Research on optimal utilization of demand side resources based on quantitative analysis

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Abstract—Through quantitative analysis, the power grid, environment and user behavior are analyzed, and the influencing factors of resource operation on demand side are found, and the high related parameters of resource operation on demand side are formulated based on this. Based on the principle of relative gain matrix, the interaction model including grid, environment and user behavior on demand side resources is established to realize the optimal utilization of demand side resources.

1. INTRODUCTION

Global resources are increasingly scarce, the environment is deteriorating, and the demand for global resources is increasing. Therefore, improving the efficiency of energy utilization has become the development trend of the future power grid. With the rapid development of power grid technology, in the future smart grid, besides the traditional load and energy efficiency resources, the demand-side resources also include Distributed Generation (DG) and energy storage resources.

The access of various demand-side resources has an influence on the network loss, system voltage, voltage quality, grid relay protection and grid power supply reliability\textsuperscript{[1]}. The "ITM" project of KEMA Institute \textsuperscript{[2]} in the Netherlands mitigates the impact of electric vehicles on the power grid by utilizing the technology of demand-side time-sharing distribution and a certain demand-side incentive mechanism. In February 2008, France proposed the comprehensive construction of "Intensive Energy Saving France". Relevant experiments were also carried out in small towns in Paris, and demand side resource regulation was carried out through building energy efficiency \textsuperscript{[3]}. The load can be adjusted through power change, power delay and power excision, and the time-divided automatic control can be realized \textsuperscript{[4]}.

Compared with foreign countries, domestic research on DSM started late, but developed rapidly in recent ten years. China Electric Power Research Institute, together with domestic universities, research institutions, power grid companies, manufacturing enterprises and service providers, takes IEC PC118 as the platform to lead the establishment of PC118 Smart Grid User Interface Expert Group to carry out...
Automated Demand Response (Auto-DR) research and international standard formulation [5-6]. Hohai University [7] has proposed energy-saving measures such as building energy saving, lighting and household appliances energy saving, gas air conditioning energy saving, rooftop solar power generation, recycling and utilization of household garbage, aiming at the characteristics of the population-intensive living areas that are conducive to energy saving.

In conclusion, on the demand side resources at home and abroad to participate in power grid operation coordination control aspect had the preliminary research, and on the power system, environmental behavior and demand side resources interaction analysis based on the joint coordination control requirements in response to a controllable resources study is less, with the in-depth development of interactive information service technology.

2. ANALYSIS OF INFLUENCING FACTORS OF DEMAND SIDE RESOURCE OPERATION

The influencing factors of demand side resource operation can be considered from three aspects: power grid operation, environment and user behavior. In terms of power grid operation, the intelligent level of power grid operation, the reserve capacity of power grid operation and the incentive mechanism all have an important impact on the operation of demand-side resources.

2.1. Analysis of the influence of power grid operation on demand side resources

Demand side resources are mainly affected by the incentive mechanism of power grid operation, intelligence level and reserve capacity.

1. Intelligent level of power grid operation
   Under the operation of smart grid, power grid enterprises release real-time electricity price, real-time load, actual power supply and other power-grid operation information related to users. Through the construction of smart grid, the on-line generation policy of green distributed power will be managed flexibly.

2. Spare capacity for power grid operation
   In an electricity market environment, a change in demand of just a few percentage points during peak hours can make the difference between a reliable supply of power to the system and a blackout.

3. Incentive mechanism for power grid operation
   In order to fully mobilize the enthusiasm of demand-side resources to participate in grid operation, power companies must give certain incentives to power users, including price incentives (such as peak and valley time-of-use price, interruptible price, seasonal price), discount incentive, free installation incentive, loan preferential incentive, special incentive for power saving, etc.

2.2. Analysis of the impact of environment on demand side resources

The development of electric power industry cannot be separated from the restriction of social environment and natural environment, and the operation of power grid demand-side resources is also affected by social environment and natural environment.

1. Social environment
   The Chinese government has always attached great importance to demand-side management. Although some obstacles have not been completely solved, the relevant government departments have created a better environment for efficient operation of power demand-side resources by formulating corresponding policies and regulations and strengthening publicity and promotion.

2. The natural environment
   Power demand side resources include demand response resources and energy efficiency resources on the demand side, including distributed power supply, electric vehicles, building insulation, etc. Obviously, the utilization of these resources will be affected by natural environment such as climate and geography.

2.3. Analysis of the impact of user behavior on demand side resources

According to the principle of consumer psychology, there is a minimum perceptible difference in the
stimulation of users, within the range of this difference threshold, users basically have no response or very small response, that is, insensitive period.

1. Use electricity orderly

At present, orderly power consumption in our country generally refers to the use of administrative means to manage power consumption in the case of power supply shortage. At present, several orderly power consumption measures in China include: peak shifting, peak avoiding, power rationing, emergency switch and so on.

2. Power saving behavior

As the problem of environmental quality becomes more and more serious, the awareness of users to save resources and protect the environment is constantly strengthened. In daily life, various power-saving products are widely used. Compared with ordinary products, energy-saving products have advanced technical indexes, low loss and high efficiency.

3. THE INTERACTION EFFECT MODEL OF DEMAND-SIDE RESOURCES

3.1. High correlation parameters of the impact of grid operation on demand side resources

Intelligent grid operating level in the short term without too big change, in the absence of major load changes of power grid is adequate spare capacity, so the power grid to run the main factors of influence on the demand side resources is one of the most commonly used and effective incentive mechanism is the electricity price incentives, so that the whole demand side resources get reasonable use, it is necessary.

3.2. High correlation parameters of environmental impact on demand side resources

According to the analysis of the output characteristics of photovoltaic cells, its output is affected by the ambient temperature, and too low or too high temperature will lead to the decline of the conversion efficiency of photovoltaic arrays. Fig. 1 shows that within a certain temperature range, the maximum output power of photovoltaic cells decreases non-linearly with the increase of temperature under the condition of constant illumination intensity.

![Figure 1: Output characteristics of photovoltaic cells at different temperatures](image)

According to the analysis and statistics of the observational data of the International Geophysical Year by the International Radiation Commission, the average data of solar radiant energy is taken as 1357 W/m², and the radiant energy varies with the geographical location, time and season. The output of photovoltaic cells mainly depends on solar radiation. Theoretically, the greater the radiation, the greater the output of the cell. Figure 2 is the output characteristic curve of the photovoltaic cell under different illumination intensity. When the temperature remains constant, the output power of the photovoltaic cell increases with the increase of illumination intensity.
Figure 2 Output characteristics of photovoltaic cells under different light intensities

However, in the actual power generation process, when the wind speed reaches the starting wind speed, the wind turbine starts to run and drives the generator to generate electricity. As the wind speed increases, the power of the generator begins to increase. When the design wind speed is reached, the wind turbine can reach the rated power. When the wind speed is further increased, the power control of the wind turbine starts to work, so that the generator will not be overloaded, but will work near the rated point. If the wind speed further increases beyond the range of energy control regulation, the wind turbine will be implemented shutdown protection. See Figure 3.

Figure 3 Wind turbine power characteristic curve

3.3. High correlation parameters for the impact of user behavior on demand-side resources

In order to improve the execution and monitoring of the optimization scheme, an "orderly power consumption management system" is proposed. The system will dispatch automation system (SCADA), electricity information collection system for real-time data after summary, storage, calculation and analysis, real-time release through a Web site form, make the grass-roots governments and the real time control of the electricity the areas under their respective jurisdiction, administration authority to work for an orderly electricity to provide a fair, open, fair show platform.

4. Quantitative analysis of the interaction impact of demand side resource operation

Grey correlation analysis method is a multi-factor statistical analysis method. Based on the sample data of each factor, it describes the size, strength or order of the relationship among factors with grey correlation degree. If the sample data reflects that the two factors have basically the same changing trend (size, direction, speed, etc.), then the correlation between them is relatively large. On the contrary, it is smaller. The basic calculation steps of grey correlation analysis are as follows:

(1) Determine the analysis sequence
Qualitative analysis of the research problem, determine a number of independent variables and a dependent variable factor. The reference sequence formed by the data of dependent variables is, and the data of each variable constitutes a comparison sequence. The data sequences form the following matrix:

\[
\begin{pmatrix}
X_0 & X_1 & \ldots & X_n
\end{pmatrix} =
\begin{bmatrix}
x_0(1) & x_1(1) & \ldots & x_n(1) \\
x_0(2) & x_1(2) & \ldots & x_n(2) \\
\vdots & \vdots & \ddots & \vdots \\
x_0(N) & x_1(N) & \ldots & x_n(N)
\end{bmatrix}_{N \times (n+1)}
\]  

(1)

(2) The variable sequence was de-dimensionalized

In general, the initial variable sequences have different orders of magnitude or dimensions. In order to fully guarantee the reliability of the results, the above variable sequences are dimensionless. The dimensionless sequence matrix of each factor is formed as follows:

\[
\begin{pmatrix}
x_0 & x_1 & \ldots & x_n
\end{pmatrix} =
\begin{bmatrix}
x_0(1) & x_1(1) & \ldots & x_n(1) \\
x_0(2) & x_1(2) & \ldots & x_n(2) \\
\vdots & \vdots & \ddots & \vdots \\
x_0(N) & x_1(N) & \ldots & x_n(N)
\end{bmatrix}_{N \times (n+1)}
\]  

(2)

The means method and initial value method of dimensionless are as follows:

\[
x_i(k) = \frac{x_i(k)}{\sum_{k=1}^{N} x_i(k)}
\]  

(3)

\[
x_i(k) = \frac{x_i(k)}{x_i(1)}
\]  

(4)

(3) Calculate the sequence of difference, maximum difference and minimum difference

Calculate the difference value of the first column (reference column) and the other columns (comparison column) in the above matrix to form the absolute difference matrix:

\[
\begin{pmatrix}
\Delta_{00} & \Delta_{01} & \ldots & \Delta_{0n} \\
\Delta_{01} & \Delta_{11} & \ldots & \Delta_{1n} \\
\vdots & \vdots & \ddots & \vdots \\
\Delta_{0n} & \Delta_{1n} & \ldots & \Delta_{nn}
\end{pmatrix}_{n \times n}
\]  

(5)

Among them, \(\Delta_{0i}(k) = |x_0(k) - x_i(k)|\)

The maximum and minimum numbers in the absolute difference matrix are defined as the maximum and minimum differences:

\[
\max \{\Delta_{0i}(k)\} = \Delta(\text{max}) \quad (6)
\]

\[
\min \{\Delta_{0i}(k)\} = \Delta(\text{min}) \quad (7)
\]

(4) Calculation of correlation coefficient

The data in the absolute difference matrix is transformed as follows:

\[
\xi_{0i}(k) = \frac{\Delta(\text{min}) + \rho \Delta(\text{max})}{\Delta_{0i}(k) + \rho \Delta(\text{max})}
\]  

Where, \(\rho\) is between 0 and 1, and the correlation coefficient matrix is finally obtained:
\[
\begin{bmatrix}
\xi_{01}(1) & \xi_{02}(1) & \cdots & \xi_{0k}(1) \\
\xi_{01}(2) & \xi_{02}(2) & \cdots & \xi_{0k}(2) \\
\vdots & \vdots & \ddots & \vdots \\
\xi_{01}(N) & \xi_{02}(N) & \cdots & \xi_{0k}(N) 
\end{bmatrix}_{N \times k}
\] (9)

In this matrix, the value of each correlation coefficient \( \xi_{0k}(k) \) is generally between 0.1 and 0.5, and the difference between the correlation coefficients is determined by the smaller \( \rho \), the greater the difference. The correlation coefficient reflects the degree of correlation \( X_i \) between any comparison sequence and the reference column \( X_0 \).

(5) Calculate the correlation degree

According to the above analysis, the correlation coefficient reflects the degree of correlation between any comparison sequence and the reference column. The correlation degree with the reference column can be obtained by averaging the correlation coefficients:

\[
r_{0i} = \frac{1}{N} \sum_{k=1}^{N} \xi_{0k}(k)
\] (10)

5. THE EXAMPLE ANALYSIS

Based on the IEEE Standard 33 node example, the IEEE Standard 33 node data are shown in Appendix 1.

According to the grid-connected active power and grid-connected bus voltage of the distributed power source, the power factor of the distributed power source can be deduced as follows:

\[
Q_p = 1.45MVA \quad Q_s = 1.064MVA
\]

Take line average data as:

\[
r = 0.01938 \quad x = 0.05917
\]

The average load of each load point is:

\[
Q_i = 0.1513MVA \quad P_i = 0.3125MVA
\]

When electric vehicles discharge in the mode of V2G, it can be regarded as a distributed power supply. According to the above calculation, the discharge power at the 16 node and the influence factors of the distributed power supply on the voltage of the distribution network are:

\[
f_{16} = 0.1453
\]

According to the grid-connected capacity and grid-connected mode of EV, the equivalent resistance of EV can be calculated:

\[
R_e = 908.224
\]

After the equivalent resistance of electric vehicles is recorded as a constant value, the influence factors of charging and discharging of electric vehicles on harmonic distortion rate of distribution network are calculated as follows:

\[
f_{e1} = 0.5291
\]

6. CONCLUSION

This chapter first analyzes the power grid, the environment, the user behavior on the influence factors of demand side resources run, and then expounds on the grid, the environment, on the impact of user behavior on the demand side resources related parameters, and then, using correlation analysis method, respectively, and the quantitative analysis is proposed on the basis of the principle of relative gain matrix of power grid, the environment, the mutual influence of user behavior on demand side resources...
and further studies the distributed power supply, electric cars the impact of parallel operation of distribution network operation indicators.

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