Application of Fuzzy Logic in Safety Computing for a Power Protection System

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Abstract. The paper proposes and exemplifies how to use the fuzzy logic in the critical analysis of the faults including abnormal workings, for the most important elements in Power Systems. An original fuzzy logic-system enables us to analyze the qualitative evaluation of an Electric Transformer Protection System. A fuzzy event-tree allows the use of verbal statement for probabilities and consequences, such as very high, moderate and low probability. The technique is used for quantitative results computing, as "General Safety Degree" associated to all the paths in the tree. The paper focuses on the "General Safety Degree" algorithm. The application of fuzzy logic system is further demonstrated for a case study. A complex software tool named "Fuzzy Event Tree Analysis" had to be elaborated on this purpose.

1 Introduction

Reliability information can be best expressed using fuzzy sets, because seldom it can be crispy, and the use of natural language expressions about reliability offers a powerful approach to handling the uncertainties more effectively [1], [2], [8]. Fuzzy - set logic is used to account for imprecision and uncertainty in data while employing a safety analysis. Fuzzy logic provides an intuitively appealing way of handling this uncertainty by treating the probability of failure as a fuzzy number. This allows the analyst to specify a range of values with an associated possibility distribution for the failure probabilities. If it is associated a triangular membership function with the interval, this implies that the analyst is "more confident" that the actual parameter lies near the center of the interval than at the edges [2], [8].

In a qualitative analysis event trees (ET) give the sequences of events and their probabilities of occurrence. They start with some initiate event (say a failure of some kind) and then develop the possible sequences of events into a tree. At the end of each path of events the result (safe shutdown, the damage of equipment) is obtained. The probability of each result is computed using the probabilities of the events in the sequence leading to it [2], [6], [7].

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The fuzzy probability of an event can be put into subcategories based on a range of probability, high-if probability is greater than 0,6 but less than 1,0; very low-if probability is greater than 0 but less than 0,2; etc. The fuzzy event-tree (FET) allows the use of verbal statement for the probabilities and consequences, such as very high, moderate and low probability. The occurrence probability of a path in the event tree is than calculated as the product of the event probabilities in the path [6], [7].

A first direction in event-tree analysis [7] uses fuzzy-set logic to account for imprecision and uncertainty in data while employing this analysis. The fuzzy event-tree allows: uncertainty in the probability of failure and verbal statements for the probabilities/consequences (such as low, moderate and high) concerning the impact of certain sequences of events (such as normal, alert and abnormal). In this case, for a simple 2-component parallel system, let $\tilde{P}_A$ ("low") and $\tilde{P}_B$ ("high") be the component fuzzy failure probability. Then $\tilde{P}_{sys}$ will be the fuzzy probability $\tilde{P}_A \times \tilde{P}_B$ illustrated in Fig.1a. [2].

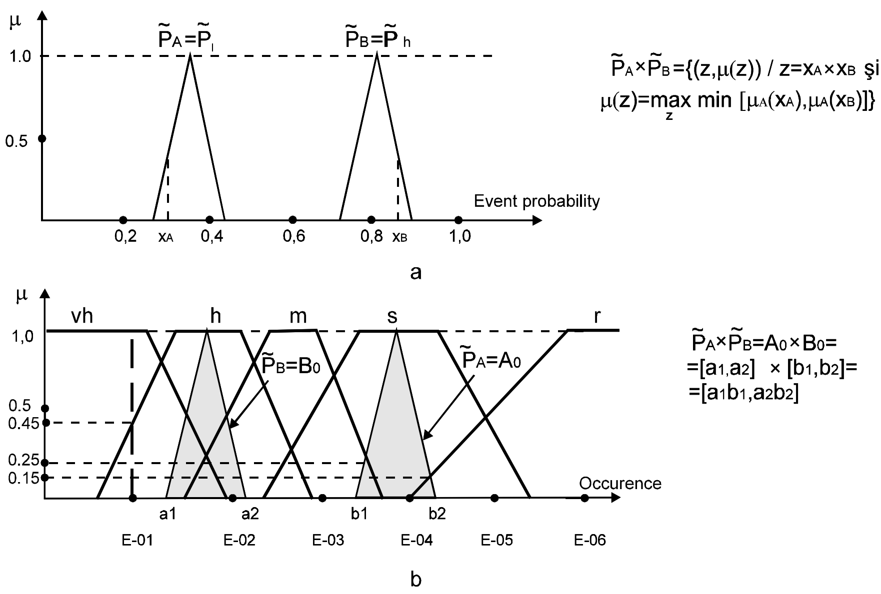

Fig. 1. Fuzzy failure probability evaluation: verbal statement (a), linguistic variable (b)

A second direction in the event- tree analysis [2] uses a linguistic variable to evaluate the fuzzy failure probability. The linguistic values, being assigned to the variable, called "term sets", are generally defined as fuzzy sets that act as restrictions on the base values that them represents. Each of these fuzzy sets means a possibility distribution over the domain of the base variable. For example (Fig. 1.b) "probability of failure" might be a linguistic variable whose values are from the set "remote" ("r"), "low"("l"),"high" ("h") and very high ("vh"). Fuzzy failure probability of the simple 2-component parallel system $\tilde{P}_{sys}$ will be the fuzzy probability $\tilde{P}_A \times \tilde{P}_B$ illustrated in Fig.1.b. The paper uses the linguistic variable in fuzzy failure probability evaluation,