opening of the distributor, oil bearings' temperature;
- winding vibration: - active and reactive power, temperature of the winding, stator voltage and field current

## Alert and alarm signals

The protection functions have been implemented via software generating alert and / or alarm signals to the operator for :

- absolute vibration of the bearing supports ( alert and alarm)
- max. allowed shaft line displacement with the group working at running speed (alert and alarm)
- data trend confirming a values of the observed variables higher than the predicted one and out of prefixed limits (alert); i.e.this is the case of the end turn vibration.

## General description of the system

The aim of the system is to achieve effective management of vibration, plant status and static data by combining the advantages of a dedicated sub-system with extensive software packages that provide tools for data display, data interpretation, data trend, long term storage and alert management.

The measured signals are acquired, processed, stored, reduced and displayed in order to obtain:

- information on the status of the monitored machinery;
- short term history;
- long term history;
- data trend

The system is formed by a complex of modular functional block (fig. 5), the main are:

- data acquisition;
- data analysis and reduction;
- management of the data information flow ( data display, data trend, alert and alarm functions);
- on - line diagnostic analysis
- interfaces with local operator and with central offices
- interfaces with local equipment (alert and alarm signals)

A hierarchical distributed system (fig. 6) composed of two types of Data Acquisition and Process Units (DASPUs) connected to an host computer via a communication network has been designed and realised. The DASPUs are placed near to the monitored machine in the more convenient position to reduce the length of the cables connecting the instruments to the DASPUs. The main advantages of this approach are: distribution and easy expandability, easy maintenance and moderate cost. The solution chosen allows to cut - off the system according to the need of the users, to increase and to improve its functions in the time. The system can work as a stand alone unit or integrated in a larger corporate network. Hereinafter a short description of the system is presented.

### Digital Acquisition and Processing sub - system

The two types of Digital Acquisition and Signal Processing Unit (DASPU) are:

- Static DASPU able to acquire and process up to 64 static signals comparing them with alarm level and transmits the necessary information to the host computer; it is a commercial unit;

- Dynamic DASPU, that is a specific data acquisition and processing unit dealing with dynamic signals; the item incorporates advanced data processing and analytical techniques, the main characteristics of the item are reported in Table1.

In its final design the dynamic DASPU is composed of two boards, connected with a high speed serial line. The first board, the Acquisition Unit (AU), depends on the type of signals that have to be acquired and implements the continuous-time signal processing (antialiasing filtering, multiplexing and analogue to digital conversion). It contains two Analogue to Digital Converters (ADC), thus allowing simultaneous hardware sampling of each couple of orthogonal transducers. The second board, the Signal Processing Unit (SPU), carries out the digital signal processing algorithms and can be connected to different types of AU's. This board is based on the TMS320C30 Digital Signal Processor. It includes fast access memory (20 ns) up to a maximum of 2 Mbytes, and normal access dynamic memories (70 ns) allowing a maximum of 16 Mbytes of storage.

In the prototype to the dynamic DASPU have been connected the instruments reported in Table 2.
To the static DASPU have been connected the signals reported in Table 3. Others signals have been planned to be connected: - flow water in air cooling exchanger, oil bearing levels.

### On - line data processing in the dynamic DASPU

The on - line data processing (done while sampling) carried out in the dynamic DASPU is composed of the high over sampling of the 16 channels, linear interpolation to assure simultaneous sampling and decimation. The sampled data are stored in memory for off - line processing.

### Off - line processing in the dynamic DASPU

After a first decimation stage, asynchronous to synchronous conversion ( for signal related to the shaft - line vibration) is obtained again by linear interpolation. The information necessary to perform this conversion is provided by a phase reference signal that gives one pulse per revolution. An FFT algorithm is applied to obtain the spectra; moreover the system includes a method for obtaining frequencies, amplitudes and phases of the fundamental frequency and the largest harmonics; this information will be used to reconstruct orbits described by the shaft. Other values such as RMS value and vibration level of the main harmonic and subharmonics are also calculated.
The off - line process related to the shaft line vibration is synthetically described in fig. 7; in fig. 8 are reported examples of results obtained.

Finally, all this information is transferred to the host for storage, display and further processing.

The characteristics of data acquisition and processing have been defined in order to obtain three bandwidth of analysis, according to the running speed, for the shaft line vibrations ( table.4).

For medium frequency vibration the characteristics of the processing have been defined in order to obtain the specification for the spectral analysis reported in Table .5

## Communication network

The digital communication network complies with the specification on Table 6.

## Operating modes of the system

The system can operate in two modes: automatic or manual.

a) Automatic mode: the DASPU is continuously sampling new data and processing it; when the DASPU is called from the PC ( at selected time interval defined by the operator) the last fully processed data are supplied to the host. The processing involved in the automatic mode is presented in fig..... The last 24 cycles of processed data are maintained in the DASPU in order to assure the monitoring for out of service of the host; these data can be retrieved any moment.

b) Manual mode: the data acquisition start under the control of the operator and is carried out till a command stop it or the maximum sampling time of three minute is completed. The time domain data acquired in manual mode are transferred after the first decimation without off - line processing and will be available on the host for analysis.

## Host computer and software

The host computer is a high performance PC ( processor PENTIUM 133MHz) using Microsoft Windows NT Operating System; the computer can work as a LAN server by the universal TCP/IP protocol or via modem. In such a way the system can work as stand - alone system or to be integrated in a more large corporate network.
The monitoring software processes the information from all the DASPUs and does the following main tasks: configuration of the system, data transfer from the DASPUs, data storage in a signal data base, statistical data analysis, neural network data processing and alert and alarm display.
The software continuously monitors the status of the DASPUs, static or dynamic, by means of a master/slave communication protocol. In the simplest form the message is very short, avoiding delays between DASPUs, indicating only if there is some variable out of alert/alarm ranges. When an alert/alarm condition occurs, a flashing and acoustic warning will appear on the operator terminal.
Two modes of operation will be possible, manual and automatic: in the manual mode the operator can monitor a particular DASPU to perform data acquisition and analysis on any selected point; in the automatic mode the host monitors the status of all DASPUs, stores the behaviour of the plant in the data base and obtains, processes and stores a selected subset of the possible data.
The software on the host include security area that can be accessed only by authorised operators.The restricted operation are registered in a diary file together with the main events occurred in the plant.
The configuration of the system is stored in "configuration files". the data collected are stored in files and organised in a "Results Database" that contain also status flags.

A "Diary file", stored as a text file, is continuously and automatically updated with the "story of the group and of the system".
The software off - line is used to process the data in order to obtain diagrams, data trends (short, medium and long term), to do orbits and diagnostic analysis.
The software, working in multitasking configuration, can be run on the host computer itself or on aremote computer via TCP/IP connection; moreover the data can be transferred via a modem connection.

## Conclusion

A prototype of protection and monitoring system addressed to hydroelectric unit have been designed and installed, in the Villarino Power Plant of IBERDROLA, and is now under test.
In the system the host computer software controls data acquisition and transmission by DASPU, builds a data base from the recorded data and process it in order to do data trend prediction based on the comparison between the measures and the estimates of the surveyed variables as function of the independent variables representative of the working points of the group or of the input parameters for the monitored phenomena; statistical kriging technique has been adopted. As an alternative / concurrent technique based on the use of neural network is under development.
The design performed according to the modular functional blocks conception (data acquisition, data analysis and reduction, management of the data and information flow , predictive analysis, interfaces with the local operator and with the Central Office of the end user) jointly with the modularity of the hardware allows to cut-off the system according to the need of the user and to increase and to improve its functions in the time. The system may work as stand alone system or be integrated in a larger corporate network

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Table 1.
Main characteristics of the dynamic DASPU.

| | |
|---|---|
| Resolution | 12 bit |
| Analogue input | 16 channels |
| Sampling rate | 15625 sample/CH |
| Alias attenuation | > 70 dB |
| Antialiasing Filters | Chebychev 4 poles |
| Digital input | 1 (reference phase signal) |
| Hardware simultaneous sampling | every two channels |
| DSP | TMS320 - C30 |
| EPROM memory | |
| RAM memory | |
| Digital signal processing | Digital filtering, decimation, interpolation, conversion of the asynchronous acquired data to the synchronous one, spectral estimates,... |
| Digital communication interface | RS - 422 |

The dynamic DASPU process signals of a bandwidth up to 450 Hz and ensure simultaneous sampling up to a bandwidth of 140 Hz ( signals related to the vibration of the shaft line and of the bearing supports).

Table2.
Instrumentation connected to the dynamic DASPU.

| Location | Measurement | Instrument type |
|---|---|---|
| Upper guide bearing | journal displacement | 2 Eddy current probe ( 0° and 90°) at 1 mm from the shaft<br>2 Low frequency accelerometers (1) on the bearing support ( 0° and 90°) |
| Lower guide bearing | journal displacement | 2 Eddy current probe ( 0° and 90°) at 1 mm from the shaft<br>2 Low frequency accelerometers (1) on the bearing support ( 0° and 90°) |
| Turbine guide bearing | journal displacement | 2 Eddy current probe ( 0° and 90°) at 1 mm from the shaft<br>2 Low frequency accelerometers (1) on the bearing support ( 0° and 90°) |
| End winding turn | End winding vibration | 3 Medium frequency accelerometers (2), one on each phase ( R, S, T) |
| | Reference phase signals<br>Running speed | 1 Phototacheometer |

(1) Low frequency optoelectronics accelerometers developed by Photonic Group of University of Cantabria .
(2) Medium frequency optoelectronic accelerometers developed by CEA / LETI [6].

Table 3.
Signals connected to the static DASPU.

| |
|---|
| Upstream water level |
| Downstream water level |
| Stator voltage ( phase R, S, T) |
| Stator current (phase R, S, T) |
| Field Voltage |
| Field current |
| Active power |
| Reactive power |
| Distributor opening angle |
| Cooling water temperature (inlet and outlet) in the air -water exchanger |
| Cooling air temperature (inlet and outlet) |
| Stator winding temperature (phases R, S, T) |
| Stator core temperature (8 signals) |
| Thrust bearing oil temperature |
| Thrust bearing pads temperature (2 signals) |
| Guide bearings' temperature (3 signals) |

Table 4.
Off - line signal processing: Main characteristics for shaft line vibration.

| | | | |
|---|---|---|---|
| Bandwidth | 50 Hz | 100 Hz | 175 Hz |
| Effective bandwidth | 40 Hz | 80 Hz | 140 Hz |
| Recommended running frequency | 1 / 4 Hz | 4 / 8 Hz | 8 / 14 Hz |
| Minimum frequency of interest | 0.2 / 0.8 Hz | 0.8 / 1.6 Hz | 1.6 / 2.8 Hz |
| Frequency resolution | 0.025 Hz | 0.05 Hz | 0.08 Hz |
| 1/2 bin FFT | 0.012 Hz | 0.025 Hz | 0.04 Hz |
| Max. acquisition time in manual mode | 180 sec. | 180 sec. | 180 sec. |

Table 5.
Off - line signal processing: End winding vibration

| | |
|---|---|
| Bandwidth | 600 Hz |
| Effective bandwidth | 450 Hz |
| Minimum frequency of inter | 30 Hz |
| Frequency resolution | 0.3 Hz |
| 1/2 bin FFT | 0.15Hz |
| Max. acquisition time in manual | 180 sec. |

Table 6.
Specification of the digital communication network.

| | |
|---|---|
| Digital Communication Standard | RS - 422 |
| Bit rate | 100 kbs |
| PC connection | Serial Line (adaptation board) |
| Max. no. of DASPUs | 32 |
| Max. distance between the PC and one DASPU | 1000 meters (without repeaters) |

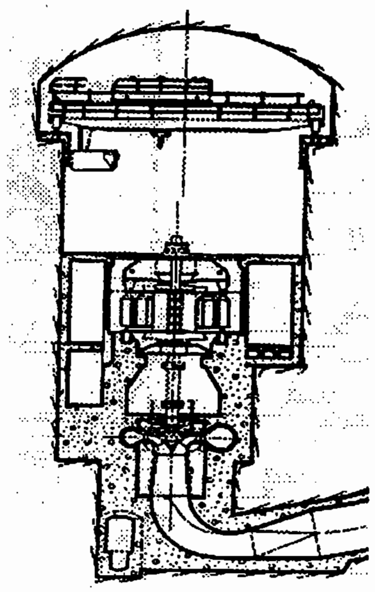

Figure 1.
Cross section of the pump - generating unit n° 3 of the Villarino Power Plant

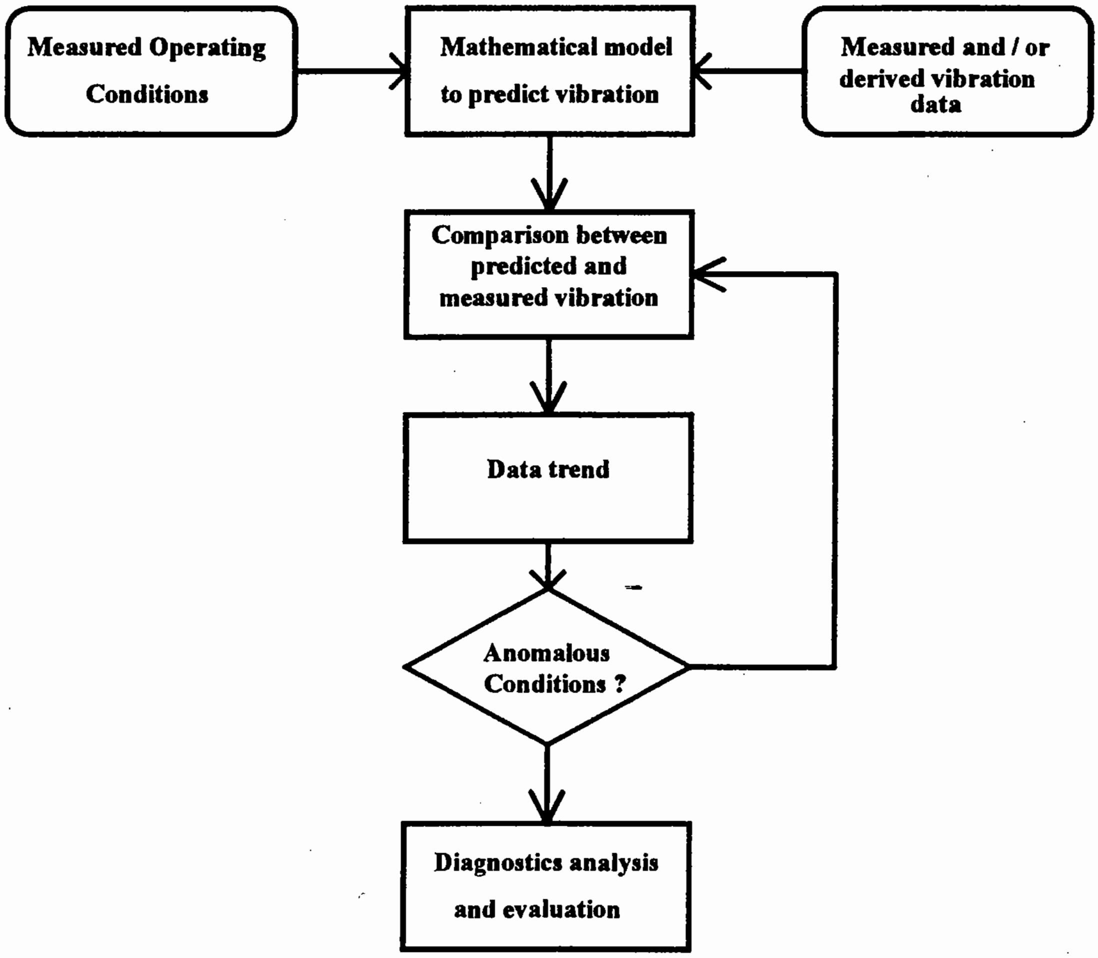


Figure 2.
Schematic block diagram of the data processing

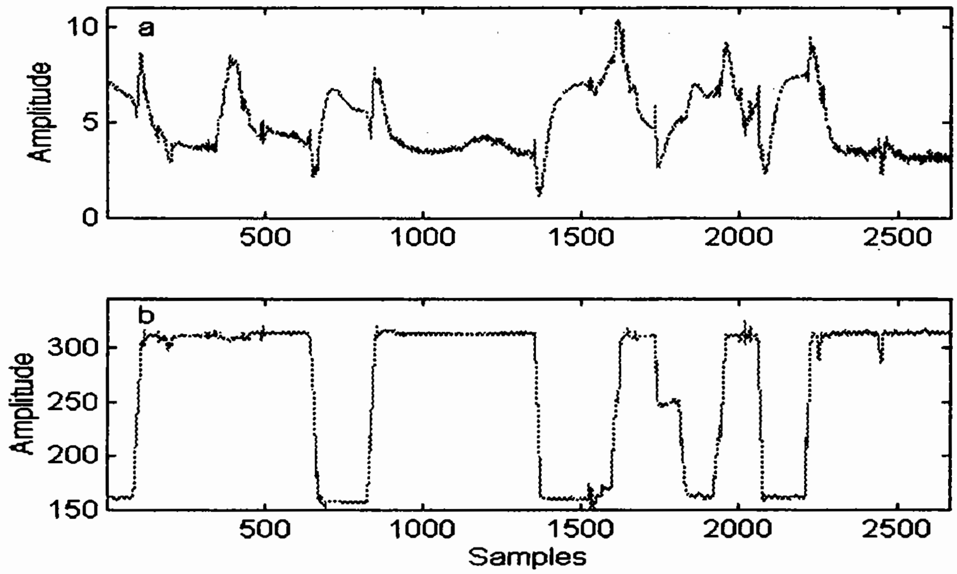


Figure 3
a) Dependent variable, b) Active power (one of the independent variables).

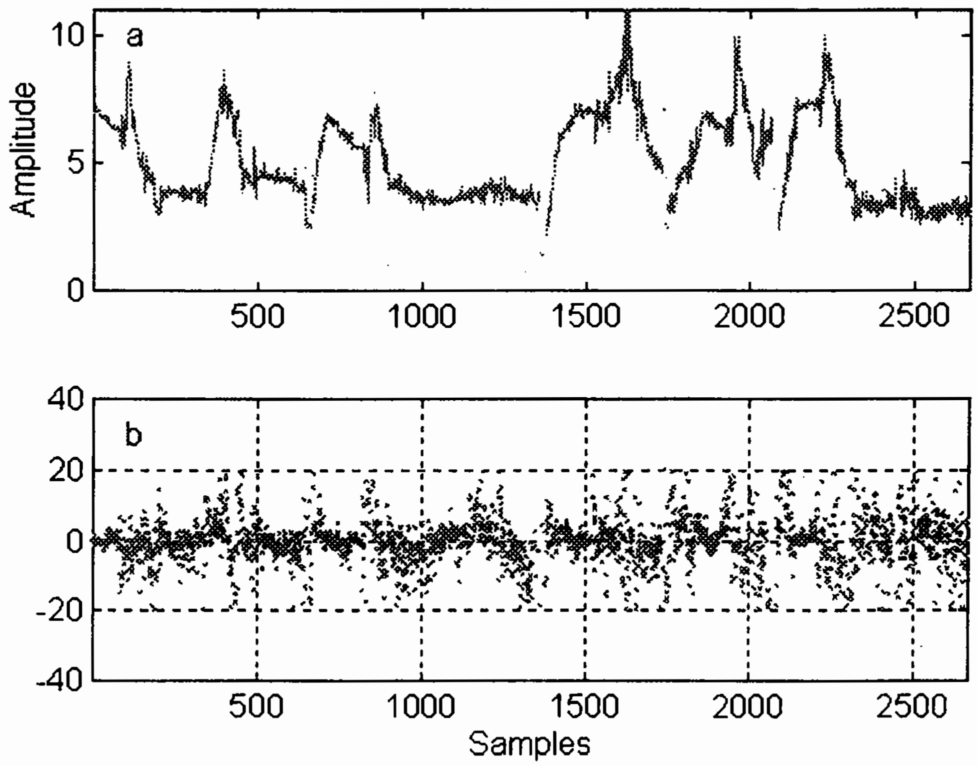


Figure 4.
a) Prediction by dynamic kriging, b) per cent error.
The maximum number k of independent variables to be used in the models (eqns. 1, 2, 3) has been chosen equal to five; they are: $X_1$ (active power), $X_2$ (reactive power), $X_3$ (SH pressure), $X_4$ (RH temperature), $X_5$ (RH pressure).

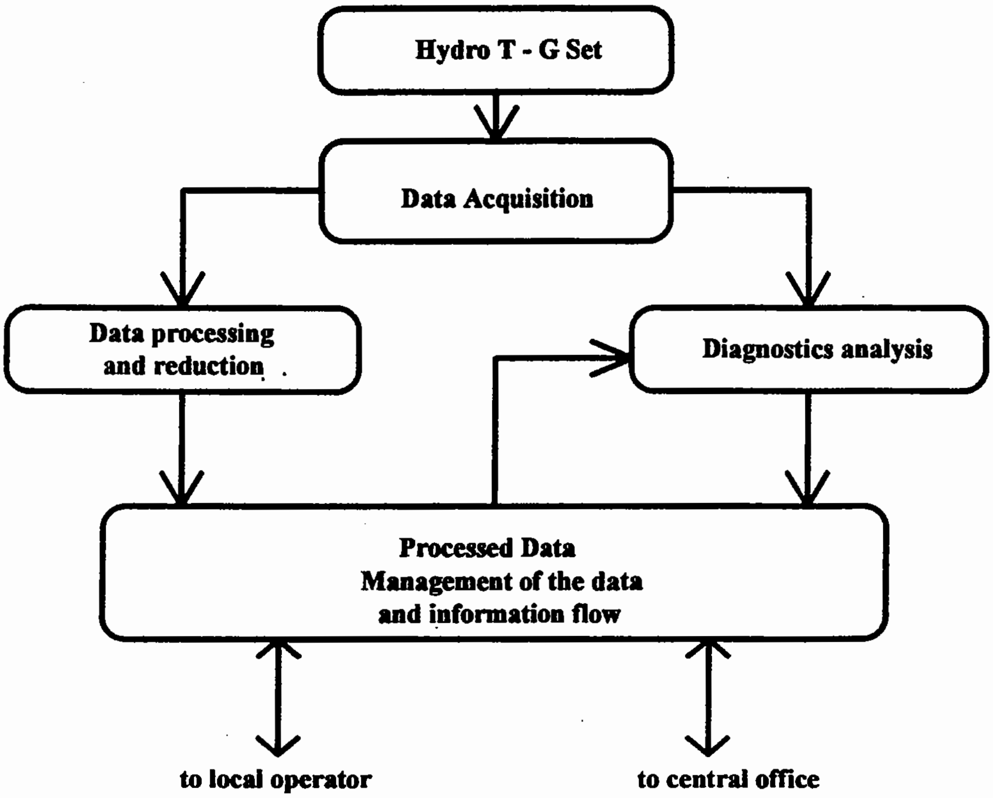


Figure 5.
Simplified functional block diagram of the system

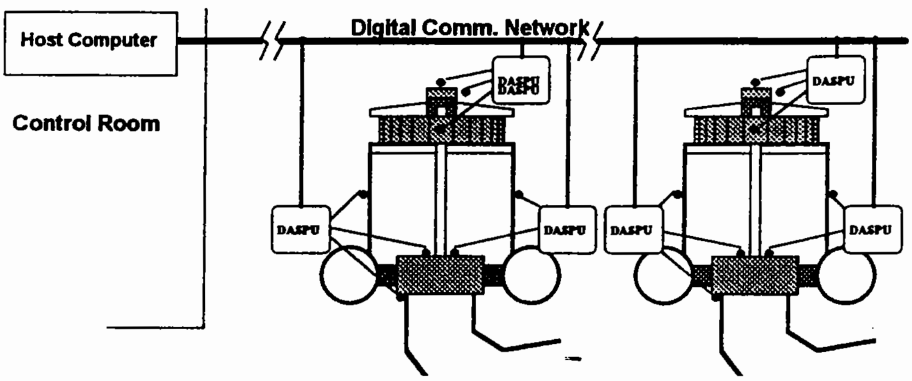


Figure 6.
Distributed monitoring system

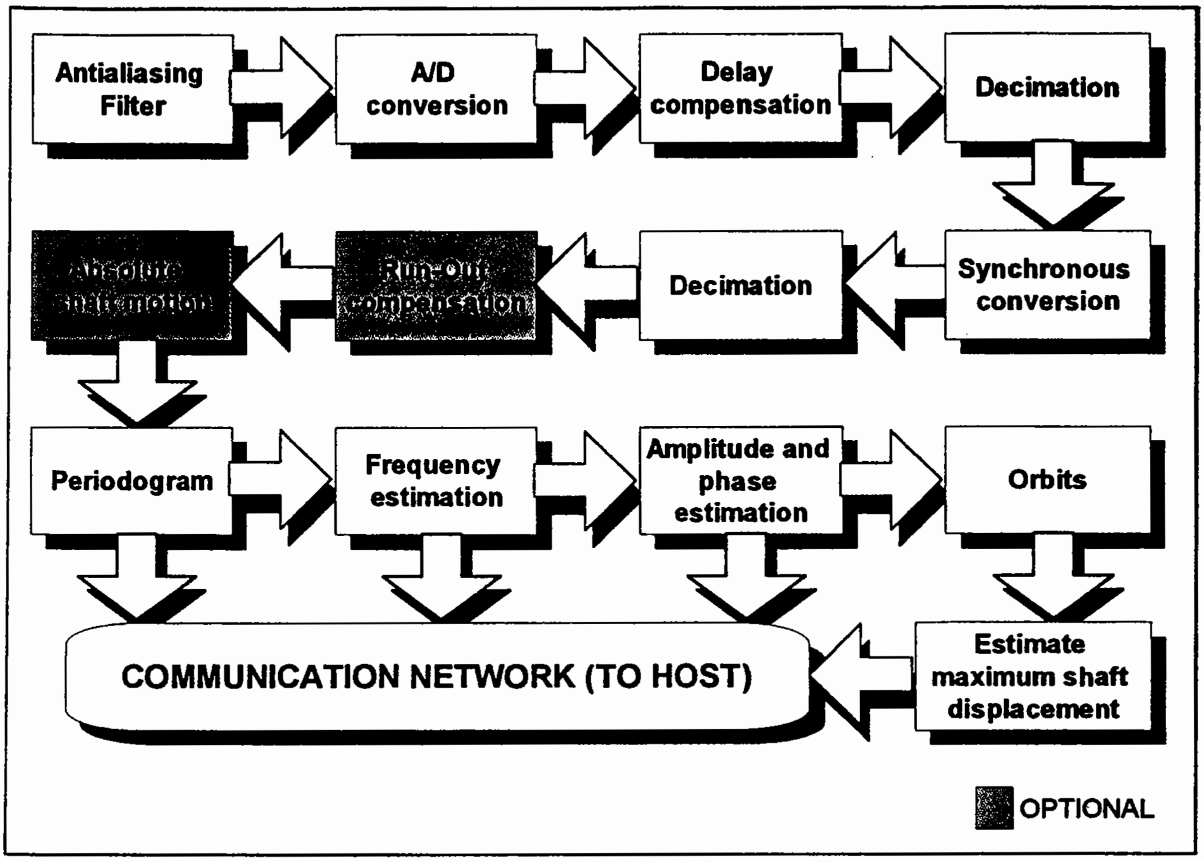


Figure 7.
Functionality of the dynamic DASPU. Schematic of the data processing for shaft line vibration

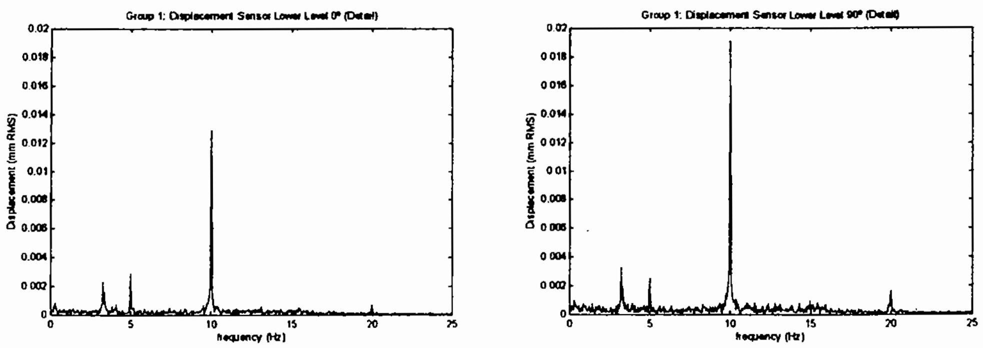


Figure 8.
Examples of data display: Displacements spectra at turbine bearing level up to 25 Hz.
Load: 95 MW