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A NOTE ON ROUGH SET THEORY APPLICATIONS IN POWER ENGINEERING

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Teoria mulţimilor rough, propusă de Zdzislaw Pawlak în anul 1982, reprezintă o tehnică utilă pentru analiza datelor incomplete. Ea are aplicaţii în diferite domenii, fiind considerată complementară altor teorii care lucrează cu astfel de date, cum sunt, de exemplu, teoria mulţimilor fuzzy sau inferenţa Bayesiană. Articolul prezintă câteva aplicaţii ale teoriei mulţimilor rough în domeniul electroenergetic.

Rough Set theory, proposed by Zdzislaw Pawlak in 1982, has proved to be an adequate technique in imperfect data analysis, which has found interesting extensions and various applications. It can be regarded as complementary to other theories that deal with imperfect knowledge, such as or fuzzy sets or Bayesian inference. The paper presents some Rough Set theory applications in electrical power engineering.

Keywords: data management, information systems, knowledge engineering, power systems

1. Introduction

The concept of Rough Sets (RS) was proposed by Zdzisław Pawlak in 1982 as a mathematical tool for data analysis [1]. In some previous works (1981), he introduced the rough relations, the concept of information systems and the classification of objects by attributes [2,3,4].

The advantage of using RS for data analysis is given by the fact that the information stored within the primary data is sufficient for performing the analysis, unlike in fuzzy logic, where a degree of membership or value of possibility are required or in statistical methods, where probability distributions are needed.

The RS theory is based on the concept of information system, which is a tabularized data set; the columns are labeled as “attributes”, while rows are labeled as “objects” or “events”. In the context of data analysis, the basic operations in RS theory are used in order to discover fundamental patterns in data, remove redundancies and generate decision rules.

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RS theory has found its applications in several fields of computational intelligence, such as intelligent systems, machine learning, expert systems, pattern recognition, knowledge discovery, and others [5-9]. These further originated real-life applications, such as signal and image processing [10-13], banking risk assessment [14,15], medicine [16-19], and many others. A small amount of applications in electrical engineering were also proposed, and will be addressed in section 2 of this paper.

Recent advances in RS foundations are presented in [20, 21].

2. Example applications of rough set theory in power engineering

Power engineering is not yet well covered from the RS relevance point of view. Several applications have been studied, some of them being presented in the following.

Using the data taken from a power system control center, the authors of [22] suggested a systematic transformation of an extensive set of examples into a concise set of rules. RS theory is used in order to classify the current state of the power system in one of the three categories: normal (S), abnormal (U1) and restorative (U2).

Based mainly on two concepts from RS theory – *reduct* and *core* - the approach reduces the power system data base by following an algorithm initially proposed in [23] and adapted for power system applications by authors of [22] previously, in [24]. The *reduct* of a family of equivalence relations, R, is defined as a reduced set of relations that conserves the same inductive classification of set R; it is denoted as RED(R). The *core* is a set of relations that appears in all reduct of R, i.e. the set of all indispensable relations needed to characterize the relation R and is denoted as CORE(R).

The proposed algorithm has 4 steps. They are firstly exemplified by using a set of power system operating states described by 4 attributes and the corresponding system state (S, U1, U2):

1. eliminate dispensable attributes;
2. compute the core of each example and the decision table core;
3. compute the reduct of each example and compose a table containing all possible decision examples;
4. obtain the final decision table by merging the two computed tables.

The algorithm was tested on a set of 25 examples, each described by 8 attributes and the decision regarding the system state. Three attributes represent voltage limits, three help in describing line loadings, and the last two are binary status signals from circuit breakers.

The decisions, used as examples, were suggested by experienced power system control operators, based on previously gained knowledge. After applying the algorithm, the set of examples is reduced and only five decision rules are generated. The complete and final decision rules are obtained after switching the values into their original domains of definition. Even though only a small set of examples, defined by a small amount of attributes, are used in the application, the proposed algorithm is general and could be applied as well on a larger scale. The results obtained in [22] justify the application of RS theory in decision support systems dedicated to power system control centers.

RS theory has been also used as complementary technique for consumer load forecasting in electrical distribution networks. In [25], self organizing maps (SOM) and RS are used for data mining in distribution companies' data bases in order to find a set of prototype profiles. These prototypes form the space of all possible consumer profiles. SOM is used for finding clusters of profiles. These are statistically aggregated into one profile, called "typical". Each cluster can therefore be represented by its typical profile. RS are used to associate to each consumer from the data base one of the typical profiles. The RS-based algorithm uses information from data bases related to consumers, like monthly bill, number of phases, consumer type and so on.

The proposed methodology was tested on a data base of 417 consumers. The SOM process resulted into 10 clusters, and RS theory was used in order to extract the rules required for classifying the consumers. Authors of [25] did not present in detail the implementation process or the mathematical formalism of the proposed methodology, but results show that the prediction errors are lower for this approach than those resulted from the technique used by the distribution company at that time.

An application of RS theory for steady state security assessment is presented in [26]. The assessment of steady state security becomes more difficult when the system dimensionality increases. The computer programs for off-line security assessment cannot be easily adapted for on-line operation, as a high number of contingencies have to be analyzed. These studies have to take into consideration a large amount of scenarios corresponding to all possible events, and furthermore, they have to be performed very frequently [27].

The proposed methodology, based on RS theory, is intended to provide a classification of the current operating state into four categories: normal, alert, alarm level 1 and alarm level 2. The tests were performed by using a software package for steady state security assessment developed by the authors of [26] and the ROSE computer program, developed within [28]. The network used for simulations was the IEEE 118-bus system. After a first order contingency analysis, 231 scenarios resulted as useful in creating a data base, each example being represented by 6 attributes. By using RS theory, only four of these attributes prove to form the *core* and *reduct* of the set of contingencies. The reported results of [30] suggest the applicability of rough sets for real time steady-state security assessment, by reducing the volumes of data that have to be processed and by fast construction of decision rules to classify the system state.

The list of applications presented here is by no means exhaustive. Other RS applications in power engineering have also been developed, including the classification of power quality disturbances [29], fault diagnosis of power transformers [30], establishing numerical distance relay operating algorithms [31], classification of system faults, attacks, contingencies and system operating points [32-35]. A general view on RS theory and its applications in electrical power engineering is given in [36].

3. Conclusions

Since the beginning of RS, mathematicians and scientists showed great interest in their development and potential applications. Remarkable advances have been made in different directions of theoretical studies, but the impressiveness of RS theory comes from its wide applicability in solving real-life problems from many domains of interests. One of these is power engineering. As this shown in the previous section of this paper, the uses of RS theory in power engineering applications are diverse.

Even though RS are easy to use and would enable the solving of many issues in electric power engineering, the number of applications employing them was quite limited at the time of this study, in relation to their potential and to the number of applications in other domains.

Nevertheless, the existing studies prove the performances of RS theory in power engineering applications and constitute a solid starting point for future work in this field.

Presently, the author of this paper is working on developing a methodology based on RS for knowledge extraction in order to automatically aggregate data in power systems control centers so as to present each human operator the correct amount of information that he needs and in a quickly discernible form. The aggregation will be made accordingly to the hierarchical level that data are addressed to and represents a work in progress that will be published in the near future.

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