KNOWLEDGE MANAGEMENT FOR WIND PARK MANAGEMENT

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SUMMARY

Knowledge Management (KM) is a process being adopted by companies to become more efficient and effective with the knowledge held within their organizations. The need for this can be seen daily, from issues dealing with people retention, the ever-increasing average age of operations and maintenance professionals, reinventing processes, and the pressure to do more with less. Pressures in the industrial market have many people voicing that:

- They can collect the data, but have no method for using it effectively or efficiently.
- They cannot maintain consistency in their analysis efforts—various personnel analyzing data with different levels of experience.
- The different skill levels of employees found operating globally further complicate their situation.
- They cannot maintain continuity of the maintenance effort; history is lost with no effective means to improve.

Technology now exists to support the KM process for Wind Turbine Generator (WTG) to improve asset management. Improvements come in the form of automated machinery health diagnosis (based upon the knowledge of the experienced workers), real-time notification of deviations in plant process variables, and Key Performance Indicators (KPIs). This knowledge can then be shared across the wind parks or enterprise, using existing network, web, or email solutions.

KEYWORDS

@ptitude, CMMS, Decision Support Systems, EAM, ERP, Information, Intellectual Capital, Knowledge Management, Models, SKF

1 WHAT IS KNOWLEDGE MANAGEMENT?

Knowledge Management (KM) is the process through which organizations generate value from their intellectual and knowledge-based assets. The term knowledge assets refers to the knowledge regarding markets, products, processes, technologies, and organizations that a business owns, which enable it to generate profits, value, etc. This knowledge is maintained in the computers, minds of the employees, filing cabinets, notebooks, and other data warehouses within the organization.

When it comes to WTG, KM pertains more towards how the machinery and processes work, and also how to maintain them. The knowledge required for these functions is more specific, and therefore solutions to capture it must be geared specifically toward these industries.

A Knowledge Management initiative must also be tied back to business goals. While work performed under the KM mantra is good for the company, ideas will ultimately fail without a connection back to the business needs.

It is important to define the type of knowledge that will be addressed in the scope of this paper. For KM, knowledge is represented in two types: explicit and tacit. Explicit knowledge can be easily written down and documented. This type of knowledge can be found in FAQs, knowledge databases, expert systems, systems executing business rules, and traditional databases. It can handle requests that can be expressed in forms of easily understandable logic. However, explicit knowledge falls short of making complex decisions involving many different types of variables which the mind easily does. This is where tacit knowledge comes in to place.

Tacit knowledge is more of an intangible knowledge that resides in a person's mind, and is not easily written down. It is based more on experiences, intuition, and hunches. For example, riding a bicycle is tacit knowledge. This knowledge is most often untapped, but if someone is able to convert it into explicit knowledge, it would provide a treasure trove for applications.

The use of tacit knowledge is still an emerging field with many rewards and pitfalls, and therefore many technologies and systems do not handle it. Explicit knowledge, on the other hand, is easily understood and can be embedded into technology very easily. This is why it will be the focus of this paper.

2 THE CASE FOR KM

There are several issues facing companies that can be addressed by using Knowledge Management. These issues include:

- Information overload
- Corporate "brain drain"
- Training
- Increasing efficiency
- Making Enterprise Asset Management (EAM) / Computerized Maintenance Management Systems (CMMS) more effective by providing them with "live" data
- Sharing knowledge and maintaining consistency in decision making
- Industry competitive pressure

2.1 Information Overload

By the time the 90s decade had reached its end, we began to hear a common concern from our customers regarding information overload. Electronics capable of delivering live data directly to our customers' desktops and hard drives supporting gigabytes, gave our customers as much information as they wanted. The problem was that there was too much information, and it became difficult to see the forest through the trees. Below are a couple of examples where too much information leads to unfavorable results:

- In the case of the Three Mile Island nuclear power plant disaster, operators had so many error messages that they could not identify the main cause of the problem. There were over 100 alarms in two minutes. By the end of the disaster, one of the nuclear reactors suffered a partial meltdown.
- Controlled experimental studies have suggested that reasoning decreases when large amounts of information are provided. As military systems increase in complexity, performance figures, such as weapons accuracy,

> have been shown to decrease. Fighter pilots often disable warning devices in the cockpit to avoid the information overload that they and their colleagues have experienced in life threatening situations. (1)

With WTG, the measurement data comes from DCS systems, PLC's, Condition Monitoring vibration systems, data historians, reports, as well as many other sources. The issue becomes how to deal with all of this efficiently and effectively to make proper use of the information we need to review. A decision support system (DSS) with the correct knowledge can filter down a multitude of discrete measurement values to identify the actual fault.

To help clarify a new term used here, a decision support system (DSS) is a computer program (possibly including an expert system or artificial intelligence) that analyzes business data and presents it in a way so that users can make business decisions more easily. It is an "informational application," in distinction to an "operational application" that collects the data in the course of normal business operation. Typical information that a decision support application might gather (in the context of this paper) and present would be:

- Operational problems.
- Machinery faults.
- Changes to Key Performance Indicators.

Using a DSS, all of the above items would be reported in real-time as the data is collected and analyzed.

2.2 Corporate Brain Drain

Advances in technology have created many new markets that were not in existence 20 years ago. For example, a study released by Andersen Consulting estimates that by 2002, the Internet had directly created 5.8 million jobs in the United States and 3 million jobs in the six European countries surveyed. These are defined as jobs created by pure Internet companies, such as portals, software consultants, web designers, telecommunications, and ISPs. This represents only jobs directly related to the Internet and not the many other markets that are derivatives of this and other technologies.

Many people that have entered the job market in the past 10 to 20 years have focused on these new technology markets, and left the older traditional Industrial jobs to a much smaller group. The amount of people entering the Maintenance field as well as the Operations field is smaller than the people retiring, leaving a shrinking work force. The result is the average age of Operations and Maintenance workers in some plants is 48 years. (2). This number is not orientated to a specific region of the world, as this is a global problem with many nations facing this issue.

SKF has seen these problems directly through our customers and partners. IDCON is a service company based in the United States, and they have told us that 80% of their clients indicate an attrition rate among their maintenance craft personnel of 40-60% in the next five to seven years. Only 10% of these clients have a good apprentice program or plans for retaining skills.

2.3 Training

To borrow a quote from a Chinese Proverb:

> *"I hear and I forget. I see and I remember. I do and I understand."*

The mechanism in which people receive training differs greatly across companies and industries. Classroom time to learn specific topics is very important, but the best teacher of all is hands-on experience. As always, the best of something usually is the most expensive, and on the job training is no exception. Since most companies do not have any formal knowledge repository, much of that is learned on the job becomes a personal collection of knowledge. Information is better understood through on the job training, but costs can also be high through bad judgment from inexperience. Worse yet, without a KM process in place, similar mistakes are repeated by new personnel taking over when the existing person changes jobs.

This problem became even clearer when we visited a customer with a strong Maintenance department, and discovered that the team had lost 90% of its experienced people in the last two years. They were now struggling to re-learn everything this team had already learned the last 10 years. How could this happen? The old Maintenance manager was promoted for doing an exceptional job at keeping unplanned downtime at an all time low. His successor, not understanding the intricacies of a good maintenance strategy, saw no need to maintain the number of people employed when the amount of machinery problems was small. The team was reduced in size (the experienced ones left) to match the amount of unplanned downtime, which after two years, started a reign of firefighting in place of proactive planning.

Now the team will spend the next five to ten years re-establishing previously acquired knowledge. If a proper KM process had been implemented, this re-establishment could have happened at a much faster rate with far fewer mistakes.

2.4 Increased Efficiency

Using a KM process with a DSS, employees can document what they know about the operational and maintenance processes, so that this knowledge is not lost. This knowledge can then be placed online to diagnose wind park issues as they occur in real-time. Emails are subsequently sent to designated personnel correlating to the fault that was identified. Below is an example from one of our customers of how @ptitude helps them make decisions in real time.

2.4.1 Real-time decision handling

One of our customers has a discrete manufacturing process in the machine tool market. The manufacturing configuration for the product has multiple stages and a special conveyor delivers the components to each stage in turn as the part is manufactured. The final product cannot be produced until each operation is complete, and thus the production rate is limited by the slowest machining operation (in other words, the 'bottleneck'). The manager in charge of that production line is responsible for all the production lines and is continually walking from line to line fixing any problems that occur.

One of the biggest problems for the production manager is when he spends too much time in one area solving a problem or attending meetings. If the bottleneck machine in a product line stops for too long of a period, the remaining part of the line will be waiting for parts. This of course causes the production numbers for that day to plummet. The production manager can fix these issues if he knows about them, but if he doesn't see them, productivity is lost. See Figure I for a graph of the lengths of stops from the bottleneck machine. As you can see, two-thirds into the shift something went wrong, which created efficiency problems.

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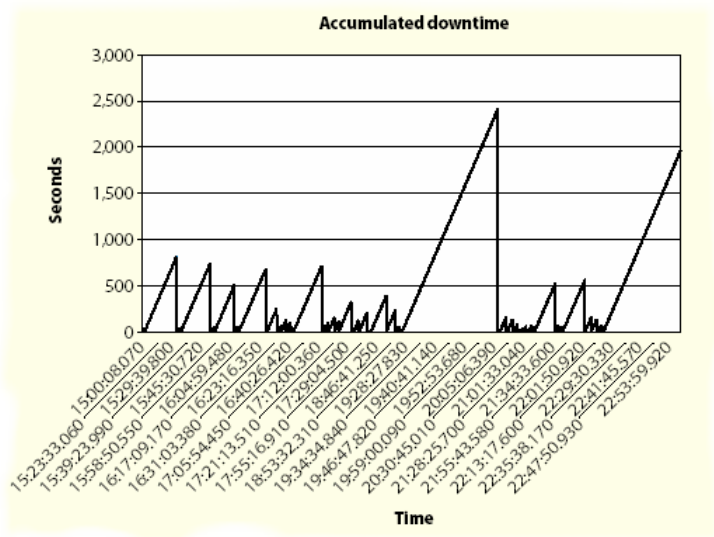

Figure I

After we installed a DSS which has criteria for a problematic bottleneck machine, he is automatically notified of a problem (Figure II). When the number of stops exceeds a preset limit, the model containing the production manager's knowledge triggers a fault. Once the fault is triggered, a message is sent in the form of an email to the production manager's inbox or mobile phone informing him of the problem.

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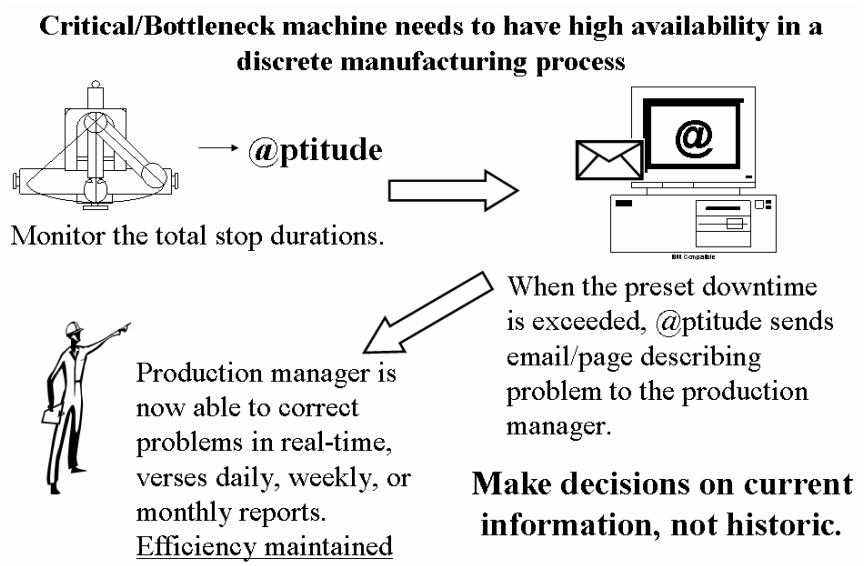

Figure II

Now the production manager can address the efficiency problem in real-time instead 2 hours later, at the end of the day, or end of the week. Decisions are made based upon current, "live" data, and issues are fixed as they occur. At this plant, the @ptitude software is also doing the vibration analysis and informing the Reliability Engineer of these issues. The production manager does not know the vibration is also being measured because the system singles out the production faults to only go to him. This is a simple example demonstrating one of the possibilities with a DSS driven by the customer's knowledge.

These benefits assist those who must do "more with less" and are limited by the number of hours in the day to accomplish their tasks.

Customers that are using a DSS with embedded knowledge have said the improved efficiencies have given them:

- a 20% increase in available time to perform other tasks.
- an increase in analysis efforts that would have cost the company $80,000 a year if contracted out.
- a 3% increase in product efficiency.
- a 1% decrease in down-time.

As described, these systems are intended to perform the day-to-day analysis which computers are perfectly designed to do. The decision process automation using the knowledge, or Intellectual Capital (IC), provides the freedom for people to spend more time on the higher level tasks, such as design issues, that bring a much larger return on investment. This progress into automation is similar to what the control industry experienced several decades ago.

2.5 Real-Time data for CMMS and EAM Systems

In the early 90's, the cost of personal computers and the power they delivered made an excellent conduit for the proliferation of Enterprise Resource Planning (ERP) system. These systems flourished and provided strong value on the business side of a company, but they lacked input from real data. All information fed into these systems was from manual entry and they were not driven from real operations or maintenance data. Also, during this time, Computer Maintenance Management Systems (CMMS) software became popular and was implemented throughout the Industrial marketplace. These systems provided the traditional scope of a work order generation and management, but were not connected to the ERP systems.

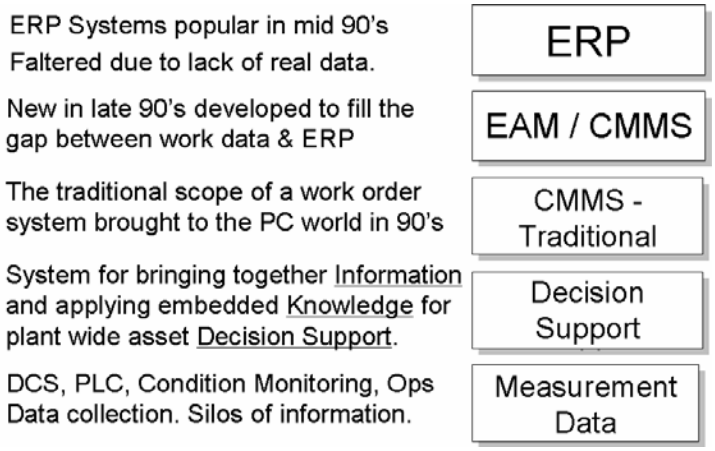

Figure III

In the late 90's, companies selling traditionally CMMS products began to increase the functionality of their package to move into the ERP arena. They enhanced their traditional CMMS product and created an EAM/CMMS product that would coincide with their new ERP systems. Likewise, ERP vendors began adding EAM/CMMS modules to their packages. These new software modules can feed the ERP systems live data from the EAM/CMMS systems. The automatic flow of EAM/CMMS information to the ERP systems provided better data to manage the business. The last missing piece was that the traditional CMMS functionality was not driven by a live data stream, and still relied on manual data input, so the process for a complete live data fed system was still incomplete.

The traditional CMMS function needed live data that would be based on the condition of the plant and machines to make the system complete. The data is unfortunately in the minds of the worker that enter data manually into these systems. One more piece of technology was needed to complete the loop. This is where Decision Support Systems, driven with the knowledge of the employees, takes measurement data from DSC systems, PLCs, Condition Monitoring packages, and Operations, and converts it into actionable tasks for the CMMS module. See Figure 1 for a graphical representation of these relationships.

The knowledge from vendors and the customers' employees is placed in models of the machines which are loaded into the Decision Support System. The DSS not only feeds the CMMS link with actionable information, it also provides the data in a consistent taxonomy, or format, that ensures reports and data mining from the EAM/CMMS systems will be meaningful. This skirts the problem where people enter fault codes in a slightly different manner, but mean the same fault. This type of input makes it very difficult to report on the issues occurring in the plant. DSS would make the input process consistent.

2.6 Sharing knowledge

One of the big problems reported by our customers is that they cannot maintain consistency in the analysis efforts. This problem occurs with just one site, but becomes increasingly complex when a business is located at multiple sites. The analysis efforts of their experienced people, of which there are fewer and fewer, are not easily re-produced across multiple people and locations.

SKF has similar issues within our global service force. What we have done is designate one person who is our expert in one particular group of machines, like electric motors for example. His job is to make sure the knowledge defined within the electric motor models (AKS based—discussed later) contains his experiences and knowledge. If he goes out on a job and improves his knowledge, he is required to go back and update the electric motor models. These models are placed on our Intranet so that any service person can download them as they need for each service contract. By doing this, three things happen:

1. The service person has a second set of eyes looking at the data so their effectiveness is higher than it normally would be. This is better for our customers.
2. The service person who downloads an electric motor model (there are many models depending on the configuration of the motor), can learn more about how to better analyze electric motors by the results the DSS produces using the model.

3. We have implemented consistency across our global network of service personnel. The knowledge from our one expert is now shared across the organization. Even though this group consists of highly skilled individuals, they are using a process that can only improve our product.

2.7 Industry competitive pressure

Why should businesses be concerned with managing the knowledge of their business? Many companies do not significantly differ in terms of basic resources like capital, raw material, or manpower. The characteristics that differentiate one company from another are additional unique competitive advantages it can offer to compete in the marketplace. Intellectual Capital, or the knowledge a company possesses within its organization, is a distinctive resource that has emerged as a major advantage in recent years. If we look at where this Intellectual Capital (IC), or knowledge, is stored, the majority of it is stored in the heads of its employees, according to the Delphi Group. This is shown in Figure IV.

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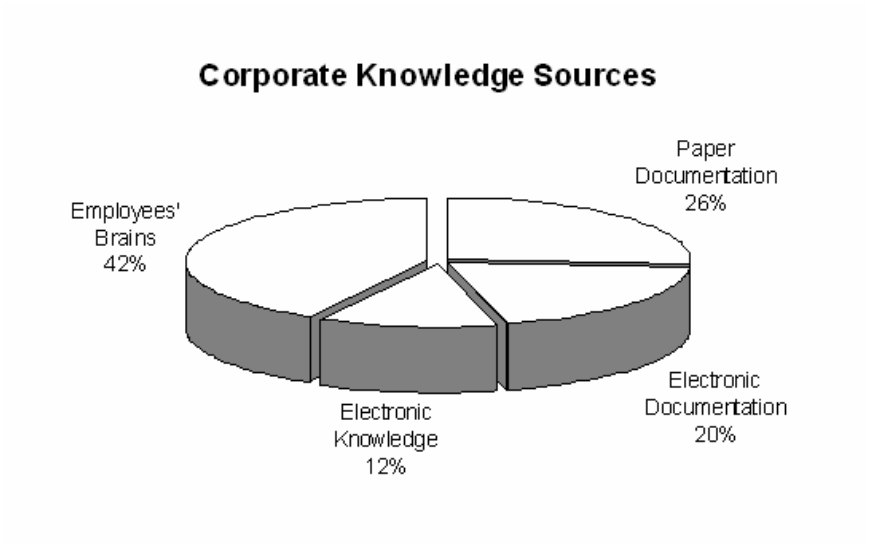

Figure IV

If we following this same line of logic, then there are significant advantages to managing the knowledge of the employees of a business. To quote Management Consultant Peter Drucker:

- "The most valuable assets of a 20th-century company were its production equipment."
- "The most valuable assets of a 21st-century institution, whether business or non-business, will be its knowledgeable workers and their productivity."

Taking the next step in Asset Management is not going to be accomplished by working harder, but instead by working smarter. A new process will need to be accepted and the company culture will need to evolve.

3 Technology, Process, Culture

For any significant initiative like this to take place, technology will not make a successful guide. Technology by itself is only an enabler that does not guarantee success, just as a CMMS system does not bring improvement if it is not used. Too often technology alone has been promoted as the solution, and the complex programs that go along with the technology make success rare.

Processes will also need to be defined when implementing a significant program that includes a technology purchase. People will need to alter their daily routine to include the technology that will invite improvement. The technology vendors can provide the basic framework for these new processes to help the customer to get started. Defining new ways of working is a critical component to implementing new technology.

The most critical aspect of the improvement process is a change in workplace culture. Culture is something that cannot be bought and simply plugged into the organization. The culture for change must be owned by the organization and believed in at the very top level of management. Culture without upper management approval will soon disappear as the

existing cultural priorities will override new activities and changes being applied by the new culture. These changes need to be recognized as requirements, even though their improvements may not be immediately seen. This is why without management involvement, and commitment, the new culture would soon disappear.

Once the technology, process, and culture are in place, the next phase begins with organizing the knowledge required to go to the next step in Asset Management. The process for defining the knowledge was an undertaking at SKF several years ago during the formation of the @ptitude business. This group was made up from application engineers, Knowledge Management engineers, service people, condition monitoring product designers, and people with experience in artificial intelligence. Together they created a technology, taxonomy, and knowledge structure to deliver the type of decision support systems discussed.

4 Knowledge Organization

In 1999 we undertook the task of defining knowledge for the Reliability group at SKF. We went to the market to find existing systems that could be of use to us. What we found was that there was no current process that we could use to define the knowledge we needed. We examined Root Cause Failure Analysis, Failure Mode Effects and Analysis, and a variety of other methodologies, and found them to be lacking in defining the total solution. We needed a system that would allow us to do anything from defining the asset type at the top of our tree, to providing a method allowing us to find the measurements that needed to be made to properly analyze the asset, and everything in between. Most of what we found was that the existing methodologies started almost at the top (Failure Modes), but stopped somewhere in the middle around the Faults. This was not enough to meet our goal of capturing all of the required knowledge. After many discussions, the team created a methodology and taxonomy that allowed SKF to create a Knowledge Management technology to use in our own plants, service contracts, and with our customers.

In order to properly diagnose asset health, the @ptitude team needed to define a process to store the Intellectual Capital of SKF and the customer. This knowledge is placed online and is the intelligence for an engine that examines condition monitoring, inspection, process, operations, and performance data to diagnose asset health. This knowledge is broken down and categorized so that it is easily understood, entered into a database, and able to analyze vast amounts of data.

Asset Knowledge Science (AKS) is the process developed by SKF, to manage this knowledge. AKS goes beyond traditional models like Failure Modes and Effects Analysis (FMEA), Fault Tree Analysis, Reliability-Centered Maintenance (RCM), and others. It provides a methodology that embodies a fundamental understanding of the predominant failure modes of equipment, the measurements required to effectively monitor equipment health, and the consequences of failure.

The core of AKS is knowledge of an asset's components, how they are assembled, and how the asset is designed to perform, allowing for fault detection and resolution prior to failure. It incorporates the best of the world's most widely used failure analysis methodologies, integrates our customer's extensive practical knowledge of components and machinery with our own, and then fuses this knowledge with live data, which is analyzed by the decision support system.

Logically, to diagnose problems, you must understand the range of possible issues before you can state what type of data you need to have. This is what makes @ptitude different from past and present systems—its capability to store Intellectual Capital in the proper format, and apply it to real data.

To show the structure and type of IC used by this system, each category within the hierarchy will be described:

ASSET: The asset is at the top of the structure. Here we specify asset name and type, which dictates the rest of the structure. Asset examples are: main shaft, generators, motors, pumps, fans, gearboxes, rolls, yaw, etc.

COMPONENTS: Each different asset type has a defined list of components that are critical to monitor. Not all components may be listed—only those that directly affect reliability and that can be measured. Component examples are: shafts, bearings, impellers, blades, gears, etc.

FAILURE MODES: Each component has a list of failure modes specific to its component type. Failure mode examples are: excessive friction, mechanical fatigue, erosion, dirt buildup, etc.

FAULTS: Each failure mode has a list of faults that can cause or contribute to each failure. Fault examples are: unbalance, misalignment, mechanical looseness, bearing defects, etc.

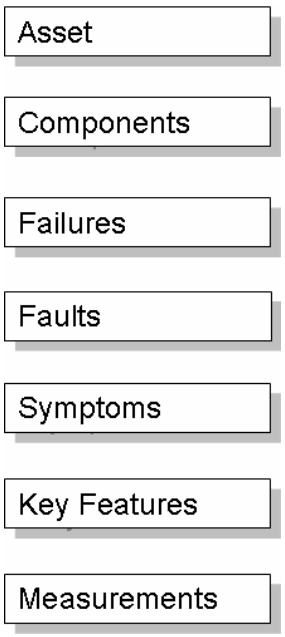

Figure V

SYMPTOMS: Each fault has a list of symptoms that can, alone or in combination, contribute to each fault. Symptom examples are: 1x RPM - moderate, bearing inner race frequency - severe, viscosity low - severe, elements wear metal - moderate, etc.

KEY FEATURES: Each symptom has a list of Key Features (KF) that can cause or contribute to each symptom. A KF is data from the measurement that is required to perform the analysis. It can be in the form of peak vibration in a spectrum band, particle count from an oil measurement, or the status of a visual inspection. Once the KF is determined, defining necessary measurements is straightforward.

MEASUREMENTS: These already exist in the current systems that @ptitude interfaces with.

Together, SKF refers to these six categories as Asset Knowledge Science (AKS), which is the model behind how @ptitude makes decisions. The system is delivered with SKF's IC, based upon specified machine types. The customer then has the ability to change these models or create new asset type models. An additional example of AKS is shown using an AC Motor and some AKS tree components (shown Figure VI and Figure VII). This example shows just a fraction of the knowledge contained in the model due to the fact that some models would produce a 60 page report if all the details were printed. The example is provided to give the reader a feel for their content.

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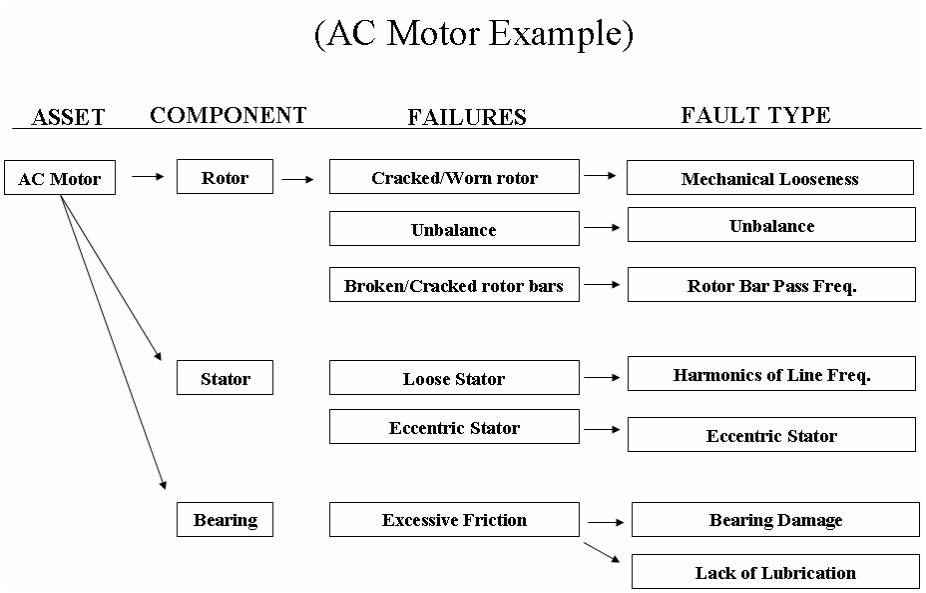

Figure VI

If we continue the example, by moving from left to right across the top of Figure VI, we end up with a fault type of mechanical looseness. For our system, there are three different types of mechanical looseness: possible, moderate, and severe. The reason for this is that each one of these levels will require a different set of rules just as a person differentiates the difference in the severity within their own mind. What is also not shown here is that at each level there are rules that coincide with the different faults, symptoms (shown in the example), or key features that are combined to form the more complex reasoning that is sometimes required. For the continuation of this example, moderate mechanical looseness was chosen.

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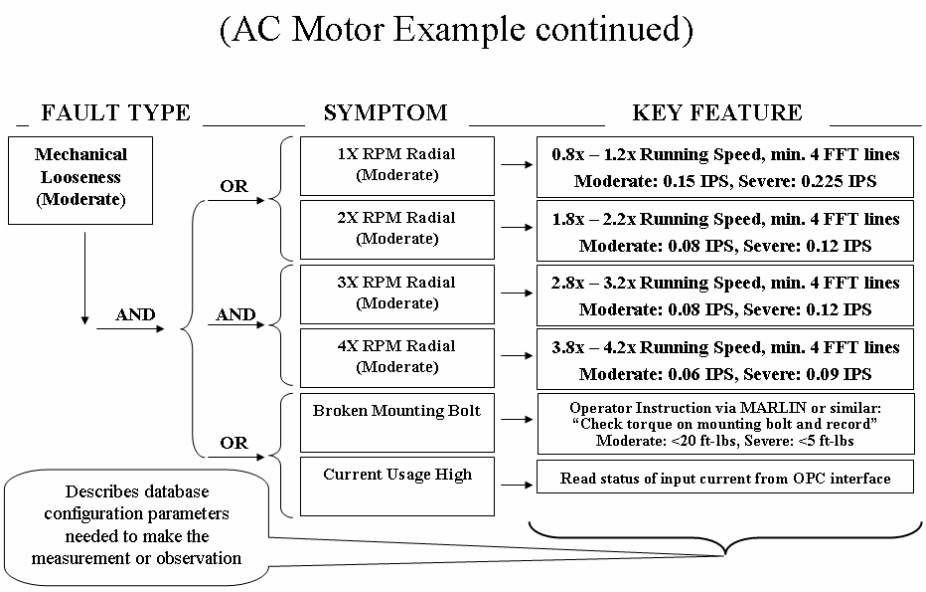

Figure VII

Now if we examine the Key Features, we can determine what measurement data we need, and the parameters needed in order to set those up, to provide the data needed to diagnose this electric motor. The need for these measurements is based upon the science of the asset, not folklore or just because "that's the way the last guy did it." This part is extremely significant, because it represents a well defined structure to identify the asset; from the components to the measurements required to determine its health.

So far the discussion has only been based upon physical assets like pumps, motors, and gearboxes. But an asset can be much more than that. An asset can also be a machine line that makes an entire product, or even an entire plant itself. In these cases, the structure presented here still holds true. A plant has Key Performance Indicators, or KPIs, (failure modes) from specific regions of interest (components). Each of these KPIs can be different than the desired value because of a fault in the system which would have correlating symptoms. The key features would define the actual data that needs to be read from the plant's data warehouse (ERP system, historians, etc.). The AKS structure is generic, yet flexible enough to handle even more than the physical assets of a business, and able to monitor the business itself.

5 CONCLUSIONS

In recent years, information technology has had a tremendous impact upon plant maintenance. The computer's ability to collect and analyze large amounts of data, and to then disseminate the resulting information, has been the principal factor in the development and adoption of various maintenance philosophies over the last two or three decades.

The computer has, for example, had a major impact in the areas of condition monitoring, inspector-driven reliability, and inspection systems. Through provision of automated data capture combined with improved communications and feedback between those collecting the data and those required to act upon the resulting information, the computer has drastically changed the entire concept of knowledge management.

Perhaps even more significant is the way in which Information Technology (IT) has been the major driving force in the evolution of Maintenance Management into Physical Asset Management, and its links to Enterprise Resource Planning systems.

Today there exist fast-growing realizations that an organization's people should also be regarded as assets. The information and experience that resides in the heads of personnel, at all levels of corporate hierarchy, is undoubtedly a principal factor in the achievement of business goals. Knowledge management is not about gathering this data and rendering people dispensable. It is about sharing information to mutual advantage, eliminating the need for talented and knowledgeable individuals to become bogged down in mundane repetitive activity, hence allowing them opportunities to innovate and to further hone their capabilities. Intellectual Asset Management through development of Decision Support Systems is thus arguably the next logical step into improving plant efficiency.

REFERENCES

1 “Too much, too soon: Information overload”, IEEE Spectrum, pages 51-55, June 1987
2 National Petrochemical & Refiners Association (NPRA) Conference, October 1-3, 2001.

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