Comprehensive costs and benefits evaluation of smart distribution network

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Abstract. As an important carrier and effective way to achieve the third industrial revolution, the smart grid, with core features of digital grid, distributed energy systems, information interactive and electric vehicles, is more secure, efficient, economic, and environmental quality compared with the traditional distribution network. By analyzing each system in the smart distribution network, the paper builds the model of costs and benefits for each system and uses the theory of the life cycle cost-benefit calculation process to evaluate payment and gain of each system. The method finds the path for the comprehensive benefit evaluation of smart distribution network.

Introduction

The smart distribution network includes the systems such as electric vehicles, distributed energy, demand response, energy storage and comprehensive energy service. In order to guide the development direction of smart distribution network during the planning stage, and measure the level of development after the implementation of the project, we should make the comprehensive benefit evaluation of intelligent distribution network, providing scientific basis and technical path to implement advanced intelligence for sustainable development of the distribution system.

However, the developed evaluation is more preliminary, with more qualitative analysis, lack of quantitative results, poor practicability and operability, not for the deep-seated problems of distribution network, especially the more in-depth work of future smart distribution network; it also does not reflect the economic and social efficiency of the construction of smart distribution network. This paper takes all the benefits in the model of each system in consideration and gets the comprehensive benefit evaluation of smart distribution network.

Significance of comprehensive benefit evaluation of smart distribution network's comprehensive benefit evaluation is mainly reflected in: clearing the expected return in many aspects and focus on the smart distribution network development; measuring the level of development of smart distribution network; predicting results of each stage of construction of smart distribution network; guiding the planning and development of intelligent distribution network and update financial evaluation system of distribution system.

Cost effective use of investment theory model

In order to objectively portray the overall efficiency of the target values and evaluation criteria, we must also introduce the concept of cost-effective use of investment theory model,

(1)Yearly investment in theory

Electrical equipment's full life cycle tends to belong, using life-cycle cost analysis method, you must take time value of money into account. The difference between the value of money in the turnover process due to the time factor and the formation known as the time value of money, the performance is interest on the funds obtained by the owner.

Because of time value of money, it occurs at different times of the matching funds are not equal its actual value. The fees must be converted to a standard time (i.e. present value) was comparable, so as to make the evaluation and select more realistic.

The different moments in terms of the amount of funds at the present time, this amount is called the present value. This conversion is called discounting the present value is also called the discounted value

The relationship of nth year's future value F between the present value P is

$$F = P(1+i)^n \tag{1}$$

In the formula, i is the discount rate.

By the value of future F calculating present value P called discounting calculation, the relationship is

$$P = F/(1+i)^n \tag{2}$$

According to total life cycle cost model as we have seen, the equipment investment cost is the present value, and the operation and maintenance costs, equipment residual value needs to be discounted value calculation.

Assume equipment investment cost expressed as C_A, annual maintenance costs of running expressed as C_{M1}、 C_{M2}、 $\cdots$、 C_{Mn}, n represents the year of equipment putting into operation, after the device reaches the useful life, residual value indicated by C_{rA}.

Therefore, according to the relationship between future value and the present value: the present value of equipment purchase equal to C_A.The discounted value of operation and maintenance costs equal to

$$C_{M1} + \frac{C_{M2}}{1+i} + \text{L} + \frac{C_{Mn}}{(1+i)^n} \tag{3}$$

The discounted value of the residual value of the equipment equal to $\frac{C_{\text{rA}}}{(1+i)^n}$.

Finishing can get the full life cycle cost of the discounted value equal to

$$LCC = C_A + \left[C_{M1} + \frac{C_{M2}}{1+i} + \text{L} + \frac{C_{Mn}}{(1+i)^n} \right] - \frac{C_{\text{rA}}}{(1+i)^n} \tag{4}$$

It is converted to discount the value of investment theory

Theoretical discounted value of the investment equal to $\frac{LCC}{n}$.

Wherein, n is the number of years to run

Distributed energy, micro-grid, energy storage device n advisable for 20 years, a variety of systems, devices n advisable for 10 years

(2) The theory of investment-benefit ratio

For system construction object, the results of the general effectiveness calculated based on model is the theoretical benefit ,then generated in the future no longer produce the benefits,that is, the result is the present value of the theoretical benefits.

For objects such as distributed energy, the benefits generated annually, benefits discounted value at that time can be calculated as:

$$BCC = B_1 + \frac{B_2}{1+i} + \cdots + \frac{B_n}{(1+i)^n} \tag{5}$$

In the formula, BCC for discounted value of benefits, B_1、 B_2、 …、 B_n for the benefit generated for each year.

Discounted value of benefits for yearly is equal to $\frac{BCC}{n}$.

Theoretical investment benefit ratio R is

$$R = \frac{LCC}{BCC} \quad \textbf{(6)}$$

(3)Evaluation criteria of theoretical investment cost-benefit ratio

Using theoretical investment benefit ratio analysis, evaluate project, Theoretical investment benefit ratio should compare to national or industry-accepted standard ratio in order to develop excellent, good, fair, poor evaluation criteria.

Cost and benefit of each sub-system

The costs and benefits of electric vehicles[2]. The electric vehicle has many advantages, such as energy conservation. A large number of electric vehicles will impact on the power system, and the impact of electric vehicles is mainly realized through the charging load. Recently, through the technology of grid-to-vehicle and vehicle-to-grid, electric vehicles not only get electricity from the grid, and can supply electric power to the grid.

Electric vehicles generate cost in the process of discharge and charge, among them:

1) When charging, except charging infrastructure investment costs and management fees, we should consider investment costs associated with an increased load of generation, transmission, distribution for the grid. For users, charging costs may not be included in the acquisition cost of the car out of the fee of traditional cars.

2) When discharging, the power company mainly pays users discharge fee. For users, they need to consider the cost of discharging energy storage.

Electric vehicles generate benefit in the process of discharge and charge, among them:

1) When charging, increased load would bring the sale of electricity to increase revenue for the grid. For users, they can reduce the daily cost of driving car and enjoy a low-carbon life by driving an electric vehicle.

2) When discharging, the grid company can reduce the cost of investment for generation, transmission and distribution, standby electricity costs and power loss. For users, they receive discharge income reduce the cost of purchasing electricity and basic electricity and increase security benefits.

The costs and benefits of distributed energy[3]. Distributed energy generation is power generation device that power generation is in a few kW to tens of MW with small modular, distribution, reliability and efficiency and can supply load economic. efficiently and independently. Distributed generation is a new, very comprehensive utilization of power generation, and has many advantages of investment and the losses reduction, environmental protection, efficiency, and energy species diversity

The costs of distributed power generation in different operation modes as follows:

1) The costs of unified purchase and marketing mode includes DG initial investment, operation and maintenance costs, loan interest, network losses fee and interruption cost.

2) The cost of contract energy management mode in addition to the cost of unified purchase and marketing mode, further comprising with users' the initial grid investment and distribution network operation and maintenance costs.

3) The cost of self-occupied mode is the same with contract energy management mode.

Distributed generation will produce a variety of benefits, including:

1) For the grid, distributed generation connected to the grid will change the power flow, and produce loss reduction benefits and delay the benefits of investment in power grid construction.

2) For users, the main benefits is low-carbon life and economic. Distributed energy economic benefits to the user is defined the distributed energy revenues constitute in different operation modes, in the mode of self-occupied, including distributed energy grid electricity revenues[4].

The costs and benefits of demand response technology. Demand response is that when the reliability of the system being threatened or electricity prices rise, the electricity users receive the induced notice to decrease load for direct compensation by power supplier or when electricity prices increase, the electricity users change their habits of consumption patterns, to reduce power load and response power supply, to ensure the stability of the grid[5].

The costs of implementing demand response are[6]:

1) For users, including re-arrangement production plan costs and comfort costs, since it is difficult to quantify, we would not be considered in this report.

2) For the grid, including building the appropriate infrastructure such as two-way interactive platform.

The main benefits of the implementation of demand response:

1) Users save electricity. By demand response, to avoid the peak hours of electricity, users can obtain economic benefits of saving electricity.

2) Power-saving and user low-carbon life benefits. According to the power system scheduling rules, during the maximum peak periods, corresponding generators coal consumption and emissions are also high, therefore, demand response can reduce the peak hours of electricity, and get the double benefit of energy saving and emission reduction.

3) Grid reliability benefits. Through demand response, the user load curve achieves to peak load shift, power flow improves and outage of power line loss reduction, thereby improving the reliability of the power network.

4) The grid economic benefits. Demand response will lead to reduction in electricity sales

5) The grid synchronous spare benefits. By demand response, reducing the peak load periods, reducing the grid transmission and distribution capacity investment cost to meet peak electricity.

The costs and benefits of energy storage device. Energy storage is a problem accompanied by the development of the power industry, such as thermal power plants operating with rated load, in order to maintain high energy conversion efficiency and quality, but electricity consumption changes with time[8].

The benefits of energy storage device[7]:

(1)The grid benefits of energy storage device

1) Delaying upgrade investment of the grid. Energy storage system charge in the low load and discharges to the load at peak load power, transforming partial quantity of electricity demand in the peak load period to the low load by load shifting

2) Reducing loss line costs. When charging, energy storage system is equivalent to a load, the load system increasing, thereby making the system network losses increasing in peak load time. But when discharging, it can significantly reduce trunk line current of the peak load, thereby reducing the peak load line and transformer losses, making the system peak load loss reducing in the network.

3) Reducing the reserve capacity. Energy distributed power is significant randomness and uncertainty, when the distributed generation access time, must be equipped with a certain capacity to quickly adjust the standby power. Local distributed generation energy storage device can reduce the required system reserve capacity.

4) Reducing the user loss benefits. Users installing energy storage device can discharge during peak hours and reduce the power drawn from the system, thereby reducing the user's loss.

(2)The user's benefits of energy storage device[9]

1) Reducing the uses, distribution capacity. If the low voltage side of the distribution system is provided with storage device, you can store electricity purchasing from the grid in valley, and release electric energy in peak, thus reducing power absorbed from the grid and the required capacity, saving corresponding capacity investment.

2) Reducing the user capacity electricity price. In case of shortage of power supply, if the users transfer the peak load to the valley, it can significantly reduce the average price per unit of electricity. Users also reduce the capacity electricity price.

3) Reducing the user electricity price. Using the energy storage device to purchase electricity in low load and using electricity in peak load. In the process of buying high in low price and buying less in high price, it can reduce electricity price.

4) Reducing user interruption cost.

The costs and benefits of comprehensive energy service system. Comprehensive energy service system is flexible and interactive intelligence electric business, energy services are senior professional services, referring to optimize the user energy behavior and improve end-use energy efficiency.

Comprehensive energy services system costs mainly include system software and hardware investments.

1) Application software investment of electricity service interactive platform. Interactive services platform application software to meet the intelligence service and the development of application software package

2) Investment of interactive devices. The interactive equipment is the key equipment for the two-way interaction between the user and the grid, and the core equipment is the integrated service gateway.

3) User side equipment investment. The user side equipment is interactive service platform of sensor, or sensing devices

4) System hardware and software operation and maintenance costs.

The benefits of comprehensive energy services system:

1) Reduce labor costs of traditional meter reading workers. For users of the installation of smart meters, statistics of the power grid companies need not depend on the traditional way of artificial copy, greatly reducing the management cost of the Power Grid Corp.

2) Reduce user interruption cost. Since the system can be used to serve the electricity event logging and reporting, record loss of power, record and report power recovery, you can receive notifications power outage released by the grid and displayed to the user, allowing users to rationalize production, reducing sudden power outage loss.

3) Saving users electricity. With the device in the service system, it can automatically improve the energy consumption of the user

Conclusions

This paper elaborates the costs and benefits model of each sub-system in the smart distribution network in detail, through calculating each parameters in the sub-system, we can get comprehensive benefit evaluation of smart distribution network. we can detect the degree of progress in smart distribution network with rational and effective evaluation methods, which can help us to construct and improve the future intelligent distribution network.

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