

Proactive Predictive Machine Maintenance (P2M2)

21st Century Systems, Incorporated
6825 Pine Street, Suite 141
Omaha, NE, 68106-2857

Dr. Robert Woodley
Mr. Warren Noll

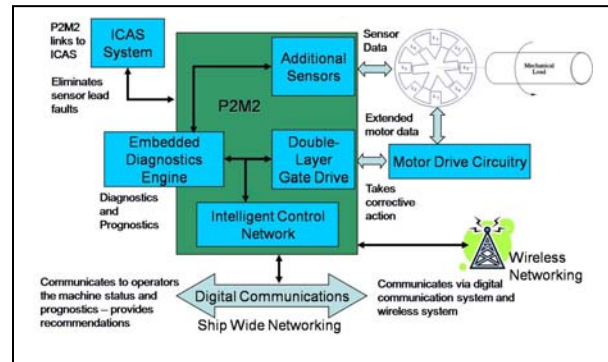
Phone: (573) 329-8526

Fax: (573) 329-1912

Email: robert.woodley@21csi.com

warren.noll@21csi.com

Website: www.21csi.com



Command: ONR - STTR
Topic: N06-T033

As commercial and military transport systems become more complex and software-intensive, the need for dependable onboard electric power increases. The machinery must be reliable, available, and safe to use. Complex relationships between power system components and utilization equipment require large amounts of measurement points along the service train and estimation of service capability. In the past, false alarms, missed failures, mishandled preventive maintenance scheduling, and underutilized resources have resulted in poor operational performance. Recent advances in information systems technology utilize intelligent monitoring of these many measurement points along with decision support algorithms to provide an increase in fault detection and isolation. New emerging capabilities are partial recovery, forecast of impending problems, as well as increased operational use during abnormal operations.

PROBLEM STATEMENT

Many Navy and industrial power system components (power converters, motor drives, etc.) have diagnostic capability. These components have the capability to record fault events and provide post-fault information to engineers which is helpful for maintenance. However, the present systems do not contain prognostics capability which would allow operators to observe an unhealthy system component in a pre-fault condition. This capability would allow scheduled downtime as opposed to unscheduled downtime. In Navy systems, this improves the fight-through capability so that maintenance can be performed in a non-combat environment. In industry applications, scheduled downtime can result in considerable cost avoidance. The next technology step is self-healing system components which can not only observe potential problems, but can take steps to continue operation during abnormal operation – whether due to long-term normal wear-and-tear or sudden combat damage.

The self-healing concept will need the help of more robust communication systems and the use of powerful embedded systems. The current CBM systems are vulnerable to the interface, such as a lead connection failure. Furthermore, the job of corrective actions must be either performed by a central computer system or, more likely, by the human operator; either case is less than ideal. The

"Approved for public release; distribution is unlimited."

central computer would become overtaxed if all the ship's systems were to be monitored and controlled by the central computer. Similarly, a human operator is an expensive alternative aboard ship. The job of fault detection and correction for the Navy's electrical machinery can be performed by embedding intelligent control systems throughout the ship, which have the capability of using multiple forms of digital communication plus the advantage of being able to operate in close proximity to the actual device.

What is needed is an automated health monitoring capability for electric machinery and systems that exhibits very high probability of detection of faults (P_d), and a very low probability of false alarm rate (P_{fa}). Additionally, the capability performs "self-healing" functions to reduce down time of electrical machinery. As new sensors and embedded processors emerge and component fault sets are identified, advances in intelligent software will be the integrating "glue" for the automated health monitoring capability. Once this technology is proven to meet requirements at the end of Phase II, we work with NAVSEA to transition into current program of record and work to transition to a possible Enabling Capability (EC) program.

WHO CAN BENEFIT?

The list of potential military applications for these capabilities is quite long. 21CSI is building the distributed software, with agents, tailored to the specific applications. The Navy will be the potential government customer, the P2M2 system will be placed in-line between the sensor and the ship's monitoring system (ICAS or similar) to monitor, diagnose, predict, and ultimately (self-healing) control Navy electrical machinery. The technology could be demonstrated 1) in simulation and 2) in a full scale medium voltage demonstrator together with global power system management capabilities currently being developed.

Commercial customers will be primarily airlines and cruise ship companies. The P2M2 system will help the airlines reduce operating costs and provide timely and required maintenance upon landing. There are currently numerous vendors of each of the key technology components required for developing the Fault Diagnostics, Prognostics, and Self-Healing Control; however, no one is offering a platform independent, COTS-based integrated solution. 21CSI has several dimensions of sustainable competitive advantage for the P2M2 system once development is completed and the system is accredited.

Expected platforms that will benefit from the P2M2 technologies are:

1. Gas turbines on CG and DDG Navy vessels
2. Ground transportation vehicles
3. Aircraft
4. Electrical machine systems

BASELINE TECHNOLOGY

Currently, the U.S. Navy's Integrated Condition Assessment System (ICAS) is the diagnostic system for naval vessels. ICAS provides a means for performing Condition Based Maintenance (CBM). ICAS is a commercial-off-the-shelf (COTS) software product for which the U.S. Navy holds Government Purpose License Rights (GPLR). It is developed in a shell type architecture to allow for varied implementation of machinery monitoring and CBM.

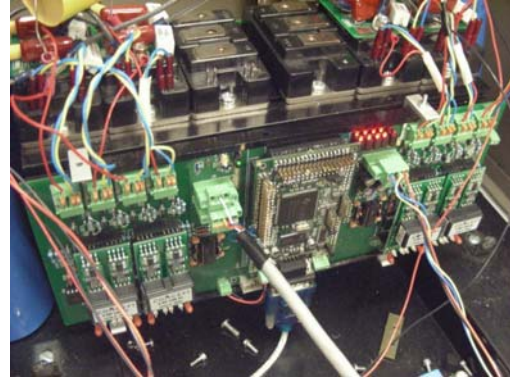
"Approved for public release; distribution is unlimited."

The strength of the ICAS system is that it is well established with a large database of fault condition analysis for the systems aboard the vessels. Sensor information is collected aboard the vessel and when a fault condition occurs the data is tagged and sent off for root-cause analysis.

The weakness of ICAS is the delay between fault identification and diagnoses of the problem. Currently the analysis takes place off-board by personnel combing through the data to try and figure out what went wrong. Furthermore, ICAS relies on sensor leads that may travel hundreds of yards through the vessel before reaching the ICAS host machine. A fault in these leads results in insufficient data to analyze a fault at the monitored machine.

TECHNOLOGY DESCRIPTION

The goal of the project is to develop a COTS-based system where embedded controllers monitor, diagnose, predict, and ultimately control Navy electrical machinery. The P2M2 system will be placed in line between the sensor and the ship's monitoring system (ICAS or similar). P2M2 will pass the raw data to ICAS, but will also perform its own processing. P2M2 will be able to access more data sources on the machine through an advanced sensor design than ICAS to make better predictions



about the performance of the machine. More importantly, it will have knowledge of the internal workings to enable fault correction that is not possible with ICAS. The ability to communicate with other P2M2 units will allow the system to further develop intelligent prediction by sharing processed information. The communication channels may also be used to send data to a specialized ICAS bridge to relay missing information in the event lead faults occur, resulting in the most robust situation possible.

P2M2 gets its strength through a threefold attack. First, the new sensor technology for machine power converters (shown in the figure above) provides an unprecedented link to the internal workings of the machine. By combining the converter's own electronics with sensing electronics, the converter itself provides an enormous amount of information to the controller. Second, the COTS embedded system can then actively monitor, diagnose, predict, and control the converter right at the motor. The direct connections to the new sensor technology combined with proven embedded systems allow for a distributed, and thus harder to defeat, health maintenance system. Finally, intelligent software makes the whole system work. Advances in computer learning allow the system to adapt to the machine's operating condition. Intelligent software can perform tasks that would be tedious for a human operator while providing the level of expertise one would expect from a subject matter expert performing the job. The software also provides for the communication and bridging back to the ship's main ICAS system for system wide diagnostics.

CURRENT STATE OF DEVELOPMENT

The new double-layer gate drive sensing system circuit board has been prototyped. The hardware testbed has been constructed for testing of the overall P2M2 system to include the double-layer gate drive. This testbed will allow for testing by emulating faults and loading on the machine. The P2M2 embedded system with its diagnostic engine is in the final stages of prototype and

"Approved for public release; distribution is unlimited."

testing with the testbed. The lab testing will provide needed feedback to finalize the prototype for in-the-field testing in the next phase.

STTR	Milestone	TRL	Risk-Test	Measure of success	TRL date
Phase 2 - current	Testbed operational with overall P2M2 testing	3	Complete	Testbed functional with all facets of P2M2 operating as expected	May 2009
Phase 2 - base	Validation and verification of P2M2	4	Low	Functional testing of P2M2 on testbed	January 2010
Option 1	Testing in simulated environment	5	Moderate	Interaction with machine system, prediction for machine health, identification of faults, and self healing interaction	June 2010
Option 2	Demonstration and in operational environment	6-7	Moderate	Successful interaction with overall ship systems, identification of faults, health maintenance predictions, and self healing operation at the machine	April 2011

REFERENCES

Office of Naval Research
Code 331
875 N Randolph Street
Arlington, VA 22203-1995
(703) 588-2435

ABOUT THE COMPANY

21st Century Systems, Inc. (21CSI) designs, develops and delivers decision support software to help operators and decision makers control and respond to complex, high-stress, rapidly changing environments through intelligent computer-assisted data monitoring and decision making. The software manages complex data flows from numerous sources and analyzes it to create actionable knowledge tailored according to user needs. Intelligent agents embedded in the software then provide decision alternatives in real time. The use of agents also enables the software to adapt, respond, and learn from individual users in a variety of situations.

21CSI's intelligent decision support software tools range from submarine warfare tactical decision aids and mission planning, monitoring and reconstruction systems, to automated geo-spatial-based command and control for disaster preparedness and response, to multi-mission distributed space situational awareness, to distributed automated intelligence analysis. They include integrated security, surveillance and infrastructure protection systems, and are used in commercial as well as military settings.