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Open Press Electrical Accident Risk Assessment based on Bayesian Network

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Abstract

Since multiple state events could not be described and accident probability could not be calculated by fault tree quantitatively for safety assessment, applications of Bayesian network (BN) in safety and reliability fields for the past few years were introduced and basic principle and inference algorithm of Bayesian network were presented. A Bayesian network was developed to model open press electric shock accident as a result of charged press enclosure. The multi-state nodes of the network were illustrated and accident probability was computed finally. The results show that Residual Current Operated Circuit-Breaker with Integral Overcurrent Protection (RCBO) installation can reduce accidents probability of phase-voltage and under-phase-voltage electric shock sharply for open press working in T - T system of low voltage power supply system. In a word, Bayesian network can model system which contains multiple state events, furthermore, accidents probability of that system can be computed correctly, in addition, it offers a comparative tool for various safety design of machine system to guarantee machine inherent safety.

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Keywords: Bayesian network, Multi-state, Electrical safety accident, Safety assessment

1. Introduction

Fault Tree Analysis (FTA) is the most popular probabilistic safety assessment tool in recent years, however, it could not be ignored that in its application the relations between various causes leading to accidents cannot be expressed correctively, especially as to the system which contains multi-state events, common cause failure events and uncertain logic relation between various events[1-2].

Bayesian network (BN) developed recently has the ability to describe multi-state, common cause failure and uncertain logic relations, in addition, attributing to its high effective probability inference algorithm and various kinds of mature software, BN has been used in safety and reliability domains widely and deeply. Zhou et al. provided a method of multi-state system reliability analysis based on BN using multi-state logic figures; Xiaowei Yin, Northeastern University, developed BN models for system reliability assessment and have found out systematic reliability weakness through computing conditional failure probability of the BN[3]; Dianqin Li presented earth-rock dams reliability BN model based on earth-rock dams failure mechanism and the wreckage probability of earth-rock dams and analyzed the importance degree of nodes by making use of the BN[4]; Xiaojia Chen and Chengwu Shen brought forward constructing way and inference

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operational methods of BN for bridge then an inferential evaluation for bridge structure in term of new evidence was finished[5]; Friis-Hansen applied BN to ocean structure reliability analysis[6]; Faber et al. employed BN to research on risk assessment of decommissioning warship options[7]; Bayraktarli et al. adopted BN to analyze reliability of earthquake resistant structure and problem of risk management[8]; Jianli Zhao converted fault tree into BN model and calculated electrical power system reliability based on BN; Holichy discussed BN application of fire risk analysis[9]; Straub put forward risk assessment BN model of natural disaster[10]; Heng Zheng substituted BN for fault tree to make safety assessments for explosive system, in addition, an example on industrial detonator production line illustrated that the BN approach is a good substitute for FTA for safety assessment in pyrotechnics production systems[11]. However, little research has been done on safety assessment of mechanical system, BN theory is introduced first and safety assessment process of open press electrical shock accident is presented, which demonstrates that it is valid to apply BN to safety assessment of electrical accident of mechanical system.

2. Bayesian network

Bayesian network (BN), also known as Bayesian belief network (BBN), is a combination of probability analysis and graph theory [12]. BN is a directed graphical model which is applied to deliver and inference of uncertain knowledge. In fact, a BN model appears to be a causal network assigned variables and the cause and effect variables are represented by nodes, each of which has its own joint probability distribution.

A BN structure for N nodes can be represented by $N=<<V, E>, P>$, which consists of two parts:

- $< V, E>$ stands for a directed acyclic graph G containing N nodes where there is a node set $V=\{V_1, \cdots\cdots, V_n\}$ and the elements of the set represent variables. The node variables could be abstract objects in terms of actual requirements, for example, event state, judgment value or evaluation index. Directed edge E between nodes denotes incidence relations, as well as causal relations between variables, so, BN is called by causal network as well. As for a directed edge (V_i, V_j), V_i is the parent node of V_j and V_j is the child node of V_i. The node without parent nodes and the node without child nodes are named by root node and leaf node respectively. Parent node set and the set which includes no descendant nodes are denoted by $P_a(V_i)$ and $A(V_i)$ respectively. A network $< V, E>$ encodes a set of conditional independence assertions, that is, given $P_a(V_i)$, V_i and $A(V_i)$ are conditional independent which is expressed by Eq. (1).

$$P(V_i \mid P_a(V_i), A(V_i)) = P(V_i \mid P_a(V_i)) \tag{1}$$

- P stands for conditional probability distributions (CPD) associated with each variable. Assuming conditional independency, CPD can be conveyed by $P(V_i \mid Pa(V_j))$ which embodies the incidence relations between nodes and their parent nodes quantitatively. Given root node prior probability distributions and local probability distributions of other nodes, the joint probability distribution of all nodes of the network can be computed.
  In according to conditional independency assumption and separation theorem of network, the joint probability distribution of BN can be calculated by Eq. (2).

$$P(x_1, x_2, \cdots x_n) = \prod_{i=1}^{n} P(x_i \mid parent(x_i)) \tag{2}$$

3. Safety assessment of open press electric shock accident owing to charged enclosure

3.1. BN of Open Press Electric Shock Accident Owing to Charged Enclosure

In practice there are often multi-state events of system components, for instance, three states of a loading motor: under loading, full loading and over loading, three states of electron component: normal, short circuit and open circuit, in addition, hydraulic system has three states: unblocked, blocked and semi-blocked. Although multi-state event tree and multi-state fault tree can describe multi-state system [13], quantitative analyze couldn't be accomplished. An application BN into representation of multi-state events and safety assessment process is put forward, which exemplified by open press electrical shock accident.

Open press power transfer depends on electromotor, gearing and flywheel. In engineering practice, equipment enclosure is charged on account of motor damping or electric circuit and electrical apparatus insulation within equipment damaged.