REVIEW ON FAULT DETECTION, IDENTIFICATION AND LOCALIZATION IN ELECTRICAL NETWORKS USING FUZZY-LOGIC

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Abstract: A methodology is presented to detect high-impedance faults in radial distribution feeders by means of fuzzy logic reasoning. The proposed technique is based on the analysis of the feeder responses to impulse waves which are periodically injected at the feeder inlet. Secondary substations are usually equipped with short-circuit detectors only indicating that an over-current has occurred for a given line. In case of a fault, further information about type and location is required to recover an assured grid operation as fast as possible. Conventional algorithms for fault detection used in high voltage grids are not well suited because of the high uncertainties regarding current and voltage measurement in secondary substations. A fuzzy-based approach is well suited in this case. This paper presents a fuzzy logic for detecting, identifying and locating faults occurring within typical medium voltage grids. These responses are compared to standard responses which were previously stored in a database. Standard responses correspond to responses of the feeder operating in normal configurations. A supervisory system processes the information in the database and, using a fuzzy inference machine, indicates possible occurrences of abnormalities. The proposed system has been tested in a real feeder; the relevant results are presented.

I. INTRODUCTION

Electrical power systems are more frequently operated close to their technical limits due to the increase of renewable energy systems and distributed generation. Therefore they become more prone to fault occurrences. Especially the medium voltage grid is affected since it experiences the most significant changes. Therefore fault detection; identification and localization are of great concern for the distribution grid operators. Fault identification and localization mainly includes the following aspects: type, direction, and distance. It is generally independent from protective relaying.

The purpose is not to protect assets through a short-term generation of a trip signal to de energize a faulted section as fast as possible. The objective is to supply the grid operator with information about the fault prior to an on-site investigation. Transmission lines are most prone to occurrence of fault. Fault detection, direction estimation and faulty phase selection play a critical role in the protection for a transmission line. Accurate and fast fault detection and classification under a variety of fault conditions are important requirements of any protective relaying scheme. The methods of fault detection and classification can be classified into the following three categories:-

- Conventional methods for fault detection, e.g. distance protection, require high accurate measuring equipment to work properly. Because of constructional and economical reasons it is not possible to install high accurate measuring equipment like in substations of high voltage (HV) grids.
- Therefore a lot of conventional algorithms, that e.g. are suitable for protective relaying, are not applicable as well for the given inaccuracy of measurement.

Also, a detailed network model is often not present or it would cause a great effort to set detailed parameters for every secondary substation in a distribution network. Therefore, the use of a fuzzy logic is particularly suitable in this case and is hence used for the method described in this paper. Secondary substations are often equipped with short-circuit detectors only indicating that a fault has occurred for the given line since reset. In case of a fault the operator will check these indications to identify and locate the fault, but any further information as well as a timeline of the events are not available. The idea is to implement a fuzzy-based fault detection algorithm in secondary substations. The fuzzy logic has to be able to identify the type and direction of a fault to supply the grid operator with further information. The localization of a fault will be improved the more secondary substations are equipped with this logic. Conventional methods for fault detection, e.g. distance protection, require high accurate measuring equipment to work properly. Because of constructional and economical reasons it is not possible to install high accurate measuring equipment like in substations of high voltage (HV) grids. Therefore a lot of conventional algorithms, that e.g. are suitable for protective relaying, are not applicable as well for the given inaccuracy of measurement. Also, a detailed network model is often not present or it would cause a great effort to set detailed parameters for every secondary substation in a distribution network. Fault identification and localization mainly includes the following aspects: type, direction, and distance. It is generally independent from protective relaying. The purpose is not to protect assets through a short-term generation of a trip signal to de-energize a faulted section as fast as possible. The objective is to supply the grid operator with information about the fault prior to an on-site investigation. Secondary substations are often equipped with short-circuit detectors only indicating that a fault has occurred for the given line since reset. In case of a fault the operator will check these indications to identify and locate the fault, but any further information as well as a timeline of the events are not available. The idea is to implement a fuzzy-based fault detection algorithm in secondary substations. The fuzzy logic has to be able to identify the type and direction of a fault to supply the grid operator with further information. The localization of a fault will be improved the more secondary substations are equipped with this logic.

II. METHODOLOGY

The forecasting of future loads for a relatively large lead time (months to few years) is studied in long term load forecasting. Future load demand estimation is done for different lead times, ranging from few seconds to years. These different lead times are called forecasting intervals. Overestimation of the future load may lead to financial crisis, as more money will be spent on new building. Underestimation of load may cause troubles in supplying this load from the available electric supplies. There will be shortage in the spinning reserve of the system, and it may lead to a system which is insecure and unreliable system. Not much work is done on the long-term load forecasting, because years of economic and demographic data is required and it not be easy to gather data for so many years. Even if we collect data, this forecasting is complex in the sense that it is affected by environmental, economical, and social factors. Different researches are being carried out in this area and numerous forecasting methods were found out. Generally any long term load demand forecasting is inaccurate. The various long-term load demand forecasting methods can be classified in to two categories, i.e. parametric methods and artificial intelligence based methods. The artificial intelligence methods are further classified into neural networks, support vector machines, genetic algorithms, wavelet networks, fuzzy logics and expert system methods. Fuzzy Logic methodology plays a very important role in the operation and management of power systems. Forecasting of future loads for a relatively large lead time is studied here (long term load forecasting). Artificial intelligence techniques are of greater accuracy as compare to the various techniques used in forecasting load. Fuzzy Logic is a very robust artificial intelligent technique and is used in this research to forecast load on long term basis.

Fuzzy Logic

In using our everyday natural language to import knowledge and information, there is a great deal of impression and vagueness. Fuzzy logic is a fascinating area of research because it does a good job of trading off between significance and precision. For example; “Jasmine is tall” and “Julia is short”. The term tall and short are fuzzy, in the sense that they cannot be sharply defined. Then it is not always possible to assert that the statement is either true or false. The fuzzy logic provides a mean for representing uncertainties.

Basic Component of Fuzzy System

The basic configuration of the fuzzy system used in this paper is shown in Fig.1. There are four basic elements in a fuzzy system which is:-

(a) Fuzzification: The process of associating crisp input values with the linguistic terms of corresponding input linguistic variable.

(b) Fuzzy inference engine: Provides the decision making logic of the system. It map the fuzzy inputs earlier to the fuzzy output based on the fuzzy rules and fuzzy set database by performing following computation:

Aggregation: Computation of the IF part of the rules (computes how appropriate each rule to the current situation)

Composition: Computation of the THEN part of the rules (computes on how each rule influences the output variables)

Result Aggregation: After the degrees of truth for the rules are computed, this step determines which rules will contribute to the deffuzzified result.

(c) Fuzzy rule base: A set of linguistic rules or conditional statements in the form of “IF a set of conditions IS satisfied, THEN a set of consequences are inferred”. These if-then rule statements are used to formulate the conditional statements that comprise fuzzy logic.

(d) Defuzzification interface: Deffuzzified the fuzzy outputs of the fuzzy inference machine and generate a non-fuzzy (crisp) output which is the actual output of the fuzzy system.

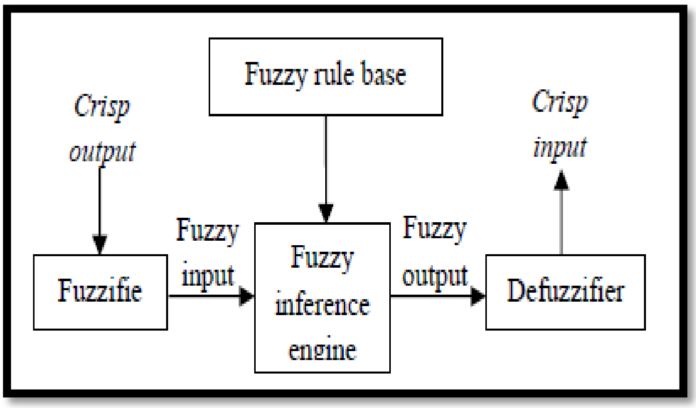

Fig.1: Basic Configuration of Fuzzy System

Principles

The overall schematic is shown in Fig. 2. The concept is based on sampled values of currents and voltages. Calculation of zero-sequence components, root mean square (RMS) values and total harmonic distortion (THD) is done. The resulting values are used for the fuzzy inference system that outputs the fault credibility as well as the most likely type and direction of the fault as a function of time.

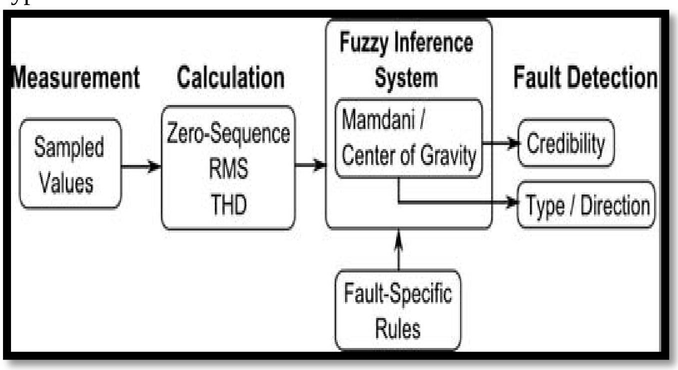

Fig. 2: Overall schematic of the fuzzy-based concept for fault

Detection, type identification and localization

The advantage of a fuzzy-based approach over conventional algorithms, like e.g. used in directional over current protection, is its flexibility concerning input values and measurement accuracy. A fuzzy approach can take any available input values into account, e.g. the THD can be used as an additional quantity. And in case of high measurement inaccuracies, the use of fuzzy sets provides more information than the application of crisp thresholds, because from a single input value multiple membership degrees are calculated. In this manner, conclusions can be drawn considering all input values in their context. This decision-making process is depicted in Fig. 3 and compared to a simple binary logic.

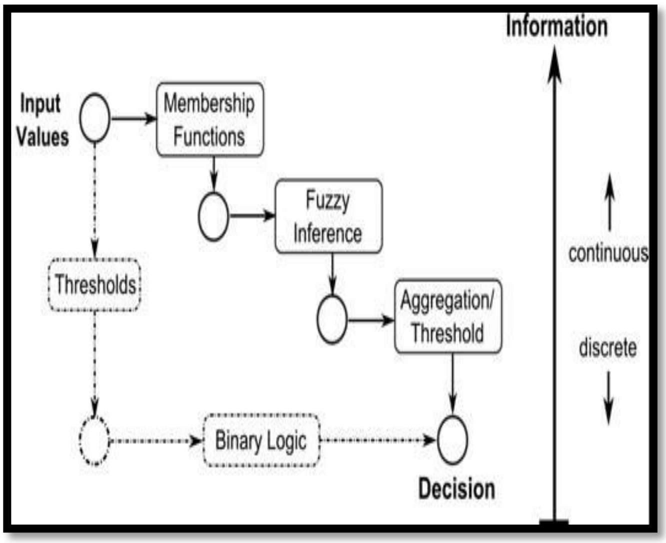

Fig. 3: Decision-making process of the fuzzy approach compared to a simple binary logic

In contrast to the related work, the novel approach is to define multiple rules for each type of fault. The rules consist of two credibility classes, being either rough with only small weight or quite distinct implying more significance. This approach makes it easier to adapt expert knowledge and the impact of the line topology and neutral point treatment can be taken into account by appropriate rules.

Proposed work

The proposed fuzzy-based method is highly suitable to detect and identify faults in typical medium-voltage feeders and is especially able to cope with the inaccuracy of measurements in secondary substations. This is due to the probabilistic approach in form of fuzzy rules. A remarkable aspect of this method compared to the research work so far is on the one hand the introduction of rule compositions consisting of two credibility classes that simplify the adaption of expert knowledge. On the other hand it is the design of the output membership functions that only indicate whether a fault is likely or not. But the identification of the fault and direction is based on a comparison of the credibility of each fault-specific rule composition. Also this approach can take any available and calculated input values into account and their accuracy is regarded by appropriate membership functions. Implementing this fuzzy-based method in secondary substations will supply the grid operator with further information about occurred faults and the localization of the fault would be supported through a directional indication.

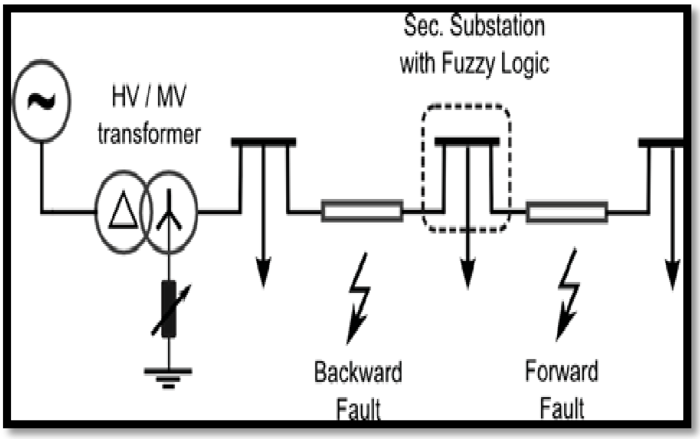

Fig. 4: Scheme of a radial medium-voltage feeder with the proposed fuzzy logic to detect fault type and direction

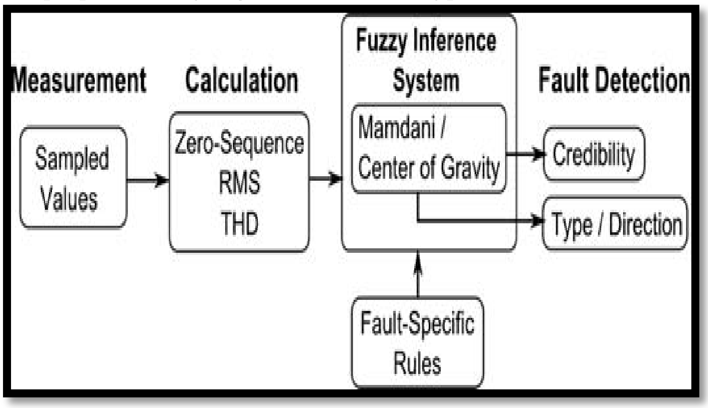

Fig. 5: Overall schematic of the fuzzy-based concept for fault detection, type identification and localization

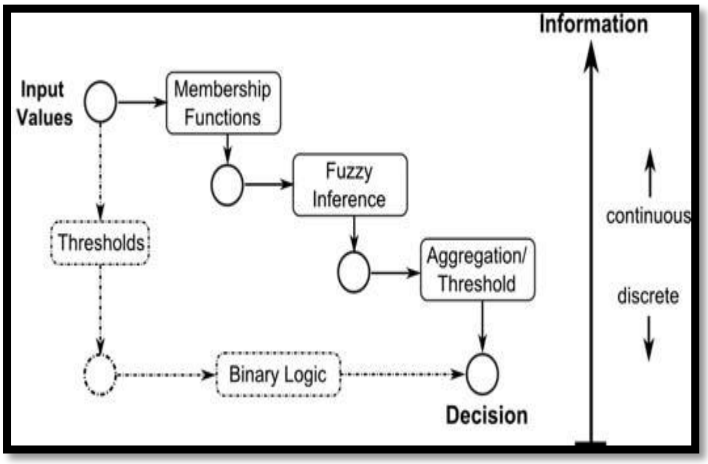

Fig. 6: Decision-making process of the fuzzy approach compared to a simple binary logic

III. CONCLUSION

The proposed fuzzy-based method is highly suitable to detect and identify faults in typical medium-voltage feeders and is especially able to cope with the inaccuracy of measurements in secondary substations. This is due to the probabilistic approach in form of fuzzy rules. A remarkable aspect of this method compared to the research work so far is on the one hand the introduction of rule compositions consisting of two credibility classes that simplify the adaption of expert knowledge. On the other hand, it is the design of the output membership functions that only indicate whether a fault is likely or not. But the identification of the fault and direction is based on a comparison of the credibility of each fault-specific rule composition. Also, this approach can take any available and calculated input values into account and their accuracy is regarded by appropriate membership functions. Implementing this fuzzy-based method in secondary substations will supply the grid operator with further information about occurred faults and the localization of the fault would be supported through a directional indication. Therefore, this method is a step towards an intelligent secondary substation.

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