# Web-based Solution of Data Integration for Predictive Maintenance of Rotating Machines

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## 1 Abstract

An innovative integrated data management solution is being developed in cooperation between Emaint and Iris Power. The goal of this project is to use current technology for an integrated methodology for data management using the results from on-site measurement sensors to facilitate condition-based monitoring that supports predictive maintenance. This solution makes use of information technology (cloud/Internet/mobile phones) to provide a modern and efficient way to produce a continuous classification of the condition of all assets of a fleet along with individual diagnostics for any unit at any time. The system acquires data either directly from continuous monitors or indirectly from portable instruments and autonomous monitors. After the application of algorithms, the risk factors and confidence factors for each of the monitored technologies are determined. If the results are outside of expected norms, then email/text notifications are sent and appropriate work orders created. Users can also access and display the complete data for every measurement series at any time on any device. Plant, asset and sensor selection is done via a user-friendly interface displaying a simple rating of the results for every technology or if desired, details of the test results. The ready availability of centralized, simplified information makes it possible for specialists and managers alike to assess the condition of any asset in a few minutes. Thus, it is possible to plan any predictive maintenance more effectively or request additional testing when doubts remain about active degradation mechanisms. This solution was developed with an expandable modular approach so that new diagnostic tools can easily be added in the future.


## 2 Introduction

The traditional model of time-based maintenance that was used when personnel and time were available, no longer meet the needs of the current situation. To effectively keep reliability at an acceptable level, it is necessary to transfer from time-based maintenance to condition-based maintenance (CBM). Unfortunately, this is not a simple task, because knowing the condition of an asset calls for a variety of results from different constantly available measurement sensors. This information then needs to be logged, analyzed and displayed in order to have an appreciation of the asset condition. The data information overload is overwhelming and therefore, assets in trouble often go unnoticed.

Over the years a variety of data management platforms have been proposed [1-6]; however, as technology changes so do the requirements for user interface. The goal is not to just have a centralized data bank, but to display condition indexes in a simple comprehensive form and to alert personnel when the condition requires further action. The user interface had to be simple and easy to use for anyone, even those with little knowledge about specific diagnostic results and their interpretation. At the same time, it meant providing detailed results from every diagnostic test so that the specialist could go back to the data and perform a more detailed diagnostic than that calculated automatically. The system is not an expert system, because it does not automatically correlate the condition indexes from each diagnostic tool with the failure mode analysis.

This paper presents some of the features of this web-based solution for data management for predictive maintenance of rotating machines.


**Figure 1. Data Extraction**

## 3 Data Extraction

The first stage of the system is the transfer of sensor data from the continuous systems or portable instruments. Data can be transferred to the cloud either automatically from specially equipped or internet enabled continuous systems, and manually from portable instruments or autonomous continuous systems. [Figure 1]

During the data extraction process, proven algorithms are utilized to evaluate the data and to assign risk and confidence factors. *Risk factors* will be based on specific factors relative to the tools, such as rate of change and magnitude for partial discharge, shaft monitoring and endwinding vibration or comparison to other coils/poles and rate of change for flux monitoring. These risk factors will be assigned based on the sensor results as well as what is considered appropriate for the asset's design and operating conditions. For example, in regards to partial discharge measurements using Iris Power equipment, the magnitude values will be compared to the results of the Iris Power database for the appropriate voltage class [7].

*Confidence factors* are based on stability of the risk factor over time, number of data inputs, and the span of time over which monitoring has occurred. Risk and Confidence factors will range from 0-10 with 0 being low risk and low confidence and 10 high risk and high confidence. The extracted data is then available for transfer into the Computerized Maintenance Management Systems (CMMS) for notifications, tracking, and easy displays for the users. Using factors that are asset design specific, makes it possible to directly compare the risk factors across multiple assets.

For example for a condition-based monitoring system it would be possible to view all of the assets in your CMMS for multiple technologies, such as Partial Discharge (PD), Round Flux (RF), Salient Flux (SF), Endwinding Vibration (EV), and Shaft Monitoring (SM), as shown in Figure 2 and Figure 3.

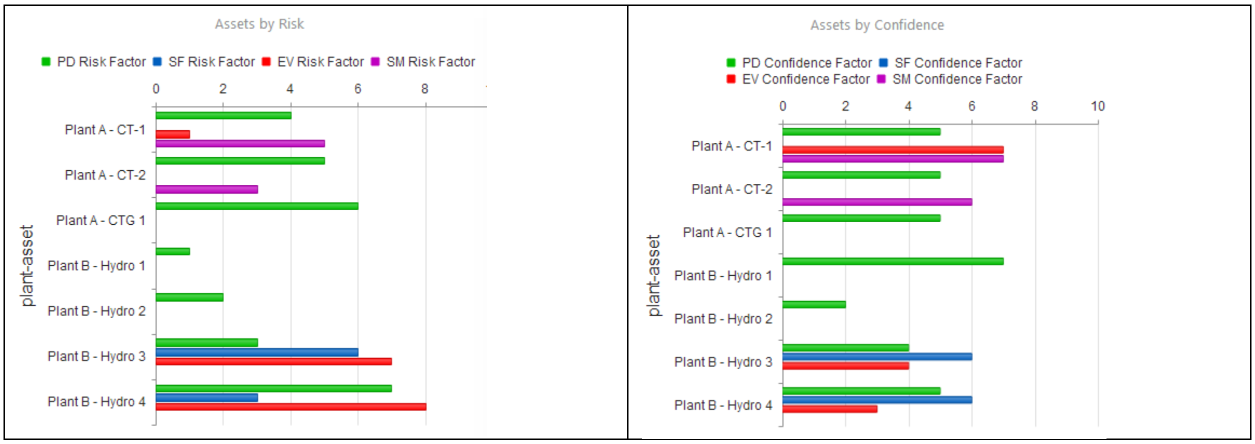


**Figure 2. Risk and Confidence Factors**

| ID Number | Date Taken | PD Risk | PD Conf | EV Risk | EV Conf | SF Risk | SF Conf | RF Risk | RF Conf | SM Risk | SM Conf |
|---|---|---|---|---|---|---|---|---|---|---|---|
| FILTER Printable? | | | | | | | | | | | |
| HYDRO_3 | 03/20/2017@10:12:52 | 4 | 5 | 6 | 6 | 5 | 4 | 4 | 5 | 6 | 6 |
| HYDRO_3 | 03/20/2017@10:15:58 | 4 | 5 | 6 | 7 | 8 | 7 | 6 | 5 | 4 | 4 |
| CT1 | 03/22/2017@16:27:58 | 4 | 5 | 1 | 7 | | | 7 | 5 | 5 | 7 |
| CT2 | 03/22/2017@16:27:58 | 5 | 5 | | | | | 6 | 4 | 3 | 6 |
| CTG1 | 03/22/2017@16:27:58 | 6 | 5 | | | | | 3 | 7 | | |
| HYDRO_1 | 03/22/2017@16:27:58 | 1 | 7 | | | | | | | | |
| HYDRO_2 | 03/22/2017@16:27:58 | 2 | 2 | | | | | | | | |
| HYDRO_3 | 03/22/2017@16:27:58 | 3 | 4 | 7 | 4 | 6 | 6 | | | | |
| HYDRO_4 | 03/22/2017@16:27:58 | 7 | 5 | 8 | 3 | 3 | 6 | | | | |

**Figure 3. Risk and Confidence Factors (green is low risk and high confidence, whereas brown is high risk and low confidence)**

# 4 Data Transfer to CMMS

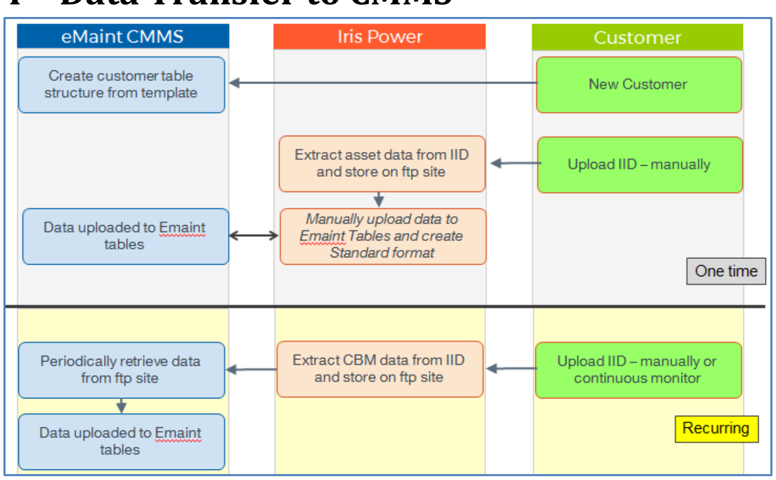


**Figure 4. Data Transfer to CMMS**

There are two (2) stages to the data transfer to the CMMS. The first stage will be manually triggered, and will then automatically upload all of the asset information from any existing Iris instrument databases (IID). This will only need to occur one time per asset. [Figure 4]

The second stage consists of recurring events that will automatically happen as new IID data loaded into the cloud repository has been analyzed via the data extraction process.

# 5 Notifications

Notifications via email or SMS text will be sent whenever a new work order is created. Work orders will be automatically created by the CMMS when one of two conditions occur: (1) routine calendar-based triggers for data collection, such as every six (6) months for partial discharge and (2) when the results exceed pre-defined limits based on the data extraction algorithms for comparisons, trends, or magnitudes.

Examples of the notifications to be received by email/SMS are:

| |
|---|
| **PD Trend Exception Report**<br>HYDRO_4 at Plant 2 South 3/15/2017 09:48:39<br>PD on A1 is above the High level<br>PD on A1 is above the Moderate level and has moderately increased over the last 3 months<br>PD on C1 is above the Moderate level and has significantly increased over the last 3 months |
| **Salient Flux Exception Report**<br>HYDRO_3 at Plant 2 South 03/22/2017 13:15:31<br>Number of shorted turns have significantly increased over the last 3 months<br>Number of shorted turns have significantly increased over the last 6 months |

# 6 Data Display

For condition monitoring, the trend analysis is arguably the most important aspect. Trends are easily selected by plant, asset and/or sensors. These are viewable as dashboards on tablets, mobile devices and of course computer screens. The data extraction will actually evaluate the trends for the notifications and determination of risk factors.

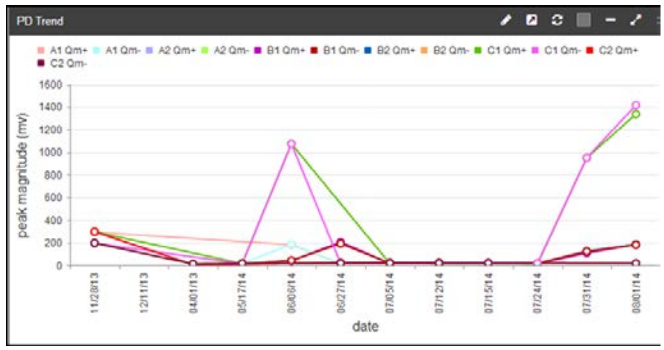


**Figure 5. Sample PD Trend Plot**

As described above, work orders are created based on calendar-based frequency and/or an exception occurs in one of the monitoring technologies. Using the CMMS application, it is possible then to view which assets have had exceptions or require additional attention. If the work order is completed or acknowledged, then they can be closed and all screens will be appropriately updated.

| | Asset Description | Plant (Site) | WO No. | WO Date | Work Description |
|---|---|---|---|---|---|
| | Hydro 1 | Plant B | 110 | 03/13/2017 | PD Data Collect and Analyze |
| Asset Description: Hydro 14 | | | | | |
| | Hydro 14 | Plant B | 114 | 03/13/2017 | PD Data Collect and Analyze |
| Asset Description: Hydro 2 | | | | | |
| | Hydro 2 | Plant B | 111 | 03/13/2017 | PD Data Collect and Analyze |
| Asset Description: Hydro 3 | | | | | |
| | Hydro 3 | Plant B | 153 | 03/15/2017 | PD on B1 is above the Moderate level and has sig... |
| | Hydro 3 | Plant B | 147 | 03/14/2017 | EV on 1T is above the Moderate level EV on 1T is ... |
| | Hydro 3 | Plant B | 156 | 03/15/2017 | Number of shorted turns have significantly increas... |
| | Hydro 3 | Plant B | 112 | 03/13/2017 | PD Data Collect and Analyze |
| | Hydro 3 | Plant B | 131 | 03/21/2017 | Flux Data Collect and Analyze |
| Asset Description: Hydro 4 | | | | | |
| | Hydro 4 | Plant B | 135 | 03/05/2017 | PD on A1 is above the High level PD on C1 is abov... |
| | Hydro 4 | Plant B | 106 | 03/04/2017 | PD on A1 is above the Moderate level and has mo... |
| | Hydro 4 | Plant B | 157 | 03/15/2017 | Number of shorted turns have moderately increas... |
| | Hydro 4 | Plant B | 107 | 03/04/2017 | PD on A1 is above the Moderate level and has sig... |

**Figure 6. Work Orders**

# 7 Asset Ranking

Assets can be ranked based on their risk based on the Ranking Index for Maintenance Expenditures (RIME). RIME ranking is based on three values: Asset criticality (RIME Code), Work Order Priority and age of Work Order (Factor).

$$\text{RIME Rank} = (\text{Priority} * \text{RIME Code}) + \text{Factor}$$

Work Order Priority is determined by Risk Factor and Confidence Factor for all technologies associated with an asset. The higher the risk and confidence factor, the higher the work order priority. For example, WO Priority may be set as follows:

| WO Priority (high is factor ≥ 7 and low is ≤ 3) | | Asset Criticality (RIME Code) examples | |
|---|---|---|---|
| 10 | High risk and high confidence | 10 | Shuts down entire production |

| | | | |
|---|---|---|---|
| 9 | High risk and mid confidence | 9 | Shuts down key production |
| 8 | High risk and low confidence | 8 | No spare |
| 7 | Mid risk and high confidence | 7 | Mobile equipment |
| 6 | Mid risk and mid confidence | 6 | Spared production equipment |
| 5 | Mid risk and low confidence | 5 | Support equipment |
| 4 | Low risk and high confidence | 4 | In frequently used |
| 3 | Low risk and mid confidence | 3 | Miscellaneous equipment |
| 2 | Low risk and low confidence | 2 | Spare equipment |

Factor is determined by the amount of time that has passed since the work order was originally issues as:

FACTOR = (Today's Date - WO Date)/7 * 5

# 8 Integrated Data Displays

Since risk factors are calculated based on sensor results appropriate to a specific asset design and operating conditions, then risk factor data can be displayed by technology as shown in Figure 7 or by asset Figure 8.

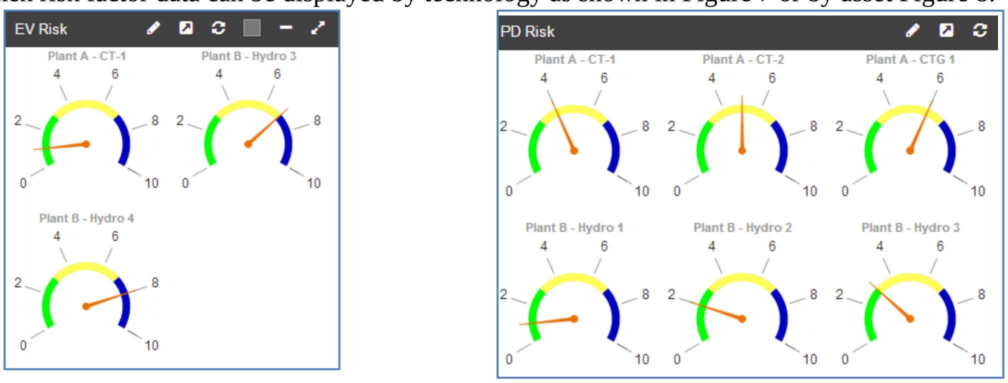


**Figure 7. Risk Factors by Technology**

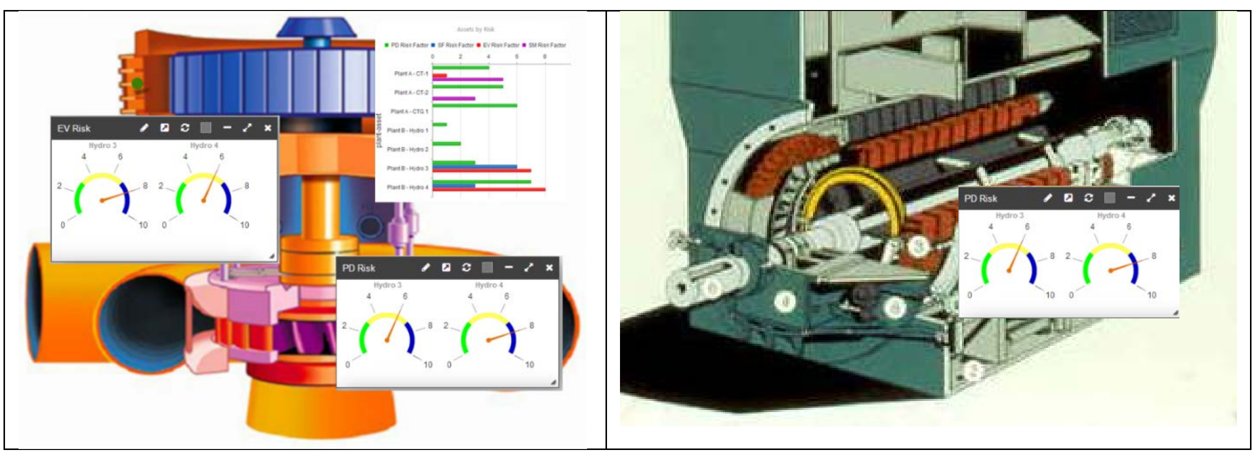


**Figure 8. Risk Factors for an Asset**

# 9 Conclusion

Through a joint effort between Emaint and Iris Power, an integrated data management system for Predictive or Condition-based maintenance is being developed. This system will use modern technology to collect, amalgamate and display data from various sensors used to monitoring rotating machines. The entire system from the sensors to data collection devices and now through the cloud to informative displays and notifications will enable maintenance personnel to quickly and easily be informed of the status of their rotating assets. With the end result defined as planning effective and timely maintenance when required.

# 10 References


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