Energy-saving indexes based on symbolic dynamic applied to Efficiency Power Plants (EPP) of typical high energy consuming industries

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Abstract. This study proposes energy-saving indexes based on symbolic dynamic, applied to Efficiency Power Plants (EPP) of typical high energy consuming industries. Building the EPP by forming power saving plans of a given area or industry will optimizes power consumption way, economizes energy and reduces cost. Set up and improve. However, data characteristics of power-saving assessment system vary greatly in different high energy consuming industries. So, this paper proposes an index theory based on symbolic dynamics to abstract and take a coarse graining on complex dynamic systems- to describe laws of change about the systems on the strength of one dimension time series. The operator system on symbolic dynamics is structured so that it is able to keep track of energy efficiency technologies with application to typical high energy consuming industries.

1 Introduction

Our country is in the process of industrial transformation, Energy intensive user like submerged arc furnace、electrolytic aluminum、 injection molding machine、motor system、data center have different feature, different heavy load center of different demand exist obvious differences in power demand. And efficiency power plant[1]can be optimal to use electricity, form a certain area, industry or enterprise saving electricity demand plan of action, reduce the demand for electricity can be thought of as a virtual power plant is providing power, in other words, the most core part of efficiency power plant is energy saving, and eventually reduce the consumption of power and power costs of electricity users.

At present energy-saving of energy-intensive industries is mainly from two aspects of technology and economy evaluation, and also made some evaluation indexes. But the current index is relatively straightforward, the actual evaluation is also difficult to guide the actual work. Analysis of key energy-consuming enterprises and quantify of emissions reduction technology can be more effective to carry out the energy efficiency of the construction of power plants. This study proposes energy-saving indexes based on symbolic dynamic, applied to Efficiency Power Plants (EPP) of typical high energy consuming industries.

2. Efficiency Power Plants evaluation index system of typical high energy consuming industries.

The basis data of describing efficiency power plants is wide variety[2-3].There is continuous data, such as the operation load, also discrete data, such as line connectivity data and equipment rating data. It is a large amount of data, especially continuous data, proper abstraction of basic data, and based on this study will be the inevitable choice. At present, we adopt fuzzy set method to abstract data, and based on this using the theory of reliability and probability to study.

This paper uses the symbol dynamics[4-5] to abstract and describe the index system of efficiency power plant ,and build a scalable index system.

3 The mathematical model of typical energy intensive user[6]

3.1 Electrolytic aluminum

Aluminum electrolysis industry is a very important basic material industry, and is also known as energy intensive industrial. In recent years, to implement the national policy for energy conservation and emissions reduction and effectively reduce the production cost of aluminum industry in our country, large-scale technical innovation is carried out. Electrolytic production process adopted is general shift in the direction of "low voltage" type.

Electrolytic aluminum lower cell voltage is the most common method of energy saving, but also cause the loss of current efficiency, may increase dc power consumption. Assumption that the dc power consumption is 13000 kWh/t - Al, if the average voltage of tank drop 44 mv causes current efficiency fell by more than 1%, it not only loss amount of aluminum, and dc power consumption increase .Therefore, through lower cell voltage to achieve energy saving, must meet the following conditions:

$$\Delta\eta < 2980\frac{\Delta U}{W_f} \tag{1}$$

and is the cell voltage and current efficiency value respectively

4 Efficiency Power Plants description based on symbolic dynamic

4.1 Evaluation operator system description based on symbolic dynamic

Symbol dynamics method, abstract and coarse graining complex reality of the power system, based on one dimensional time series describe the changing rule of the dynamic system, build the system operator. As a result, symbolic dynamics method is used to continuous tracking for energy-intensive users and energy-saving technologies.

4.2 The basic principle of symbolic dynamics

Symbol sequence is used to abstract and coarse graining complex reality of the power system in symbolic dynamics, based on one dimensional time series to describe the changing rule of the power system, and is widely used in pattern recognition and failure prediction.

one dimensional time series sequence classification method of a typical symbol dynamics shows in the following:

$$L_X(L,i) = \sum_{p=1}^{L} m^{L-P} S(p+i) \tag{2}$$

There：m is the number of different symbol of symbol set$\{S_0, S_1, \dots, S_{m-1}\}$;L is the length of short series; i is the ith symbol of {S(1),S(2),…};S(p+i) is the (p+i)th symbol. Refer to the related regulations, energy saving technology and efficiency power plant can be divided into 5 levels to carry out the description. As symbolic dynamics often adopts double time scales to describe objects, and large time scale is 2 scale bigger than the small time. Therefore, this paper uses the set of 15 symbols to describe the efficiency power plant and energy saving technology ,in general, define as Ω ={A,B,C,⋯,O}. The results is described by three order symbol characters, such as the description of the minimum of the result with a symbolic representation of {ABC}; With a specific symbol sequence describe result has to depict its fuzziness, and have definition of symbolic weight. In symbol sequence, weight according to the practical experience of the first character to the third character is 0.6, 0.3, 0.1, describe the result belongs to the membership of the symbol.

4.3 The basic data type mapping

(1)The non-time-varying possibility probability data mapping

For the time-varying data, direct linear mapping, for example, Line user level is divided into four levels, the corresponding mapping formula (3):

$$P_{Idx} = [\frac{Level}{5} \times k] \tag{3}$$

Here [] is gaussian function, P_{Idx} is first word in the symbol set Ω, L is the energy saving level，k=|Ω| is the length of symbol set, using 3 continuous characters express its possibilities.

(2) The time-varying possibility probability data mapping

Assume that the maximum and minimum value describe index is Ind_{Max} and Ind_{Min} respectively, and, after an evaluation calculation of the index is Ind_{Cur} then possibility of probability map of the index is formula (4) and formula (5).

$$Ind_R = \begin{cases} \frac{Ind_{Cur} - Ind_{Min}}{(Ind_{Max} - Ind_{Min})} \times 100, Ind_{Cur} \le Ind_{Max} \\ 100 \qquad\qquad , Ind_{Cur} > Ind_{Max} \end{cases} \tag{4}$$

$$P_{Idx} = \begin{cases} \left[\left[\frac{Ind_R}{20}+1\right]\times 3, x - \left[\frac{Ind_R}{20}\right]\times 20 < 12 \\ \left[\frac{Ind_R}{20}+1\right]\times 3 + 1, 12 \le x - \left[\frac{Ind_R}{20}\right]\times 20 < 18 \\ \left[\frac{Ind_R}{20}+1\right]\times 3 + 2, 18 \le x - \left[\frac{Ind_R}{20}\right]\times 20 < 20 \end{cases} \tag{5}$$

P_{Idx} is the correspond serial number of the index in the symbol set Ω letters, and each section divided by the same principles of symbols and symbols weighting WS.

4.4 Symbolic Operator Definition

For ease of management, the method of symbolic dynamics based on hierarchical management structure, and iterative cumulative process need to be done on the basis of symbol sequence.

Definition 1: Sequence operator

$$t = NO(S_x(3)) \tag{6}$$

In formula (6), $S_x(3)$ is symbolic sequence contains three element, t is the serial number of first symbol in the sequence in symbolic set Ω.

Definition 2: Shift operator SO

$$S_{x1}(3) = SO(S_x(3), t) \tag{7}$$

In formula (7), t is integer when positive right shift or left shift, the range after shift is still within sequence set Ω.

Definition 3: Addition operator ⊕

$$NO(S_{x1}(3) \oplus S_{x2}(3)) = [\sum_{i=1}^{3} \begin{matrix} (NO(S_{x1}(3,i)) \times W_s(X1,i) \\ +NO(S_{x2}(3,i)) \times W_s(X2,i)) \end{matrix}] \tag{8}$$

In formula (8)，[]is round down function, Ws(X1,l) and Ws(X2,l) is the weight of corresponding to the symbol in symbol sequence respectively, its definition and recursive calculation method has been given in the prophase study.

Definition 4: Multiplication operator ⊛

$$NO(S_{x1}(3) \circledast S_{x2}(3)) = [\sum_{i=1}^{3} \begin{matrix} (NO(S_{x1}(3,i)) \times W_s(X1,i) \\ \times NO(S_{x2}(3,i)) \times W_s(X2,i)) \end{matrix}] \tag{9}$$

Definition 4: Proportion operator ⊙

$$NO(S_x(3) \odot a) = [\sum_{i=1}^{3} (NO(S_x(3,i))a)] \tag{10}$$

In formula (10), a is a rational number, the range after proportion operation is still within sequence set Ω.

Thus, to the most typical structure of the series and parallel in the corresponding transmission line and efficiency power plant, there are:

(1)Parallel structure simplified

Parallel structure simplified steps are as follows：

The evaluation index overlay

$$NO(S_{l3}) = NO(S_{l1} \circledast S_{l2}) \tag{11}$$

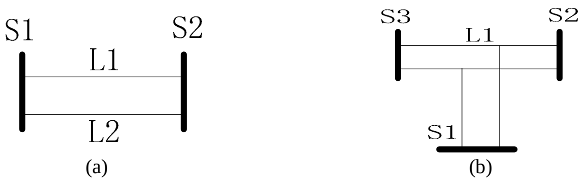

Fig. 1 Parallel structure reduction

Simplified topology structure is showed in figure 2.

Fig. 2 Reduction results

(2) Series structure simplified

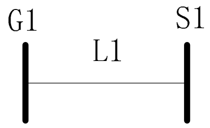

Fig. 3 Hub-and-spoke power transmission line

The simplify equation corresponding figure 3 is formula (12), after simplifying, equipment S1 and L1 can be got rid of for network topology.

$$\begin{aligned} NO(S_{L1}) &= NO(S_{L1} \oplus S_{s1}) \\ NO(S_{G1}) &= NO(S_{G1} \oplus S_{s1}) \end{aligned} \quad (12)$$

By the method of symbolic dynamics, the energy-intensive users and transformation of energy saving technology can be equivalent to virtual device, therefore, it is helpful for unified analysis of the late actual and virtual devices, with many kinds of methods to analyze the actual influence of virtual equipment on the power grid.

5 Conclusion

This paper proposes transformation method of time-invariant likelihood probability of data mapping and the time-varying possibility probability data mapping based on symbolic dynamics, users of different high energy consumption and energy saving technology can be described.

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