Novel Model of Security Region of Metering Networks and Its Application in Meters' Status Estimation

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Abstract. With a large number of smart meters installation and application, the power companies can get a variety of information such as meter metering device via a communication network. Considering the needs of grid state estimation for metering device, we propose a new security domain model network metering devices at the same time on the measurement network analysis, given the security system of metering device. The algorithm of calculating the network security domain by using metering device is designed in this paper. Through the security domain model and AHP in obtaining network security at the same time measuring device, given the state of metering devices affect the reliability of the key factors is estimated to improve the state estimation accuracy and timeliness.

Introduction

Digitization of industrial production and social life made high demands on the power grid reliability and power quality [1]. The current grid can't meet reliability needs of the digital society. For residential electricity, because of the low informatization level of its management control, it is difficult in obtaining efficient, real-time information of residential electricity [2].

Smart Grid is a modern power supply systems, the ability to monitor, protect and optimize the operation of its internal, including smart meters, including interconnection elements [3]. National Grid and other power companies have installed smart meters for a large number of users.

In order to achieve timely and effective information processing and intelligent residential electricity consumption, power systems need to ensure the reliability of the measurement device, timely access to state of the metering device and reliability, measurement accuracy of the device to be evaluated.

Meter data collection and security domain

Data acquisition and state estimation

Now part of the power company uses a remote meter reading system based on wireless network through power communication network, mobile communications network energy data and other information gathering reliable back, through the application of a system with intelligent analysis software, to achieve user of electricity amount of statistics, analysis and use of the user's state electricity consumption [4]. Smart meters are programmable meters which can measure and store a variety of measurement values according to a pre-set time interval. It also has built-in communication modules, to access two-way communication systems and data centers for information exchange [5]. Smart meters have two-way communication capabilities to support real-time meter reading device interference.

On the other hand, a strong communications network also provides an effective means for online management and monitoring meters. If all the meters are available through the communication network to the grid as well as measuring and testing department, we can state the non-site meter data collection, remote diagnostics, to detect the abnormal state and measurement failures. For the process of being intelligent electricity network, especially residential electricity, often do not have efficient, comprehensive network communication systems. In general, the residential area of household table does not have a network connection. Therefore, through the metering device network analysis, rely on

the system model data associated with the power grid from a plurality of data sources analysis, metering means to obtain a state estimation and reliability information.

Security domain

Security domain (security region, SR) method is a new method developed on the basis of the by-point method, it is starting to consider the issue from the perspective of a domain, describes the overall safe and stable operation of the area. The relative relationship between the system operating point and SR border can provide a safety margin and optimum control information. Power system enables real-time online security surveillance, prevention and control of more scientific and more effective.

Comprehensive security domain Ω is the trend of the power system security domain (also known as static security domain) Ω_{SS}, to ensure that the small signal stability and ensure security domain transient stability of dynamic security domain Ω_d intersection, i.e. $\Omega := \Omega_{SS} \cap \Omega_{SD} \cap \Omega_d$. At the operating point is within the safe Ω.

Metering device network state estimation and security domain

State estimation

Also known as state estimation filter, it is the use of redundant measurement system data to improve the accuracy of estimates, the automatic exclusion of error messages caused by random interference and noise, it is estimated the system running.

State estimation function can be classified into the following:

(1) Estimated value estimated in accordance with Kirchhoff's law and measurement accuracy, the most similar to the real states;

(2) The detection and identification of bad data, delete bad data;

(3) According to the measured data to accurately calculate the amount of systems of various important parameters;

(4) Estimated based on the actual state of remote measurement system, system status information to correct the error occurrences to ensure the correctness of the system status;

(5) Application state estimation algorithm based on existing data to predict the future state of the system;

(6) By state estimation system simulation test to determine the parameters of the system more rational collection and transmission system.

Based on the above, the state estimation is an important part between the measuring device and system databases. It can accept the accuracy is not high, coarse incomplete data from the measuring device, the output of the system is estimated by the state to the state of the database is high precision, complete and reliable data.

Metering device network security domain

A notable feature of meter cluster is a tree topology. Electrical energy flow into the total electricity meter table, and flow out from the sub-meter tables. Remote automatic meter reading technology greatly reduces the cost of access to data, so that the "autonomous error algorithm" has the practical possibility.

In order to reduce the actual existence of the loss in meter cluster (meter loss, leakage losses, line resistance loss, etc.), the virtual branch was introduced. The branch includes virtual meter and dummy load. Clusters can be equivalent to the total loss of energy as a virtual load. In Fig.2, imaginary closed surface S defines a meter cluster. The symbol $M_j\ (j=0,1,\mathbf{L},n)$ represents a power meter. M_n is a virtual meter. As agreed, the Electrical energy which flow into s is positive, the outflow is negative. Located in the i-th measurement period T_i, the electrical energy flowing through the M_j is $x_{i,j}\ (i=1,2,\mathbf{L},m$, i is the identification number for each measurement period; m is the number of measurements). According to the law of conservation of energy has the following hold.

$$\sum_{j=0}^{n} x_{i,j} = 0 \tag{1}$$

Generally considered to be within the i-th measurement period, readings increment M_j is $y_{i,j}$, which has the following relationship with $x_{i,j}$.

$$y_{i,j} = (1+d_j)x_{i,j} \tag{2}$$

In the formula (2), d_j is M_j (average) relative error. If

$$e_j = \frac{1}{1+d_j} \tag{3}$$

Then the formula (1) can be turned into

$$\sum_{j=0}^{n} y_{i,j}e_j = 0 \quad (i = 1,2,\mathbf{L},m) \tag{4}$$

Without loss of generality, assume that d_0 is relative error of M_0, e_0 thus apparent as the follow. It is predetermined that A is the relative error of virtual meter M. Thus X and Y have thus established as the following.

$$y_{i,0}e_0 + \sum_{j=1}^{n-1} y_{i,j}e_j + x_{i,n} = 0 \quad (i = 1,2,\mathbf{L},m) \tag{5}$$

The formula (5) is n-1 linear equations, e_j $(j = 1,2,\mathbf{L},n-1)$ is the unknown variables. Equation parameters $y_{i,j}$ determined by reading M_j; T_i is determined by the time of reading; e_0 is determined by the known d_0. By solving this equation, the relative error of the meter can be obtained.

After analyzing the above steps, in order to timely access to state metering device network reliability, security domains is proposed acquisition means of the following algorithm.

Steps of the algorithm are as follows:

(1) The metering devices are classified according to the voltage level, high-pressure high as high-grade category.

(2) Remove all lines and load devices, which are connected in line with and replaced with virtual load vertexes.

(3) Vertexes represent metering devices, and graph edges represent connections between devices remaining lines, which constitute a virtual network model

Then consider the voltage level, the use of time, Measurement accuracy, Error Testing, period checking for each metering device, according to life expectancy, test plans, etc. to determine the reliability of the domain model: $\Omega_d(i,j,F) \triangleq \{y \mid x_d(y) \in A(y)\}$ .Among them, F is the established device failure; i, j, respectively, for the Pre-fault and post-fault virtual network structure; xd(y) is the instantaneous state of the system fault is cleared; A(y) is surrounded by injecting y is determined to balance the state space stable domain points.

Then follow the steps below, to give the state an estimated critical factor.

(1) If the overall device status is normal, no subsequent steps, otherwise step (2);

(2) Calculated separately for each device reliability, reliability in accordance with descending sort;

(3) For a given percentage of the sort carried out in the apparatus after the key impact of AHP analysis of key factors. Get its state estimate the reliability of the main factors.

The introduction of the Analytic Hierarchy Process

Analytic Hierarchy Process refers to a complex multi-objective decision problem as a system, the target is decomposed into multiple targets or guidelines, and then broken down into a number of multi-level indicators, fuzzy quantification methods of qualitative indicators calculated by the single-level sorting and total ordering provide the basis for a systematic approach to choose the best option

Using AHP, generally according to the following four steps:

(1) By analyzing the relationship between the various factors in the system, create a system of hierarchical structure;

(2) The same level of importance of each element on the previous level in a pair wise comparison criteria, construct pair wise comparison judgment matrix;

(3) By judgment matrix element is calculated by comparing the relative weights of the criteria for heavy, and judgment matrix consistency test;

(4) Calculate the levels of total system weight right sort, and sorted. Finally, get the total of each program's overall goal for sorting.

Analysis of the application of AHP decision problem, we must first issue principled, hierarchical, construct a hierarchical structure model. Under this model, complex problem is broken down into component elements, these elements according to their attributes and relationships they form a number of levels, the levels of the element as a criterion for the next level of the relevant elements from the dominant role. These levels can be divided into three categories:

(1) The highest level (target level): Only one element is generally intended target or desired results to analyze problems;

(2) The middle layer (Layer Guidelines): Included involved to achieve the objectives of intermediate links, which can consist of several levels of composition, criteria include the need to consider the sub-criteria;

(3) The lowest level (program level): includes various measures to achieve the goal of alternative decision-making programs.

The complexity of the problem class delivery times and the number of hierarchical structures and the need to analyze in detail the extent relevant, in general, the number of levels is unlimited. Elements in each level of each element is dominant for generally not more than 9, this is because the elements will dominate the excessive pairwise comparisons difficult. A good hierarchy to solve the problem is extremely important, if indecisive on the relations of domination and determine levels of hierarchical division between the elements, you should re-analyze the problem and clarify the relationship between the elements in order to ensure a rational hierarchy. AHP hierarchical structure is the simplest and most practical form of hierarchy. AHP hierarchical structure is the simplest and most practical form of hierarchy. When a complex problem with a hierarchical structure is difficult to express, you can extend the use of more complex forms, such as hierarchical structure of internal interdependence, feedback hierarchical structure.

Construct pairwise comparison judgment matrix

After the establishment of hierarchical structure, affiliation between the upper and lower elements was determined. The next step is to determine the weight of heavy elements at all levels. For most social and economic issues, especially the more complex problems, weight is not easy right elements directly, then you need to export their weights by appropriate methods, AHP judgment matrix gives decision makers use methods derived weights. The next level of the elements in mind the criteria of Element C is dominated by $u_1, u_2, \ldots, u_n$. For criterion C, decision-makers to compare two elements u_i and u_j that one is more important, how important degree, according to the proportion of the scale is defined of the importance of the extent of the assignment, the formation of judgment matrix $A = (a_{ij})_{n \times n}$. In the matrix, a_{ij} is a u_i element and $u_j$relative importance of the criteria C, the ratio of the scale.

Conclusion

This paper analyzes the effect of the measurement devices. The method proposed mechanisms and key metering device network status assessment. Proposed network security domain model metering device, gives the correlation algorithm. In order to timely computing security domain, this paper analyzes the key factor, and introduces the method of AHP analysis.

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