A RELIABLE PREDICTOR FOR BATTERY REMAINING USEFUL LIFE PROGNOSTICS

Battery-powered systems have been widely used in our daily life, ranging from consumer electronics and electric transportation to aerospace electronics. The batteries are very critical components that provide necessary power to ensure the battery-powered systems to function appropriately. An unexpected battery failure could not only affect the system’s normal functionality and performance but lead to catastrophic events. For example, the Mars global surveyor was lost in November 2006 due to battery failure. Another battery failure disabled the landing gear extension that resulted in a Beech A200 airliner crash accident during landing on April 8, 2000. Many other battery failures have also been reported in data center’s uninterruptible power supply (UPS) systems. A recent survey conducted by the Emerson Network Power showed that 30% of the data center outages were a result of battery failures in the UPS. The cost incurred with detecting and recovering from one UPS failure alone has been estimated to be around $687,000. Apart from this, there is also cost associated with the resulting system downtime which has been estimated as $5600 per minute.

In order to prevent unexpected battery failure, a reliable predictor is needed to accurately estimate the remaining useful life (RUL) of battery or how much capacity left for current and future charge-and-discharge cycles. In the prognostics community, RUL prediction has been widely studied. However, there are few studies on RUL prediction in the battery community, particularly on prognostics uncertainty management that is considered as the most challenging difficulty in battery RUL prediction. Prediction uncertainties can arise from many sources, such as unit-to-unit variation, operation and environment changes, modeling inaccuracy, measurement noise, etc.

CALCE has been developing a reliable predictor for battery prognostics in the particle filtering (PF) framework. An empirical battery aging model is derived via the regression analysis of many battery degradation data. Several model adaptation schemes have been developed, such as state-and-parameter joint PF, Bayesian Monte Carlo method, nonlinear least squares using Levenberg-Marquardt optimization. PF propagates the aging trend of each particle via the adapted model, and the corresponding weight for each particle is generated using online measurements. Through these particles and associated weights, a probability density function (PDF) of RUL can be obtained. Different battery degradation data have been employed to verify the developed algorithms and the reasonable and reliable predictions are achieved.

The developing battery RUL predictor is able to work reliably in real world applications, since the robust online model adaptation in the PF framework can accommodate various types of uncertainties and the probabilistic prediction results are provided, such as RUL PDF, RUL confidence level, etc. For further information, please contact Dr. Chaochao Chen (chaochao@umd.edu).
**PROGNOSTICS OF INSULATED GATE BIPOLAR TRANSISTORS (IGBTs)**

Insulated gate bipolar transistors (IGBTs) are widely applied in industry, from power plants to consumer electronics manufactures. For instance, IGBTs are used as switches in power convertors, speed and direction controls for motor drives, and high current switches for flashes in digital cameras. Although designed to endure high power usage, they are the major failure parts in such applications and can cause the failure of the whole power system. Therefore, anomaly detection and remaining useful life (RUL) estimation of IGBT can be very valuable for power system maintenance and safety protection.

There are many researches on the PHM of IGBT to address this issue. Most of them focus on the physics-of-failure (PoF) models development. PoF models are based on identifying critical components of IGBT and calculate its lifetime according to the predefined models and parameters of these components. Since in practical applications, the degradation processes of those components are much more complex than the PoF models and often interact, the PoF models might not be able to produce reasonable estimation. On the other hand, data driven approach uses failure precursors for anomaly detection and RUL estimation. It simplifies the analysis of the physics of failure mechanisms while “digs into” the data mining algorithms based on the data collected during the ageing of IGBTs. In CALCE, we developed some data driven methods that can be applied to the anomaly detection and RUL estimation of IGBTs in-situ. The anomaly detection algorithms successfully recognize anomalies and produce reasonable prognostic distances; and RUL estimation algorithms predict the results with error less than 10%.

At present, CALCE is continuing to develop the data driven methods based on the data that includes more application conditions and failure precursors. Besides, CALCE is developing fusion approach that combines both PoF models and data driven algorithms as well. This approach takes advantages of both physics of failure mechanisms analysis and data mining techniques, in order to produce more accurate results. To achieve this goal, the failure precursors have to be able to relate their trends to the failure mechanisms of the IGBT, and thus choose the PoF models accordingly. CALCE has such experience that can build delicate experiments to collect these precursors. For further information, please contact Dr. Diganta Das (diganta@umd.edu).

**PROGNOSTICS OF ELECTROSTATIC MICROELECTROMECHANICAL SYSTEMS (MEMS)**

Electrostatic microelectromechanical systems (MEMS) devices have found their applications in various industries, ranging from optical switches to inertia sensors, from energy harvesters to projectors. However, their further commercialization, especially those in critical usage conditions, requires more stable performance and longer life time. One of the predominant failure mechanisms is stiction, stuck of adjacent micro structures when they come into contact and restoring forces are not great enough to overcome the surface adhesion.

In order to prevent system loss due to the stiction failure of electrostatic MEMS devices, CALCE has been working on the algorithms of predicting the onset of MEMS failure. A type of electrostatic MEMS used in wireless communication application is accelerated tested and its electrical properties such as capacitance-voltage (C-V) are monitored and recorded in real time. Based on the electrical properties, two different categories of algorithms have been developed to assess the state of health and detect anomaly. One category is reliability models based on physics understanding of stiction and its effect on devices’ electrical performance. By understanding charge injection, charge trapping in dielectric material and consequent membrane distortion, we can build up a mathematical model of assessing devices’ state of health. The other category is data-driven models which include time-domain data processing, feature extraction using Mahalanobis distance method, anomaly detection, and auto-regression for prognostics. Both categories of algorithms have been compared and their performances been assessed in real world applications. Data from tests will be used to find out the best algorithm, which will be used for both lifetime determination and future device design. For further information, please contact Dr. Michael Osterman (osterman@calce.umd.edu).
MFPT 2012: THE PHM SOLUTIONS CONFERENCE

The MFPT 2012 Conference will be held April 24-26, 2012, at the Crowne Plaza Hotel in Dayton, OH. The conference will focus on the development and application of prognostics and health management technologies and show how practical technologies can be integrated into platforms and systems.

We're excited to announce our 3 distinguished keynote speakers for MFPT 2012. First, we have Mr Ted Fecke, a member of the Senior Executive Service, and the US Air Force's Technical Adviser for Propulsion, from the Aeronautical Systems Center at Wright-Patterson AFB, Ohio. A long-time proponent of health management for aero-engines, Mr Fecke has for over 30 years led teams of engineers and scientists in solving critical problems that have ensured the safety of turbine engines, and he is recognized as a leader for his structural integrity expertise in the areas of advanced materials, high cycle fatigue, probabilistic design and life prediction. We also have Professor Michael Pecht from the Center for Advanced Life Cycle Engineering (CALCE) at the University of Maryland, a world renowned reliability engineer and educator who in 2008 was awarded the IEEE Reliability Society's Lifetime Achievement Award, and in 2010 received the IEEE Exceptional Technical Achievement Award for his reliability contributions in the area of prognostics and systems health management. Finally, we have our outgoing MFPT Chairman, Dr Fred Discenzo, a Rockwell Automation Fellow with over 60 US patents to his name who has published many papers spanning artificial intelligence, machinery diagnostics, sensors, control, power scavenging and neural networks. His research efforts have earned him multiple corporate awards and trade industry awards. Once again, we have intentionally covered the spectrum of Academia, Government and Industry to bring perspectives that will be of interest to all attendees.

UK MOD IVHM CONFERENCE

The UK Defense Academy is holding a Vehicle Health and Prognostic Health Management Symposium from the 22nd to 23rd February 2012. The conference, at Shrivenham near Swindon and Oxford, is well situated for access to and from London airports.

While the Symposium has an understandable military flavor, the program reflects both military and industry interests. Notable speakers from the USA and Australia include Professor Peter Sandborn from the CALCE PHM Center (addressing cost and availability impacts of the incorporation of prognostics and health management into systems) and Dr Eric Lee from the Defence Science and Technology Organisation (DSTO) in Melbourne Australia (reviewing developments of HUMS and prognostics in Australian military systems). Developments in US military systems for both HUMS and prognostics and the Land transformation progress for both HUMS and Condition Based Maintenance (CBM) in the UK will also be covered along with cost benefits of HUMS, CBM and Prognostics and benefits to Through-life Capability Management. Brigadier Martin Boswell, (British Army) Director Electrical and Mechanical Engineering and professional head of the Corps of Royal Electrical & Mechanical Engineers will address the policies and progress towards HUMS, Prognostic Health Management (PHM) and CBM in UK Land Forces. Academia will address developments in prognostic technologies and applications and the exploitation of prognostic health management techniques together with research programs for these techniques. For further details, please visit: http://www.cranfield.ac.uk/cds/symposia/vhpm.html
Prognostics are an engineering discipline focused on predicting the future condition of a component and/or system of components. The science of prognostics is based on the analysis of failure modes, detection of early signs of wear and aging in complex systems and components, and correlation of these signs with an aging profile (or model). Potential uses for prognostics include estimation of remaining useful life and condition-based maintenance. The discipline that links studies of failure mechanisms to system lifecycle management is often referred to as Prognostics and Health Management (PHM). Technical approaches to prognostics can be categorized broadly into data-driven approaches, model-based approaches, and hybrid approaches. During the last few years, many leading companies in the world have been applying PHM from product design to supply chain management and have already established a fruitful Return-Of-Investment (ROI) in this regard. The market applications are wide ranging. PHM has been recognized to give a competitive advantage in the market place where competition is ever growing. Companies around the world are increasingly investing in developing PHM technologies to be at the forefront of competition.

The 2012 Prognostics and System Health Management Conference (PHM-2012) will be held in Beijing, China, on May 23-25, 2012, following the success of the PHM-2010 Macau and PHM-2011 Shenzhen conferences. The PHM-2012 conference aims to bring together the global community of PHM experts from industry, academia, and government in diverse research and application areas such as aeronautics and astronautics, defense, marine systems, power and electronic systems, process industries, computers and telecommunications, material systems, industrial automation, and healthcare and medical technology, etc. For more information, please visit: http://www.icphm.org

AREAS OF INTEREST:

- Advanced Sensors
- Data Pre-processing
- Health Monitoring
- Health Management
- Fault Diagnostics
- Fault Prognostics
- Maintenance Decision Support
- Reliability, Maintainability and Supportability
- Data driven/Data Mining
- Data Fusion
- Methods Fusion
- Physics of Failure
- Modeling and Simulation
- System-level PHM
- Component-level PHM
- PHM Innovative Applications
- PHM Industrial Applications
- Knowledge of PHM System
- Design and Integration of PHM System
- PHM Standards and Methodologies
- PHM Systems and Platform
- Cost Analysis of PHM
- Verification, Validation, and Maturation of PHM System