



Nano Topological Analysis For Power System Control

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ABSTRACT

In this paper, we introduce an approach for analysis of information concerning electrical power system. The suggested method is a result of hybridizing rough set concepts with nano topology constructed on the set of all data using the boundary of uncertain decision sets and its lower approximation. Bases of nano topologies are used as indicators for selecting effective features in information system of a power control. This method is applied using the main experimental data which make the suggested model near from the real life information.

Keywords

Rough Sets, Nano Topology, Lower Approximation, Upper Approximation, Core.

INTRODUCTION

Electrical power system is one of the most complex artificial systems in this world, which safe, steady, economical and reliable operation plays a very important part in social economic development, even in social stability due to high degree of uncertainty and the large number of variables involved. The various supervision and control actions require the presence of an operator, who must be capable of efficiently responding to the most diverse requests, by handling various types of data and information [3,4,16].

Rough set theory (RST) is a relatively new mathematical and AI technique introduced in the early 1980's by Pawlak [8,9,10,11,12]. The technique is particularly suited to reasoning about imprecise or incomplete data, and discovering relationships in this data. A classification is simply a partition of a universe [14]. Thus, in rough set theory, objects are partitioned into equivalence classes based on their attribute-values, which are essentially functional information associated with the objects. Many databases only contain functional information about objects; however, data about the relationships between objects has become increasingly important in decision analysis.

The main advantage of rough set theory is that it does not require any preliminary or additional information about data-like probability in statistics, basic probability assignment in Dempster Shafer theory of evidence or the value of possibility in fuzzy set theory. Lellis Thivagar et al [15] introduced a nano topological space with respect to a subset X of an universe which is defined in terms of lower and upper approximations of X . The elements of a nano topological space are called the nano-open sets. He has also studied nano closure and nano interior of a set.

The word "nano" itself refers to the length scale (one nanometre is one billionth of a metre) that is one thousand times smaller than the micro scale, the scale that was traditionally associated with the electronics industry. Viruses and DNA are examples of natural objects on the nano scale, in contrast a human cell can appear enormous. The term nanotechnology refers to the engineering, measurement understanding of nano-scaled materials and devices.

The elements of nano topology can be characterized by through two crisp sets, called lower and upper approximations belong to the set. Following these definitions, the boundary region is the difference between the two approximations and we have applied the concept of topological basis to find the deciding factors in power system control.

In this paper, we apply nano topology to find the deciding factors in power system control.

1- Preliminaries

Definition 1.1 [2,4,7,13]: Let U be a non-empty finite set of objects called the universe and R be an equivalence relation on U named as the indiscernibility relation. The pair (U, R) is called the approximation space. Let X be a subset of U .

- i) The lower approximation of X with respect to R is the set of all objects, which can be for certain classified as X with respect to R and it is denoted by $R_*(X)$

$$R_*(X) = \bigcup_{x \in U} \{R(x) : R(x) \subseteq X\} \text{ where } R(x)$$

denotes the equivalence class determined by X

- ii) The upper approximation of X with respect to R is the set of all objects, which can be possibly classified as X with respect to R and it is denoted by $R^*(X)$ That is,



$$R^*(X) = \bigcup_{x \in U} \{R(x) : R(x) \cap X \neq \emptyset\}$$

- iii) The boundary region of X with respect to R is the set of all objects, which can be classified neither as X nor as not- X with respect to R and it is denoted by $B_R(X)$. That is, $B_R(X) = R^*(X) - R_*(X)$

The set X is said to be rough with respect to R if $R^*(X) \neq R_*(X)$. That is, if $B_R(X) \neq \emptyset$.

Proposition 1.2 [6]:

If (U, R) is an approximation space and X and Y are subsets of U , then

- i) $R_*(X) \subseteq X \subseteq R^*(X)$
- ii) $R_*(\emptyset) = R^*(\emptyset) = \emptyset$ and $R_*(U) = R^*(U) = U$
- iii) $R^*(X \cup Y) = R^*(X) \cup R^*(Y)$
- iv) $R_*(X \cup Y) \supseteq R_*(X) \cup R_*(Y)$
- v) $R_*(X \cap Y) = R_*(X) \cap R_*(Y)$
- vi) $R^*(X \cap Y) \subseteq R^*(X) \cap R^*(Y)$
- vii) $R_*(X) \subseteq R_*(Y)$ and $R^*(X) \subseteq R^*(Y)$ whenever $X \subseteq Y$
- viii) $R_*(XC) = [R^*(X)]C$ and $R^*(XC) = [R_*(X)]C$
- ix) $R_*R_*(X) = R_*R^*(X) = R_*(X)$
- x) $R^*R^*(X) = R^*R_*(X) = R^*(X)$

Remark 1.3: $R^*: P(U) \rightarrow P(U)$ satisfies the Kuratowski closure axioms that

- i) $R^*(\emptyset) = \emptyset$
- ii) $X \subseteq R^*(X)$
- iii) $R^*(X \cup Y) = R^*(X) \cup R^*(Y)$
- iv) $R^*R^*(X) = R^*(X)$ for all subsets X and Y of U

If $F = \{X \subseteq U / R^*(X) = X\}$, using conditions (i) to (iv), we see that \emptyset and U are in F ;

$X \cup Y \in F$ whenever X and Y are in F and $\bigcap X_\alpha \in F$ for all X_α in F . Therefore the family T , of complements of members of F is a topology on U . Thus, F is the family of T -closed sets. Also, $Cl(X) = R^*(X)$. Therefore, R^* is the

Kuratowski's closure operator

Remark 2.4: Since $R^*: P(U) \rightarrow P(U)$ satisfies the following properties that

- v) $R_*(U) = U$
- vi) $R_*(X) \subseteq X$
- vii) $R_*(X \cap Y) = R_*(X) \cap R_*(Y)$
- viii) $R_*R_*(X) = R_*(X)$ for all subsets X and Y of U , the operator R_* is the Interior operator.

2- Nano Topology

In this section we use nano topology Lellis Thivagar et al [15] in terms of the lower and upper approximations.

Remark 2.1: Let U be the universe of objects and R be an equivalence relation on U . For $X \subseteq U$, we define

$\tau_R = \{U, \emptyset, R^*(X), R_*(X), B_R(X)\}$, where $R^*(X)$, $R_*(X)$ and $B_R(X)$ are respectively the upper approximation, the lower approximation and the boundary region of X with respect to R . We note that U and $\emptyset \in \tau_R$.

Since $R_*(X) \subseteq R^*(X)$, $R_*(X) \cup R^*(X) = R^*(X) \in \tau_R$. Also,



$R^*(X) \cup B_R(X) = R^*(X) \in \tau_R$ and $R_*(X) \cup B_R(X) = R^*(X) \in \tau_R$. Also,

$R_*(X) \cap R^*(X) = R_*(X) \in \tau_R$; $R^*(X) \cap B_R(X) = B_R(X) \in \tau_R$ and $R_*(X) \cap B_R(X) = \varphi \in \tau_R$.

Definition 2.2: Let U be the universe, R be an equivalence relation on U and

$$\tau_R = \{U, \varphi, R_*(X)\},$$

$\{R^*(X), B_R(X)\}$ where $X \subseteq U$. τ_R satisfies the following axioms:

- i) U and $\varphi \in \tau_R$.
- ii) The union of the elements of any subcollection of τ_R is in τ_R .
- iii) The intersection of the elements of any finite subcollection of τ_R is in τ_R .

τ_R forms a topology on U called as the nano topology on U with respect to X . We call (U, τ_R, X) as the nano topological space.

Example 2.3: Let $U = \{a, b, c, d, e\}$, $U/R = \{\{a, b\}, \{c, d\}, \{e\}\}$, the family of equivalence classes of U by the equivalence relation R and $X = \{a, c, d\}$. Then $R^*(X) = \{a, b, c, d\}$, $R_*(X) = \{c, d\}$ and $B_R(X) = \{a, b\}$. Therefore the nano topology $\tau_R = \{U, \varphi, \{a, b, c, d\}, \{c, d\}, \{a, b\}\}$.

Proposition 3.4: If τ_R is the nano topology on U with respect to X , then the set $B = \{U, R_*(X), B_R(X)\}$ is the basis for τ_R .

Proof:

$$i) \bigcup_{A \in B} A = U$$

ii) Consider U and $R_*(X)$ from B . Let $W = R_*(X)$. Since $U \cap R_*(X) = R_*(X)$, $W \subset U \cap R_*(X)$ and every x in $U \cap R_*(X)$ belongs to W . If we consider U and $B_R(X)$ from B , taking $W = B_R(X)$, $W \subset U \cap B_R(X)$ and every x in $U \cap B_R(X)$ belongs to W , since $U \cap B_R(X) = B_R(X)$. And when we consider $R_*(X)$ and $B_R(X)$, $R_*(X) \cap B_R(X) = \varphi$. Thus, B is a basis for τ_R .

Definition 2.4: Let U be the universe and R be an equivalence relation on U . Let τ_R be the nano topology on U and β_R be the basis for τ_R . A subset M of A , the set of attributes is called the core of R if $\beta_M \neq \beta_{R-(r)}$ for every r in M . That is, a core of R is a subset of attributes which is such that none of its elements can be removed without affecting the classification power of attributes.

3- Nano Topology in Power System Control Center

The operation of a power system is intrinsically complex due to high degree of uncertainty and the large number of variables involved [5]. The various supervision and control actions require the presence of an operator, who must be capable of efficiently responding to the most diverse requests, by handling various types of data and information [6].

One of the most important operator task is to determine the current operational state of the system. To accomplish this task, the operator receives many data measured into the system. These data can be analogical (e.g., position of circuit breakers) or digital (e.g., real power flow in a specific transmission line). By handling these data, the operator tries to built an image of the operation point of the power system supervised for him/her.

The analysis performed by the operator tries to make a classification of the operational state of the system in one of the two states: normal, and restorative.

In the first state, normal state, all loads are supplied and all measurements are inside of the nominal rates. For the restorative operational state, some loads are not supplied, i.e., there was a loading shedding process .

The problem found by the operator is to use all available data in his/her analyses. A huge number of data and information in a control center database must be manipulated and, mainly, composed to allow the operator to have a visualization of the current state of the system. The manipulation of all data/information is not an easy task.

- 4- This paper presents an example of an alternative approach to help the operators to produce the classification of the system in its possible states. This approach is based on the Nano Topological Analysis, proposed by Lellis Thivagar et al [7].

4- Example

Let Table 1, where the information system proposed is composed by $R=\{A, B, C, D, R \mid \{A,B,C,D\} \Rightarrow \{R\}\}$, being A, B, C, D and R , the attributes for transmission lines A and B , self-generation, self-load, and operation point, respectively. Using these values. In many cases, power system problems can be analyzed by considering only an incomplete set of cases. In power system, it should be noticed that it is impossible to get all possible intervals of each measure and produce all combinations among them, because the number of observed points is enormous. Thus, the produced set of examples in a real system is always incomplete.

Table 1. The information system

EX.	Trans.Line A	Trans.Line B	Self-Gen C	Self-Load D	Result
E1	medium	medium	Medium	medium	Normal
E2	medium	low	Low	medium	Rest
E3	medium	low	Low	medium	Normal
E4	low	low	Low	high	Rest
E5	low	medium	Medium	medium	Rest
E6	medium	medium	Low	high	Normal
E7	medium	medium	Low	low	Rest
E8	medium	medium	Low	high	Normal

$$U = \{E_1, E_2, E_3, E_4, E_5, E_6, E_7, E_8\}$$

Case 1

$$\text{Let } X = \{E_1, E_3, E_6, E_8\}$$

Let R be the equivalence relation on U with respect to the condition attributes. The family of equivalence classes corresponding to r is given by

$$U/I(R) = \{\{E_1\}, \{E_2, E_3\}, \{E_4\}, \{E_5\}, \{E_6, E_8\}, \{E_7\}\}.$$

The lower and upper approximations of X with respect to R are given by

$$R_*(X) = \{E_1, E_6, E_8\} \quad R^*(X) = \{E_1, E_2, E_3, E_6, E_8\}$$

The nano topology on U with respect to X is given by

$$\tau_R = \{U, \varphi, \{E_1, E_6, E_8\}, \{E_1, E_2, E_3, E_6, E_8\}, \{E_2, E_3\}\}$$

The basis for this topology τ_R is given by $\beta_R = \{U, \{E_1, E_6, E_8\}, \{E_2, E_3\}\}$

- 1- If we remove the attribute trans.Line A from the set of condition attributes, the family of equivalence classes corresponding to the resulting set of attributes is given by

$$U/I(R - (A)) = \{\{E_1, E_5\}, \{E_2, E_3\}, \{E_4\}, \{E_6, E_8\}, \{E_7\}\}.$$

The corresponding lower and upper approximation are given by

$$(R - (A))_*(X) = \{E_6, E_8\} \quad ; \quad (R - (A))^*(X) = \{E_1, E_2, E_3, E_5, E_6, E_8\}$$

$$\text{And hence } \tau_{R-(A)} = \{U, \varphi, \{E_6, E_8\}, \{E_1, E_2, E_3, E_5, E_6, E_8\}, \{E_1, E_2, E_3, E_5\}\}$$

$$\text{And its basis } \beta_{R-(A)} = \{U, \{E_6, E_8\}, \{E_1, E_2, E_3, E_5\}\} \neq \beta_R$$

- 2- If we remove the attribute trans.Line B from the set of condition attributes, the family of equivalence classes corresponding to the resulting set of attributes is given by



$$U/I(R - (B)) = \{ \{E_1\}, \{E_2, E_3\}, \{E_4\}, \{E_5\}, \{E_6, E_8\}, \{E_7\} \}$$

Which is the same as $U/I(R)$ and hence $\tau_{R-(B)} = \tau_R$ and $\beta_{R-(B)} = \beta_R$

- 3- If we remove the attribute Self Gen. C from the set of condition attributes, the family of equivalence classes corresponding to the resulting set of attributes is given by

$$U/I(R - (C)) = \{ \{E_1\}, \{E_2, E_3\}, \{E_4\}, \{E_5\}, \{E_6, E_8\}, \{E_7\} \}$$

Which is the same as $U/I(R)$ and hence $\tau_{R-(C)} = \tau_R$ and $\beta_{R-(C)} = \beta_R$

- 4- If we remove the attribute Self Load D from the set of condition attributes, the family of equivalence classes corresponding to the resulting set of attributes is given by

$$U/I(R - (D)) = \{ \{E_1\}, \{E_2, E_3\}, \{E_4\}, \{E_5\}, \{E_6, E_7, E_8\} \}.$$

The corresponding lower and upper approximation are given by

$$(R - (D))_*(X) = \{E_1\} ; (R - (D))^*(X) = \{E_1, E_2, E_3, E_6, E_7, E_8\}$$

And hence $\tau_{R-(D)} = \{U, \varphi, \{E_1\}, \{E_1, E_2, E_3, E_6, E_7, E_8\}, \{E_2, E_3, E_6, E_7, E_8\}\}$

And its basis $\beta_{R-(D)} = \{U, \{E_1\}, \{E_2, E_3, E_6, E_7, E_8\}\} \neq \beta_R$

If $M = \{A, D\}$, Then the basis of thr rough topology corresponding to M is given by

$$\beta_M = \{U, \{E_6, E_8\}, \{E_1, E_2, E_3\}\}$$

Also $\beta_M \neq \beta_{R-(X)}$ for all x in M. Therefore, CORE = {A, D}

Case 2

Let $X = \{E_2, E_4, E_5, E_7\}$

Let R be the equivalence relation on U with respect to the condition attributes. The family of equivalence classes corresponding to r is given by

$$U/I(R) = \{ \{E_1\}, \{E_2, E_3\}, \{E_4\}, \{E_5\}, \{E_6, E_8\}, \{E_7\} \}.$$

The lower and upper approximations of X with respect to R are given by

$$R_*(X) = \{E_4, E_5, E_7\} \quad R^*(X) = \{E_2, E_3, E_4, E_5, E_7\}$$

The rough topology on U with respect to X is given by

$$\tau_R = \{U, \varphi, \{E_4, E_5, E_7\}, \{E_2, E_3, E_4, E_5, E_7\}, \{E_2, E_3\}\}$$

The basis for this topology τ_R is given by $\beta_R = \{U, \{E_4, E_5, E_7\}, \{E_2, E_3\}\}$

- 1- If we remove the attribute trans.Line A from the set of condition attributes, the family of equivalence classes corresponding to the resulting set of attributes is given by

$$U/I(R - (A)) = \{ \{E_1, E_5\}, \{E_2, E_3\}, \{E_4\}, \{E_6, E_8\}, \{E_7\} \}.$$

The corresponding lower and upper approximation are given by

$$(R - (A))_*(X) = \{E_4, E_7\} ; (R - (A))^*(X) = \{E_1, E_2, E_3, E_4, E_5, E_7\}$$

And hence $\tau_{R-(A)} = \{U, \varphi, \{E_4, E_7\}, \{E_1, E_2, E_3, E_4, E_5, E_7\}, \{E_1, E_2, E_3, E_5\}\}$

And its basis $\beta_{R-(A)} = \{U, \{E_4, E_7\}, \{E_1, E_2, E_3, E_5\}\} \neq \beta_R$

- 2- If we remove the attribute trans.Line B from the set of condition attributes, the family of equivalence classes corresponding to the resulting set of attributes is given by

$$U/I(R - (B)) = \{ \{E_1\}, \{E_2, E_3\}, \{E_4\}, \{E_5\}, \{E_6, E_8\}, \{E_7\} \}$$

Which is the same as $U/I(R)$ and hence $\beta_{R-(B)} = \beta_R$

- 3- If we remove the attribute Self Gen. C from the set of condition attributes, the family of equivalence classes corresponding to the resulting set of attributes is given by

$$U/I(R - (C)) = \{ \{E_1\}, \{E_2, E_3\}, \{E_4\}, \{E_5\}, \{E_6, E_8\}, \{E_7\} \}$$

Which is the same as $U/I(R)$ and hence $\tau_{R-(C)} = \tau_R$ and $\beta_{R-(C)} = \beta_R$

- 1- If we remove the attribute Self Load D from the set of condition attributes, the family of equivalence classes corresponding to the resulting set of attributes is given by

$$U/I(R - (D)) = \{ \{E_1\}, \{E_2, E_3\}, \{E_4\}, \{E_5\}, \{E_6, E_7, E_8\} \}.$$

The corresponding lower and upper approximation are given by

$$(R - (D))_*(X) = \{E_4, E_5\} ; (R - (D))^*(X) = \{E_2, E_3, E_4, E_5, E_6, E_7, E_8\}$$

And hence

$$\tau_{R-(D)} = \{U, \varphi, \{E_4, E_5\}, \{E_2, E_3, E_4, E_5, E_6, E_7, E_8\}, \{E_2, E_3, E_6, E_7, E_8\}\}$$

And its basis $\beta_{R-(D)} = \{U, \{E_4, E_5\}, \{E_2, E_3, E_6, E_7, E_8\}\} \neq \beta_R$

$$\text{If } M = \{A, D\}, U/I(r) = \{ \{E_1, E_2, E_3\}, \{E_4, E_5\}, \{E_6, E_8\}, \{E_7\} \} ,$$

$$r_*(X) = \{E_4, E_5, E_7\}$$

$$r^*(X) = \{E_1, E_2, E_3, E_4, E_5, E_7\}$$

Where r is the equivalence relation on U with respect to M. Therefore ,

$$\beta_M = \{U, \{E_4, E_5, E_7\}, \{E_1, E_2, E_3\}\} \neq \beta_{R-(X)} \text{ for all } x \text{ in } M. \text{ Therefore, here again}$$

$$\text{CORE} = \{A, D\}$$

5- Observation of the two cases

we conclude that Trans.Line A and Self Load D are the key attributes that can cover all possible intervals of each measure and produce all combinations among them in spite of the enormous number of observed points.

Conclusion

The suggested method for reduction and decision rule extraction is based on applying nano topology concepts which are suitable models for uncertain analysis . This will open up the way for obtaining quantitative measures from qualitative data without coding .

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