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Feature selection filter for classification of power system operating states

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ABSTRACT

The classification of power system operating states plays an important role in power system control and operation. Determining the state of a power system is crucial and requirements for real-time decision making in power system security assessment demand low dimensionality and low computational time. This paper investigates the benefits of using feature selection based on mutual information in power system state classification with machine learning. The AdaBoost algorithm is used for classification based on large training datasets and feature selection is applied in order to reduce their dimensionality. The selection is implemented as a filter in the pre-processing stage of AdaBoost and uses genetic algorithms to perform the search with the fitness function computed based on mutual information. The proposed method is tested on the IEEE New England 39-bus network and a comparison between the learning algorithm performances with and without feature selection is provided. Results for different genetic algorithm parameters are also presented.

1. Introduction

Decision making processes in power systems require several types of aggregated data, from topology analysis, bad data rejection and alarm processing to system operation state identification for security assessment. Most of these applications rely on classification tasks.

The states of the monitored system change over time, so data collected on-line have to be assessed in a suitable manner. Moreover, power system data consists of both analogue (e.g. voltages, currents, power flows) and digital signals (e.g. status of circuit breakers, flags coding the operation of relays). But decision making is not done based on data. Data has to be transformed subsequently into information and then into knowledge, in a timely manner. Therefore, new instruments are needed, which use data as inputs and transform it internally into information to then output aggregated state reports that help operators understand the current situation of the network.

One example is determining the state of the power system concerning its security in operation. This can be done by classifying the state either into two classes (safe/unsafe) or into multiple classes (for example, normal, alert, emergency and safe). Whatever the case, the classification technique has to process and summarize and, most importantly, to identify key information about the system operating conditions [1].

This approach would lead to a relief of the human operator, who would no longer have to cope with large amounts of data, some of which inconsistent, or with avalanches of alarms and would only be provided with concise information regarding the power system.

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This paper proposes a methodology for dimensionality reduction in power system classification tasks. Feature selection based on mutual information is applied on large datasets in order to reduce their dimensionality during the classification of power system states with machine learning. This is applied to the methodology proposed in [1] and an investigation of its performances is provided.

The remaining of this paper is structured as follows: Section 2 investigates some classification applications in power systems with dimensionality reduction, Section 3 describes the proposed approach and Section 4 presents the case study and results. Section 5 contains the concluding remarks and directions for future work.

2. Dimensionality in power system classification tasks

As previously stated, the classification of power system states can be made, in the simplest form, into two classes. A simple example is given in Table 1(N—within normal values, H—higher, L—lower than normal). The $2n$ attributes correspond to voltage (V) and current (I) measurements acquired from n intelligent electronic devices (IEDs) deployed in the power system.

Using the data taken from a power system control centre, the authors of [2] suggested a systematic transformation of an extensive set of examples into a concise set of rules. In essence, Rough Sets (*RS*) theory is used in order to classify the current state of the power system in one of three categories: normal (S), abnormal ($U1$) and restorative ($U2$).

The approach, based mainly on two concepts from *RS* theory—reduct and core, reduces the power system data base by following an algorithm initially proposed in [3] and adapted for power system applications by the authors of [2] previously, in [4].

The 4 steps of the algorithm 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 is tested on a set of 25 examples, each described by 8 attributes and the decision regarding the system state. Of the 8 attributes, three help in describing line loadings, three represent voltage limits 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.

The values from the initial table are of different natures, so normalization is required. Each value is compared against values corresponding to usual operating states of the power system. The attribute values for line loadings and voltage levels can be “low”, “normal” or “high”. For example, if the loading is below 40%, the value is set to “low”. Similarly, if the voltage level is between 0.95 p.u. and 1.05 p.u., then its value is set to “normal”. The circuit breaker statuses are maintained the same, as binary values.

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 [2] justify the application of *RS* theory in decision support systems dedicated to power system control centres.

The four steps of the algorithm presented above are also applied in [5], in order to classify attacks and faults in power systems.

The anomaly detection algorithm is structured into two stages. First, knowledge is extracted by a module that generates a set of rules that allows the classification of the system state as normal or abnormal. Data collected from RTUs are verified by these rules in order to define the consistency of the measurements. The second stage is the anomaly detection. During this stage, the anomaly detector will recognize the type of attack. In order to minimize the computational effort, the volumes of input data and examples have to be reduced.

The knowledge base used for testing contained 162 examples of 57 measured values. The *RS* theory based rule extractor generated, in this case, 15 rules. The anomaly detection system performances were compared against the state estimator and the results showed the suitability of the proposed technique.

Power system steady state security assessment is investigated in [6]. 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 [7]. Therefore, steady state stability assessment studies result in large volumes of data and information.

The methodology proposed in [5] 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 [6] and the ROSE computer program, developed within [8]. The network used for simulations was the IEEE 118-bus system. After a first order contingency analysis, 231 scenarios resulted as useful in creating