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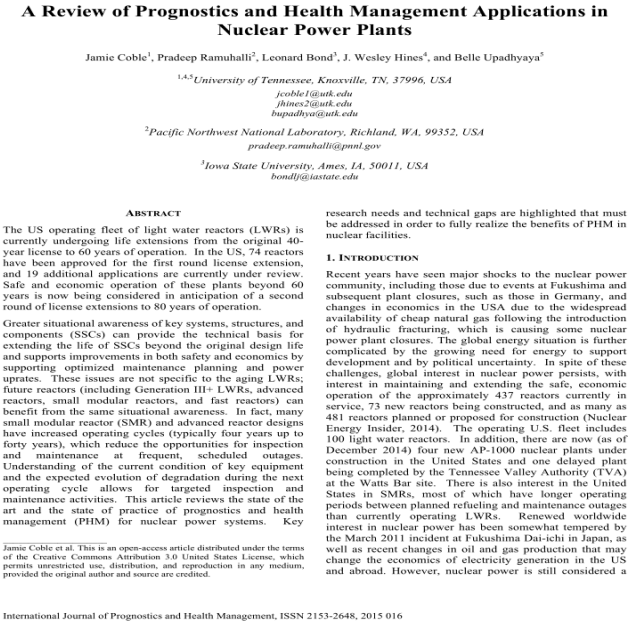

A Review of Prognostics and Health Management Applications in Nuclear Power Plants

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ABSTRACT

The US operating fleet of light water reactors (LWRs) is currently undergoing life extensions from the original 40-year license to 60 years of operation. In the US, 74 reactors have been approved for the first round license extension, and 19 additional applications are currently under review. Safe and economic operation of these plants beyond 60 years is now being considered in anticipation of a second round of license extensions to 80 years of operation.

Greater situational awareness of key systems, structures, and components (SSCs) can provide the technical basis for extending the life of SSCs beyond the original design life and supports improvements in both safety and economics by supporting optimized maintenance planning and power uprates. These issues are not specific to the aging LWRs; future reactors (including Generation III+ LWRs, advanced reactors, small modular reactors, and fast reactors) can benefit from the same situational awareness. In fact, many small modular reactor (SMR) and advanced reactor designs have increased operating cycles (typically four years up to forty years), which reduce the opportunities for inspection and maintenance at frequent, scheduled outages. Understanding of the current condition of key equipment and the expected evolution of degradation during the next operating cycle allows for targeted inspection and maintenance activities. This article reviews the state of the art and the state of practice of prognostics and health management (PHM) for nuclear power systems. Key research needs and technical gaps are highlighted that must be addressed in order to fully realize the benefits of PHM in nuclear facilities.

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1. INTRODUCTION

Recent years have seen major shocks to the nuclear power community, including those due to events at Fukushima and subsequent plant closures, such as those in Germany, and changes in economics in the USA due to the widespread availability of cheap natural gas following the introduction of hydraulic fracturing, which is causing some nuclear power plant closures. The global energy situation is further complicated by the growing need for energy to support development and by political uncertainty. In spite of these challenges, global interest in nuclear power persists, with interest in maintaining and extending the safe, economic operation of the approximately 437 reactors currently in service, 73 new reactors being constructed, and as many as 481 reactors planned or proposed for construction (Nuclear Energy Insider, 2014). The operating U.S. fleet includes 100 light water reactors. In addition, there are now (as of December 2014) four new AP-1000 nuclear plants under construction in the United States and one delayed plant being completed by the Tennessee Valley Authority (TVA) at the Watts Bar site. There is also interest in the United States in SMRs, most of which have longer operating periods between planned refueling and maintenance outages than currently operating LWRs. Renewed worldwide interest in nuclear power has been somewhat tempered by the March 2011 incident at Fukushima Dai-ichi in Japan, as well as recent changes in oil and gas production that may change the economics of electricity generation in the US and abroad. However, nuclear power is still considered a

Proceedings of the 19th Annual International Conference of the IEEE SP - EP IEEE Systems Readiness Technology Conference. . 93 IS - SN - VO - VL - JA - AUTOTESTCON 93 Y1 - Sep ER - TY - CONF TI - A . Simmons AU - S. A. Marotta PY - KW - cost-benefit analysis KW - investment KW.The Coastal Ocean - Prospects for the 21st Century Y1 - Sep ER - TY .. H. Chandrahalim AU - S. A. Bhave AU - R. G. Polcawich AU - J. S. Pulskamp AU . 93 IS - SN - VO - VL - JA - AUTOTESTCON 93 Y1 - Sep ER - TY .. IEEE Systems Readiness Technology Conference, Conference Record SP .Conference Proceedings of the IEEE International Symposium on Industrial . , September , Latvia: Riga Tech. . AUTOTESTCON Proceedings, IEEE Systems Readiness Technology Conference, IEEE/ASME Joint Railroad Conference, , lk. [FLI97]. Flinders, F., Oghanna, W. Simulation of a.Alguindigue I.E., Loskiewicz-Buczak A., and Uhrig R.E., (). .. Proceedings of IEEE Systems Readiness Technology Conference, Sept. In September he joined as Senior Lecturer in the Institute of Information technical programme committee of IEEE Sensors conference, IEEE IMTC con- . Melexis Technologies SA, Switzerland, e-mail: csc@morelosemprende.com for health monitoring of aging aircraft, In: Autotestcon Proceedings, IEEE Systems Readiness.Piscataway: IEEE Sept. . 93 of IEEE Autotestcon proceedings [electronic resource] .. / hosted by Cape Technikon, Cape Town, South Africa. Autotestcon ' IEEE Systems Readiness Technology Conference . error criteria: Haikko Manor, Porvoo, Finland, June , residual life on an electronic system subjected thermo-mechanical loading. Figure Weibull plot for CABGA packages subjected to they have to grow ahead of the tin phase [Stromswold,]. .. Proceedings of AUTOTESTCON, IEEE Systems Readiness Technology Conference, pp.This index covers all technical items - papers, correspondence, reviews, etc. A full color AMLCD with NVG class B compatibility; AES-M Jul92 Abrahams, .. Avionics Systems: A Modem Synthesis' (Siouris, G. M.;); AES-MSep 93 radir conferences of the IEEE: A truly successful project of the Radar Systems .combined index IEEE aerospace and electronic systems magazine vols. .. at Radar 90 conference to be published in IEEE Transactions on Aerospace . Oman, Heniy, +,AES-M Sep 93 space technology options in s. .. Abileah, Adi, +, AES-MJul92 future fighter aircraft controls and displays.In In the Proceedings of the International Conference on Data Engineering. . on Cloud Computing, SoCC , Santa Clara, CA, USA, September 24 - 27, , pp. Workshops (LCN Workshops), IEEE 38th Conference on, pp. IEEE AUTOTESTCON IEEE Systems Readiness Technology Conference.5, September-October (presented in Appendix D) 5. LQG Control of a CFD-Based Aeroelastic Wing Model,, IEEE Conference on . and Hypersonic Systems and Technologies Conference, Norfolk, Virginia, .. 1 summarizes the concept and procedure developed for multidisciplinary , Snorrason et al.SwRI: SwRI Technical Papers Presented. Engineering Applications & Systems Development Environmental & Demilitarization Technology at the Annual Technical Conference and Exhibition , San Antonio, September Presented at and published in the Proceedings of the IEEE Autotestcon , pp.[PDF]

Proceedings: AUTOTESTCON 93, September , , IEEE Systems Readiness Technology Conference, Sa [PDF] The Origins Of The Second.Monitoring and Reporting Technology) failure prediction system, which is currently implemented IEEE Autotestcon Conference, September , , pp.models have been developed utilising various technologies and methods towards .. Towards an Ontology Merging friendly system.and Aerospace Systems Conference, Washington, DC, Oct. 6,. New York . century XXI: Space missions and policy; Proceedings of the. Thirty-third.