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A risk-based shutdown inspection and maintenance interval estimation considering human error

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ABSTRACT

This paper presents a risk-based methodology to estimate shutdown inspection and maintenance interval by integrating human errors with degradation modeling of a processing unit. The methodology presented in this paper addresses to identify the number of shutdown intervals required to achieve a target reliability over a goal period. The proposed methodology is the extension of the previously published work by the authors to determine the shutdown interval considering the system's desired availability. The proposed work is novel in the sense that a concept of human error during shutdown inspection and maintenance is introduced while modeling the system failure. Selection of critical equipment is the most important aspect in obtaining the shutdown interval to minimize overall operational risk. In order to achieve this, a risk criticality matrix is proposed to select the critical equipment for shutdown inspection and maintenance. Probability of human error induced during shutdown inspection and maintenance is estimated using Success Likelihood methodology (SLIM). The proposed methodology is composed of three steps namely, equipment selection considering criticality of operation, system failure modeling considering human error and finally a risk-based shutdown inspection and maintenance interval estimation. The proposed methodology is applied to a gas chilling and liquefaction unit of a hydrocarbon processing facility. The methodology is used to ensure the practicality of the proposed formulation to the real industry. The proposed methodology can be applied to any plant (process or non-process) such as those for LNG processing, petrochemicals, refineries or manufacturing plants. The key elements for the success of the proposed methodology are the identification and selection of critical equipment, breakdown of activities to estimate human error probability and plant-specific data for modeling system failures.

1. Introduction:

Due to continuous production demands, processing facilities are getting not only bigger and bigger but also more complex in nature. The increase in complexity and size is inviting maintenance and reliability engineers to put more emphasis on system inspection and maintenance optimization to minimize unplanned downtime, overall cost and risk exposure. Effective inspection and maintenance is one of the critical elements for operating facilities. The core objective of inspection and maintenance is to make sure that the facilities or equipment are optimized in a way, which does not only increase the reliability and availability of the plant but also minimizes the overall operational risk. Taking the unit or facility out of the service, generally termed as shutdown, performs inspection and maintenance on some of the

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equipment. Duffua and Daya (2004) and Lawrence (2012) have stated that a planned periodic shut down is carried out to perform maintenance and to inspect, test and replace process materials and equipment. Inspection and maintenance strategies of the equipment, which do not require facility to be taken in shutdown mode, can be developed based on individual equipment. Shutdown interval is one of the most important factors in determining an effective inspection and maintenance policy. In case if the shutdown inspection and maintenance interval is too short, facility shutdown time and production loss along with the inspection and maintenance cost will be too high, vice versa if the shutdown interval is too long, the production loss and inspection and maintenance cost will be low but the risk exposure will be high. This leads to find an optimal solution for shutdown inspection and maintenance interval. Failure of equipment may lead to significant consequences due to improper planning. Understanding the facilities system from operation and safety is the most important faucet when selecting and designing a shutdown inspection and maintenance model. A typical processing facility consists of hundreds of equipment, which works, in rigorous environment. One of the key aspects, which should be covered and included when modeling for shutdown inspection and maintenance optimization, is to include human error and its impact on the equipment or system failure. Integration and design of the systems such as acting in series, parallel, combination of series–parallel, 50% load capacity or 100% load capacity dictate the development of shutdown inspection and maintenance strategy for the processing plant. Inspection and maintenance operation is one of the key links in the process chain for achieving the required production and management goals. While performing inspection and maintenance, a minor failure and omission in following a clear guideline or process not only minimizes all of the inspection and maintenance benefits but also increases and changes the failure rate or behavior of the equipment or system due to introduction of human error. Despite technological advancement in equipment design and consideration given for maintainability, man–machine interface cannot be eliminated. In general, any inspection and maintenance process involves disassembly, reassembly and/or replacement of components. These processes require human interaction and, under various circumstances, create potential to include human error by installing or replacing a wrong part or assembling the part in wrong sequence despite all technological enhancement. In this paper, the focus is on the group of equipment which cannot be inspected or maintained and requires a shutdown of the facility. Thus, in order to develop an optimal inspection and maintenance strategy, attention must be paid while selecting these critical equipment.

2. Past studies

Inspection and maintenance optimization has gained huge momentum and dynamic changes over the last couple of decades due to the realization of potential benefits in plant availability, reliability, scheduling, cost and risk minimization. Risk, reliability and availability are the three facet of facility operation and are interminably linked together. A high risk is generally an indication of facility lower reliability and availability, while higher availability means higher reliability and lower risk. Operation risk is associated with the probability of equipment or component failure and the consequences of failure such as loss of revenue due to production loss, asset damages, safety and health issues and inspection and maintenance costs. Obiajunwa (2012) reported that typically, power plant turnaround maintenance is planned for every four years, oil refinery and petrochemical plant shutdown maintenance is planned for every two years, and chemical, steel, glass and food and beverage plant shutdown maintenance is planned for every year. Alsyouf (2007) presented a model enabling the decision-makers to identify how an effective maintenance policy could influence the productivity and profitability through its direct impact on quality, efficiency and effectiveness of operation. Backlund and Hanu (2002) reported that while doing the risk analysis, focus must be put on the function required of the subsystem and equipment. Fujiyama et al. (2004) proposed a risk-based maintenance system for steam turbine plants which is coupled with an inspection system. Ghosh and Roy (2009), Rusin and Wojaczek (2012), Vaurio (1995), Khan and Haddara (2003, 2004a,b), Krishnasamy et al. (2005), Tan and Kramer (1997), Duarte et al. (2006) and Vatn et al. (1996) have presented methods to estimate the optimal maintenance and inspection interval considering cost, risk, availability and reliability for individual equipment and have not considered the impact of facility shutdown. Neil and Marquez (2012) proposed a hybrid Bayesian network (HBN) framework to model the availability of renewable systems considering corrective repair time, logistics delay time and scheduled maintenance. These were combined with time-to-failure distributions using HBN. Mannan and Yang (2010) proposed a dynamic risk assessment (DORA) methodology considering various process variables such as level, flow rate, temperature, pressure and chemical concentration and their impact to guide and improve the process design and optimize failure probability. However, the proposed methodology is not considering whether a sequence of component failure will lead to the system failure. The uniqueness of the presented methodology is that it helps to optimize the shutdown inspection and maintenance interval to minimize the overall system failure which will lead to reduce the un-necessary shutdown. Jacob and Amari (2005) presented a binary decision diagram to calculate system reliability and availability. Pil et al. (2008) proposed a redundancy optimization and maintenance strategies based on a time-dependent Markov approach. Khan and Haddara (2003) proposed a comprehensive and quantitative methodology for risk-based maintenance. Dey et al. (1998) and Dey (2001) have applied risk-based approach to the maintenance of oil pipelines. Khan et al. (2008) have presented a risk-based methodology to maximize a system's availability by considering risk-based inspection and maintenance program to reduce the risk of failure and enhance the overall availability of the system. Sarkar and Behra (2012), Bertolini et al. (2009), Kumar and Chaturvedi (2008), Zhaoyang et al. (2011) and Wang et al. (2012) proposed that selecting a maintenance strategy based on risk reduces the overall risk. However, most of these studies are concerned with optimizing equipment inspection and maintenance cycles based on perfect (AGAN) as good as new or minimal (ABAO) as bad as old repair. AGAN strategy holds the assumption that after the maintenance intervention, the system starts its life under the same failure rate as if it were new. On the other hand, ABAO holds that the equipment or system is maintained with minor action, which has not changed the failure rate behavior, and after the maintenance activity, the failure rate remains the same as it was before the maintenance. In order to overcome the short fall of AGAN or ABAO strategy,