Abstract

Modeling, analysis and implementation of maintenance activities of systems have been a complex and cumbersome task since ages. Multi-component maintenance models are concerned with optimal maintenance policies for a system consisting of several units of machines or components, which may or may not depend on each other on three counts, viz., economically/ stochastically/ structurally. On one hand, interactions between components complicate the modeling and optimization of maintenance, on the other hand, interactions also offer the opportunity to group maintenance activities of components which may lead to save substantial costs. Therefore, maintenance models considering maintenance grouping optimization and dependencies or interactions among components make multi-component repairable system modelling are useful and attractive proposition for many industries. Additionally, on several occasions and due to diverse reasons, collection of relevant failure data/history from industries is a difficult task, and in some cases, we get only partial/incomplete data of system which makes the maintenance modelling a difficult task. Therefore, this research focuses on the following three objectives, viz., 1) Failure interaction or stochastic dependency modelling among components of a system, 2) A multi-component maintenance cost and availability model which utilizes both economic as well as stochastic dependency to group maintenance activities of components 3) Develop a model which deals with the missingness in the failure data or partial set of failure data of components in maintenance engineering analysis.

The research work modelled stochastic dependency or failure interaction among components of a system by using Bayesian Network (BN). Failure probabilities of components have been used as the variables in BN. Two scenarios have been considered in this BN modeling; one with aggregated expert opinion approach and other with the help of failure time data of components in a system. The training and testing of the BN are carried out, and to infer on unobserved variables, Recursive Conditioning (RC) algorithm has been used. In RC algorithm, BN is decomposed into smaller sub- networks, known as *d-trees,* that can be solved (inferred) independently. The results from the BN have been compared with the real time data to check the prediction accuracy of BN. The Root Mean Square Deviation (RMSD) and Percentage accuracy of the prediction have been used to check how well the BN predicts unknown scenarios.

The failure interaction information is utilized in modelling to group components to determine the time to carry out their maintenance activities simultaneously. The formation of group(s) is based on extent of dependency among them. Both maintenance cost as well as availability optimization of grouped components have been performed. It is compared with maintenance cost and availability of system when maintenance activities performed on components individually. Penalty functions have been formulated for shifting of maintenance activities of components.

The issue of missingness in failure data of components while reliability modelling has been tackled using *m-graph*. In a missingness problem, we check whether we can find a consistent estimator of joint probability distribution value with missingness present in failure data of components in a system. Based on the type of missingness present in data. a missingness graph is made, which includes fully observed variables, partially observed variables, proxy variables and causal mechanisms responsible for missingness with dependency among them. Based on this dependency information, joint distribution equations have been derived for each type of missingness present in the data. Case studies for each objective have been presented to validate and demonstrate the suitability of each approach in practical scenario.

Keywords: Stochastic dependency, Bayesian network, Penalty function, grouping optimization, missingness graphs.