MCMSCADA + Diagnostics

Diagnosis

Diagnostic feature allow the user to plot the selected parameters of MCM. The user can select or unselect any of the parameters of MCM clicking on the colored cells. The selected cells are shown with black back color. After selection of the parameters the user may right click one of the grids and select plot from the popup menu to plot the selected parameters as shown below.

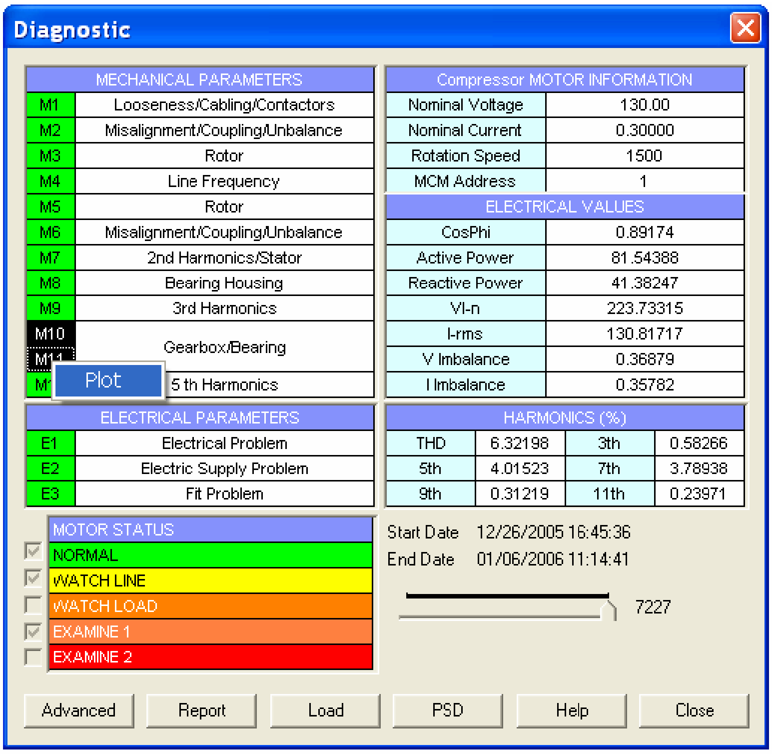

Figure 1: Diagnostic Window

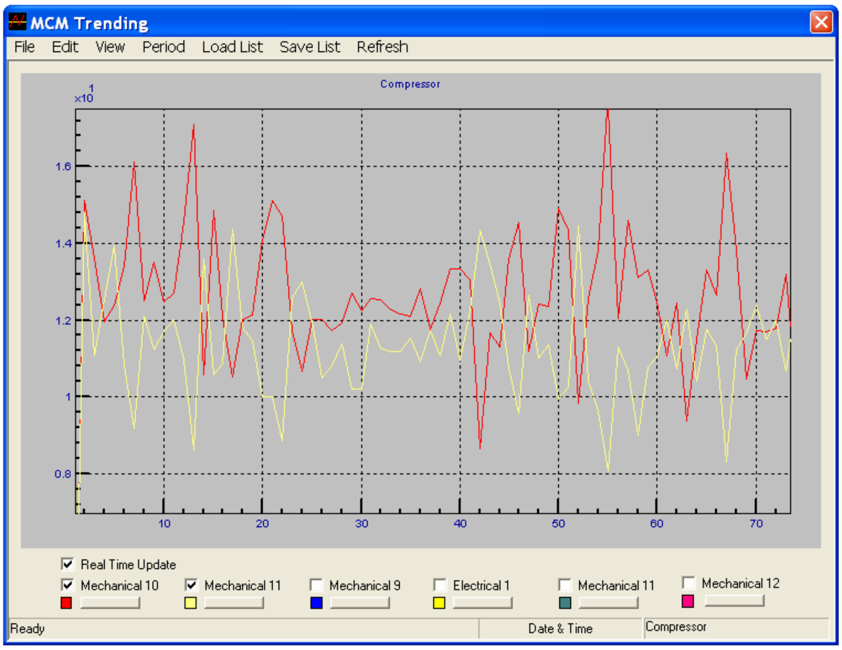

Figure 2: Plot of Mechanical Parameters 10 and 11

Advanced:

Power Spectral Density (PSD) intervals can be seen by pressing the advanced button as shown in below figure. Each mechanical parameter's corresponding minimum and maximum frequency points in Hz are displayed in this window

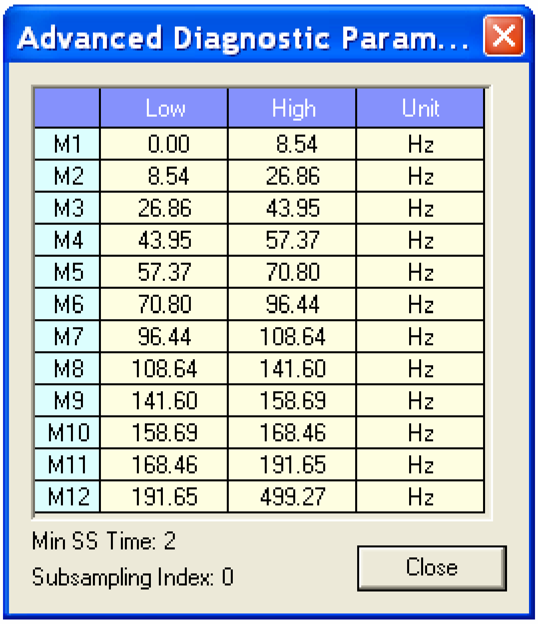

Figure 3: PSD Intervals

Report:

Diagnostic feature can prepare a report for the currently selected MCM by pressing report button as shown below. This report can be printed or sent as email attachments to selected recipients by pressing the appropriate buttons on the MCM report window toolbar.

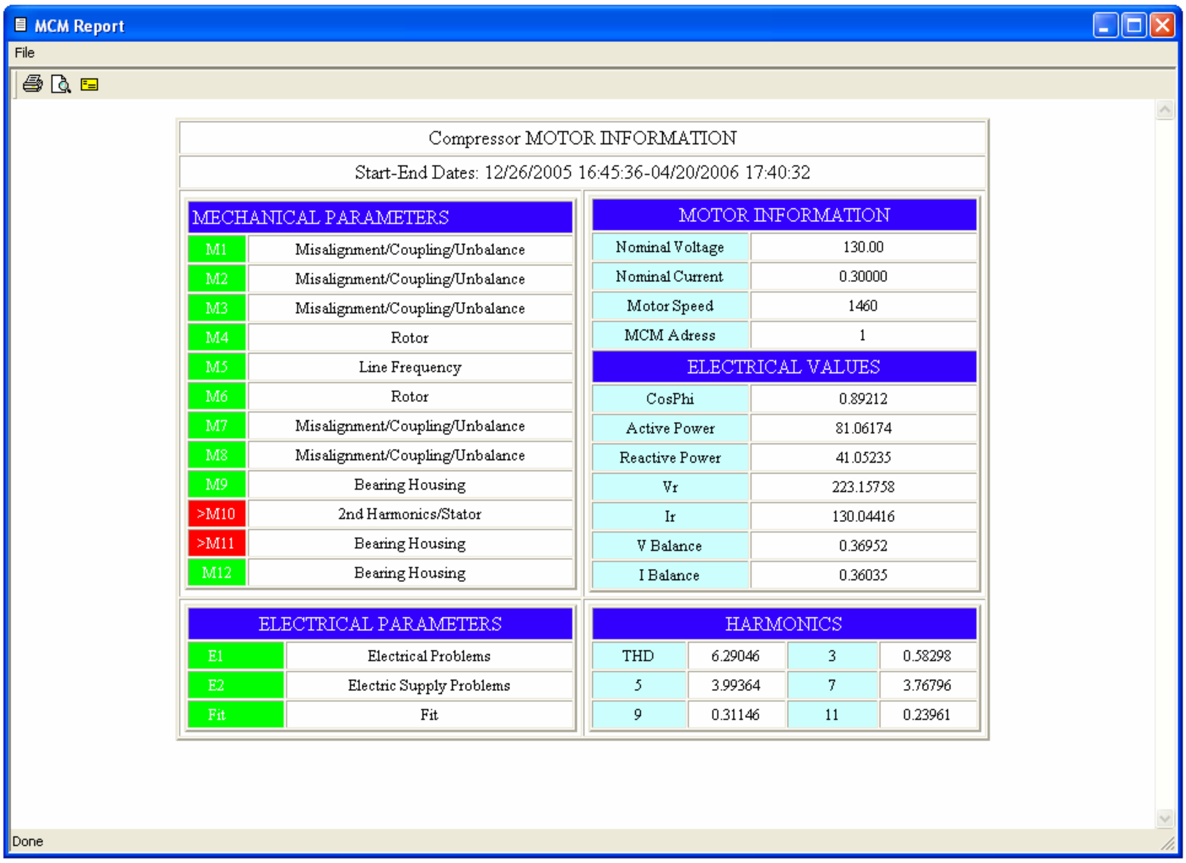

Figure 4: Diagnostic Report

Load:

In order to make analysis on Diagnostics window, Diagnostic information has to be downloaded from MCM. MCM diagnostic information can be downloaded by pressing load button. In order to download Diagnostic information, MCM must be in IDLE mode and learning phase of MCM has to be completed. Otherwise MCMScada will not be able to access diagnostic information and it will display below message.

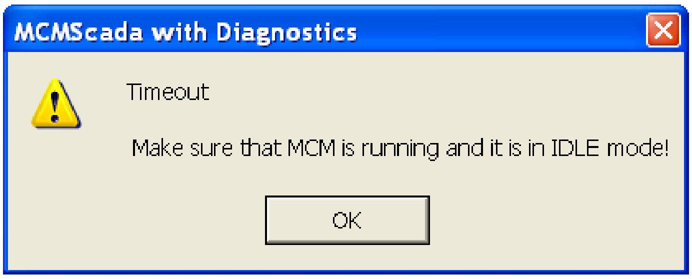

Figure 5: Timeout message

PSD:

Diagnostic feature also allows the user to plot Power Spectral Density (PSD) graphs of D and Q phases as shown in below figure. There are four PSD graphics in this window. These are Average values of D and Q phases and Variance of D and Q phases. Average and variance values are obtained during the learning period of MCM.

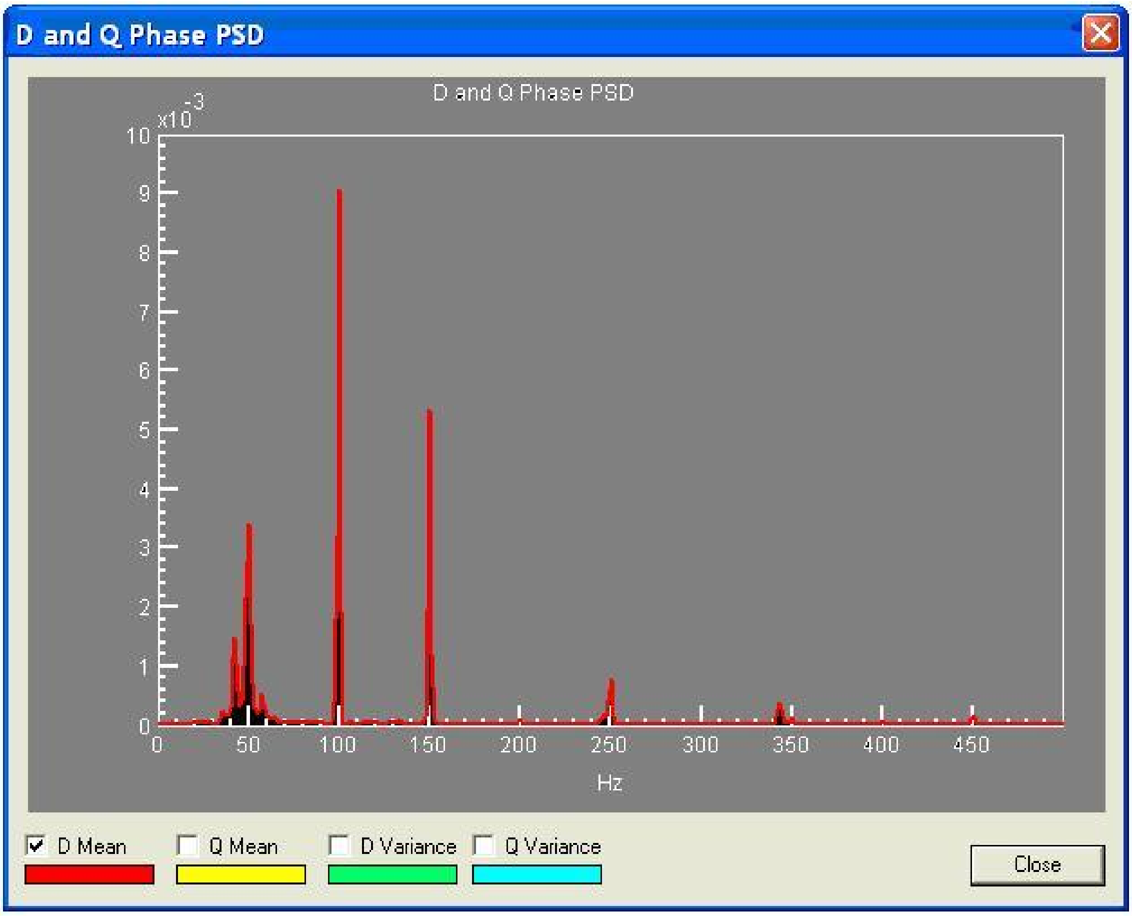

Figure 6: Plot of D Phase Mean Parameter

Equipment Faults and Their Diagnoses Using MCM

MCM uses a model based fault detection and diagnostics technique. In this technique, the expected dynamic behavior (model) of the three phase system under varying conditions, such as load, is determined and compared with the measured dynamic behavior to monitor abnormalities. MCM first learns the system for a period of time through acquiring and processing the real-time data from the system. The data is processed using system identification algorithms for the calculation of expected dynamic behavior and the model parameters. The changes in the parameters of the system indicate to abnormalities developing in the system. Further processing of these parameters is used for diagnosis.

As opposed to traditional vibration and current signature analysis, this approach uses a cause-effect (input-output) relationship and therefore immune to the surrounding noise or noise in inputs. Also the difference between expected and actual behavior filters out and enhances ONLY abnormalities generated by the system which allows to earlier and accurate warnings. The expert system approach eliminates the needs for data base or record keeping, expert personnel, time consuming data gathering and analysis. It provides comprehensive (mechanical and electrical as well as driven system) fault coverage though it measures only voltages and currents.

MCM uses the electric motor of the equipment as a sensor. Therefore, any fault of the equipment that affects the motor or the three phase system is also observed by MCM.

MCM first learns the motor-based system for a period of time by acquiring and processing the motor data. The results of the processed data are stored in its internal database and a reference model is established. This reference model basically consists of model parameters, their mean values and their standard deviations. While monitoring, MCM processes the acquired motor data and compares the results to the data stored in its internal database. If the results obtained from the acquired data are significantly different from the reference model, MCM indicates a fault level. The level is determined by taking into account the magnitude and the time duration of the difference. In total, MCM monitors and compares 22 different parameters (model parameters). These parameters are classified into three groups, electrical parameters, mechanical parameters and fit parameters. These are explained in detail in the following sections.

1. Electrical Parameters

There are 8 parameters in the first group which are called electrical parameters. These are the network equivalent parameters and are correlated to the physical parameter of the motor, like inductances, resistances, etc. They are sensitive to electrical faults developing in the motor. MCM evaluates and analyzes the differences between the model parameters at any instant and the average value of the same parameters that are obtained during the learn stage. These differences are normalized with respect to their standard deviations obtained during the learn stage. Hence the values indicate the number of standard deviations they are away from the average values obtained during the learn stage. If they exceed threshold values, than an alarm is given. The changes in their values are associated with the faults that are developing in the system. As an example an isolation problem in winding will affect the parameters associated with resistances. Their change will allow MCM to detect the isolation problem at an early stage. Though they are primarily used to detect electrical problems, they also can indicate mechanical problems as well. As an example an imbalance or gear problem would cause dynamic eccentricity in the air gap. This eccentricity will cause a change in the induction parameters and therefore in the model parameters. By monitoring the changes in these model parameters imbalance can be detected at an early stage. This eccentricity eventually affects bearing and it will also eventually damage the bearing. Therefore its detection at an early stage can prevent further damages

The electrical parameters are further classified in two groups, E1 (internal) and E2 (external) parameters. Electrical parameters 1-4 (E1) indicate problems associated with rotor, stator, winding etc. while 5-8 (E2) indicate electrical supply problems such as voltage imbalance, isolation problem of cabling, capacitor, motor connector, terminal slackness, defective contactors etc.

2. Mechanical Parameters

The parameters in the second group are sensitive to mechanical faults such as load imbalance, misalignment, coupling and bearing problems. They are called Mechanical Parameters 1-12. These parameters are obtained from the frequency spectrum of the electrical signals by extracting information from the line current and voltage supplied to a motor. The variances in the stator-rotor air gap are reflected back in the motor's current through the air gap flux affecting the counter electromotive force. Therefore current carries information related to both mechanical and electrical faults. Hence faults will exhibit a change in the frequency spectrum of the current in specific frequencies.

MCM uses the power spectral density (psd) obtained from the differences between the expected current obtained from the model and the actual current. These differences include only abnormalities generated by the motor. Therefore, they are immune to the noise or harmonics present in the supply voltages. The mechanical parameters indicate the power level of the difference between measured and estimated current at frequencies they occur in terms of number of standard deviations. If they exceed the threshold value, which is 8, an abnormality is indicated.

The mechanical parameters (M1-M12) correspond to the 12 maximum values obtained in the frequency spectrum. These parameters are also used for diagnoses. The frequencies they occur indicate the type of fault, i.e., an imbalance, loose foundation, oil whip, fan blades, inner or outer race of bearing etc. These parameters provided to the user for trending and diagnostic purposes. Some common equipment faults and their psd spectrum are outlined below based on the frequencies depended on rotational speed and the line frequency.:

Faults Related to Rotational Speed (RPM)

Unbalance/Coupling/Misalignment/Bent Shaft/Loose Rotor/Eccentric Rotor

Unbalance, misalignment and bent shaft appears at 1xRPM, 2xRPM and 3xRPM. Depending on the number of pole pairs of the motor one of those frequencies may coincide with the line frequency. In such a case, the other two frequencies will be more appearant.

Loose Foundation

Loose foundation appears at frequencies between ½ x RPM and 0.75 x RPM.

Oil Whirl

Oil whirl appears between 0.38 x RPM and 0.75 RPM.

Belts/Transmission Elements

Problems with belts and transmission elements appear at belt/transmission element frequency and its multiples. Belt frequency may be calculated using

Belt Frequency= 3.142(D/L)xRPM where D and L are the diameter of the motor mounted pulley and L is the length. A range of frequency between 0.5 x RPM and 0.75 RPM is used in MCM diagnostic.

Motor Bearings

There are formulas to calculate bearing problems which require specific knowledge about the bearing geometry. However, good approximations for bearing frequencies for most common ball bearings are as follows:

Outer race fault= # of rollers x RPM x 0.4

Inner Race= # of rollers x RPM x 0.6

Fundamental Train Frequency = RPM x 0.4

MCM Diagnostic indicates bearing housing problems between 3.25 x RPM and 6.5 RPM. Others appear at higher frequencies between 6.5 RPM and 20 RPM.

Pumps

Unbalance: Impeller unbalance shows up at 1xRPM of pump speed. Unbalance can also be caused by broken blades. For centrifugal pumps vane frequencies can be monitored at a frequency that is equal to the number of vanes times the pump speed.

Cavitation: MCM detects the cavitation between 0.5 x RPM and 1.5 RPM as well as at higher frequencies 12 x RPM and 20 x RPM.

Fans

Fan unbalance shows at 1 x RPM, 2 x RPM and 3 x RPM. Unbalance can be caused by dust buildup, broken blades etc. Fan blade defects show up at # of fan blades x fan RPM.

Gearboxes

Gear defects can be detected at frequencies around # of gear teeth x RPM.

Faults Related to Line Frequency

Contactor/Loose Cable

These faults appear at frequencies between 0 Hz and 0.5 Hz.

Eccentricity in the air gap

If the air gap is not uniform it generates unbalance forces on the rotor which in turn can induce a peak at 2 x line frequency.

Loose windings

If the stator windings are slightly loose the peak at 2 x line frequency will increase. This looseness causes scraped thread isolation which leads to short circuits between the windings. It can also cause short circuits between the windings and earth, which leads to stator breakdown.

Problem with rotor bars

These problems show themselves at sideband frequencies around the line frequency. An important cause of problems in electrical motors is when the rotor cracks. This mainly happens to motors often exposed to starts with load. During start the current in the rotor bars become very high as the speed of the rotor is much lower than the synchronous speed. The electric current causes heated rotor bars, causing them to expand in relation to the rotor itself. In turn, the difference in resistance between the rotor bars results in uneven heating and uneven expansion. This leads to cracks in the joint between the bars and the shorting rings. When a crack appears the resistance in the bar increases, which in turn increases the heating and thereby enlarges the crack. The current also becomes larger in the other rotor bars as the current has been reduced in

Stator Problems/Winding Shorting

These problems show themselves, in general, at line frequency, especially twice the line frequency ad its multiples.

3. Fit Parameters

The parameters in the third group are sensitive to changes in the behavior of the system. These are called fit parameters (or residuals). There are 2 fit parameters. These are deviations between the actual currents (d phase and q phase) and the currents calculated from the model. If these parameters increase above their threshold values the system is considered to behave differently than it did during the learn stage which indicates that a fault is developing in the system.