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Integrated Intelligent Equipment Health Management System to Support Life Cycle Decisions Considering Environmentally Conscious Production

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Abstract

Integrated Intelligent Equipment Health Management System (IIEHMS) is a systematic engineering design Framework that includes multi-functional disciplines (such as mechanical, electrical, optical and software engineering, quality assurance, and manufacturing) with their partners and suppliers works together to achieve a green topology plant with respect to life cycle cost. The proposed structural framework is defined as fitness for operation at any time during plant life cycle. Plant life cycle includes the entire spectrum of activities; beginning with the identification of need and extending through plant design and development, production and/or construction, operational use and sustaining maintenance and support, and plant retirement and material disposal. The methodology recognizes five main aspects of the framework as follows: a) Plant Topology and Semantic Knowledge Acquisition Modeling, to synchronize different failure mechanisms database, environment and safety incident and accident reports, and properly retrieve recorded data and synchronize them during decision making process b) Equipment Failure Reasoning & Modeling, to better understand, represent and address equipment failure mode and their impacts on process, environment and human health c) Adaptive Intelligent Fault Diagnosis & Prognosis, which is fault diagnosis process modeling and recommendations including fault detection, fault isolation, scenario assessment and mitigation plan according to Environmental/safety/Health/Business requirements, d) Green Assessment of diagnosis scenarios, to particularly evaluate CO_2 emissions, the consequence of each failure scenario from the view point of pollution, risk, and global warming human health and ecological risks due to toxicity of pollutants emitted into the environment and social impact e) Reliability, Maintainability and Availability prediction and lifetime estimation and, to calculate some measure of performance that can be used in the instantaneous actions decision making, and to prevent future accidents through preventive actions f) Optimization of purchasing cost considering lifetime, warranty and environmental consciousness, to choose suppliers that minimize LCC and maximize the reliability of equipment and spare parts. Moreover, in the model, we incorporated failure mode, effects, and criticality analysis (FMECA) through which an enterprise is able to evaluate the external failure costs of purchased equipment/components in order to optimize their choice of suppliers/vendors who provide better components for operation. Those aspects are included in an Equipment Health Management System that aims at assuring the best actions and decisions during plant life cycle and lifetime. They are linked to the result-type information and knowledge flows coming from internal/external parties, experts and stake holders and finally from the dynamic and continuous fault recognition process.

Keywords: Ontology engineering; Knowledge modeling and acquisition; Adaptive fault diagnosis; Green production system

Introduction

Current energy production chains are carbon-based or derived from a carbon source (i.e. oil and gas), which have negative impacts on environment because of CO_2 emission and other greenhouse gases. Growing world energy demand from fossil fuels plays a key role in the upward trend in CO_2 emissions. Petrochemical and chemicals industries among other industrial sectors have much devastative influences on CO_2 emissions through producing organic and inorganic products embodied carbon such as olefins, aromatics ammonia and carbon black or oil and gas combustions. The Organization of the Petroleum Exporting Countries (OPEC) states that the average portion of CO_2 emissions from oil & gas usage is expected to double by 2050 [1]. With current available technologies, the options for replacing fossil fuels or switching to less carbon fossil fuels are limited. These fossil fuels will likely remain to be the predominant source of energy in industry at least for this century. However, increasing costs for waste disposal and emissions control, growing international regulatory pressure, and increasing public demands for environmental quality are forcing nations to lay foundations for global agreement to curb CO_2 emissions, for example the UN climate negotiation in Qatar, KYOTO protocol and OECD. To mitigate or eliminate adverse environmental impacts due to specific products and processes, national efforts have been conducted in order to switch to more efficient technologies, and to life cycle and system optimization approaches [2]. The Waste and Resources Action Program (WRAP) highlights life cycle and system optimization as two complementary approaches for achieving sustainable production process in USA, UK, EU and Japan [3]. These two approaches attempt to obtain the optimal resource efficiency and sufficiency through waste reduction, lean production, industrial synergies, extended product life time, efficient use of equipment, and equipment life time optimization [4].

Methodology

The methodology is composed of ontology correlated-layers, and AND-OR partitioning matrices for fault propagation reasoning and failure mode partitioning [5-8]. Ontology correlated-layers matrix considers fault propagation as a sequence of actions to achieve a specific failure mode. In other words, each failure mode can be described as cascade events in which the start and finish points are root causes and equipment errors. The matrix defines cascade events through parsing (reaching to context-free grammars and may be classified as unification grammars) of equipment function and then the mapping from the syntactic form to a logical form by the semantic interpretation (deriving the syntactic structure of a sentence toward the construction of the behavior understanding model), and finally mapping from both syntactic and logical forms (Preconditions, Body, Effects) to a final representation by a contextual knowledge component (using knowledge of the present context to identify the particular consequences of a certain sentence) [5]. The context-free grammars are supported by ISO 14224 [5] and OREDA [6], in which an exhaustive technical terminology and format related to maintenance, safety are explain by relevant experts. To provide syntactic and logical forms, we employ FMEA, FTA, ETA & HAZOP to identify cascade events [4,8-10]. To reach a pure knowledge and interpretation from a causality context (logic form), prepared by semantic interpretation, which can be developed and shared among users, we need a base to define and support a common data model for long-term data integration, access and exchange. In this matter, we applied ISO 15926 as a core concept on which ontology is expanded to exchange and share knowledge among users [66, 64 and 70]. Through ISO 15926's concept, logic form in causality, and cause-consequence-event relationship are modeled clearly and then fed on the next step of contextual interpretation process.

Conclusion

The main anticipated and expected result of this methodology is the development of An Integrated Intelligent Equipment Health Management System, and its adaptation to meet energy sustainability, system application integration and HSE requirements based on Qatar National Priorities Research Program. The system integrates an intelligent framework that takes into consideration the equipment's life cycle and the environmental requirements for a conscientious production to achieve low-carbon economy and energy efficiency and sufficiency. As a special part of this overall system is an expert system 'shell' which contains modules for maintenance management, defect analysis and failure analysis, and which emphasizes the importance of the environment and safety risk reduction. The capabilities of the elaborated system will be tested by a pilot run, with data extracted specific standards and handbooks.

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