Business Pattern of Distributed Energy in Electric Power System Reformation

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Abstract. Under the trend of the electric power system revolution, the operation mode of micro power grid that including distributed power will be more diversified. User's demand response and different strategies on electricity all have great influence on the operation of distributed power grid. This paper will not only research sensitive factors of micro power grid operation, but also analyze and calculate the cost and benefit of micro power grid operation upon different types. Then it will build a tech-economic calculation model, which applies to different types of micro power grid under the reformation of electric power system.

1. Introduction

In March 2015, the State Council of Central Committee of the Communist Party of China issued Some Opinions on Further Deepening the Reform of Electric Power System (Electric Reform Document 9) [1]. In the opinions, it is mentioned to open the power grid for fair access, and it encourages distributed generations to participate in operation & control of power grid as power user and power generator so as to positively guide construction in three parts, namely, the advanced technology, completing grid-connected operation services and enhancing and specifying supervision and administration for owned power plant. In July, the National Energy Administration published Some Opinions of Propelling Construction of New Energy Micro-grid Demonstration Project, which aims at specifying and guiding how to propelling construction and operation of demonstration project for institutes and enterprises with implemental foundations to efficiently use renewable energies [2]. The opinion insists on energy internet as philosophy, adopts the advanced "internet + information" technology to realize intelligent matching and coordinated operation of new energy's research and development and applications.

Now, micro-grid is a new and green power system, and there are some deficiencies in its operation mode, standard of grid connection, safety protection, management mechanism and other aspects [3]. Meanwhile, there are many uncertainties and risks in the process of exploration and construction. Therefore, under the trend of reformation of electric power system, the micro-grid's operation mode with distributed generation is greatly influenced by the user side's demand respondence to the participation in power grid and different power consumption decisions; the operational delicacy degree under micro-grid condition should be studied, and the operational cost and revenue for different type of micro-grids should be analyzed and calculated scientifically and objectively. Under the new reformation of power grid, it aims to construct calculation model of technical economy which is

suitable for different types of micro-grids to vigorously propel sustainable development of green energy in the field of energy conservation and emission reduction and low carbon environmental protection in the nation.

2. Research on the micro-grid operational model under the new power grid reformation with distributed generations

Our nation is vast in territory, but the unbalanced distribution of natural resources and otherness of population density result in difference of constructing the distributed generations of micro-grids and the load characteristics of power consumption side. To satisfy the reliability of power supply for customers and make best use of natural resources so as to let the micro-grid reach the best economic operation, different types of micro-grids will be allocated. Through the analysis of load characteristics of power grids in various regions, it applies the plan of power grids which can adjust measures to local conditions. The 'one to one' power supply profit model is proposed aiming at the usage characteristics of different regions so as to realize the applicable generalization of new energies in cities, countryside and islands with different power consumptions. The operation mode of micro-grid with distributed power supply is shown in table 1.

Table 1. Operation Mode of Micro-grid with Distributed Power Supply

Area Type	Users	Distribute energy	Micro grid operating mode
City	Industry load	Self-prepared power plants, clean energy	Load Micro-grids for Urban Industry
	Mainly industrial users, The second is the commercial, residential users	Clean energy, gas turbine, diesel motor	Load Micro-grids for Industry and light industry
	Public buildings and municipal facilities Construction, transport facilities, construction, commercial buildings, residential construction	PV, gas turbine	Load Micro-grid of Urban City Proper
Country	Aquaculture users, public utilities construction, residential construction	PV, micro gas turbine, biomass energy	Load Micro-grid in Countryside
Island	Public utilities construction, residential construction	Clean energy	Load Micro-grid for Islands

2.1 Load Micro-grids for Urban Industry

The load micro-grids for urban industry usually considerate the industries' self-prepared power plants as the main powers for production and active region to enhance the reliability of power supply for important industrial loads [4]. Meanwhile, the cost of power generation is lower than that of urban electric supply. According to the power consumption characteristics of the enterprise itself (such as the working hours of workers), its power supply model is flexible. The heavy industry load micro-grid profit model is shown in figure 1.
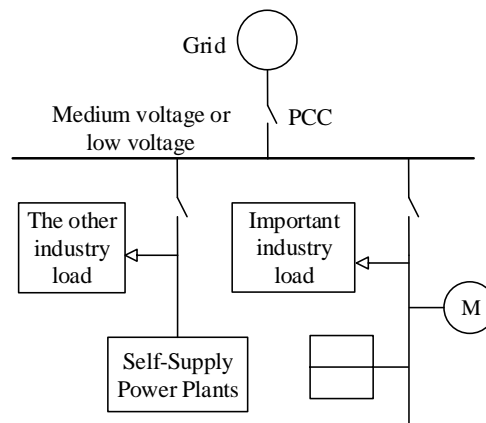
Figure 1. Heavy industry load micro - grid profit model

Urban heavy industries are usually located in suburban areas with high industrial density and easy formation of regional micro-grid. Due to the different behavioral habits of power consumption for different enterprises, the energy complement can be formed through the complex power regulation & control platform to make best use of resources and reach the goal of economical operation. Other stoppable loads in enterprise's production activity can join in operational regulation and control of micro-grid so as to reduce the operational cost of enterprise. In addition, the industrial zone is usually allocated with accommodation and entertainment areas; the rooftop resources are uses to build distributed generators and power restore system to satisfy the daily life power consumptions for employees.

Power consumption characteristics of light industry enterprises are different with that of heavy industry enterprises, namely, its production activity's time is more flexible, the stoppable loads are more abundant, and the reliability of power supply can be properly reduced. However, analyzing from the production and profit of enterprise, to satisfy the power grid's request of cutting the peak to fill the valley and production and operational activates of enterprise, it usually selects to use the rooftop resource to construct new micro-grid of distributed generators and power restore units [5], which ensures the power distribution reliability for itself. For the enterprises which need other energy supplies and have natural gas pipeline, the cold and hot power co-production system can supply both hot and cold power to lower the energy consumption cost of enterprise [6]. Its micro-grid structural diagram is shown below. The profit model of industrial hybrid micro-grid is shown in figure 2.
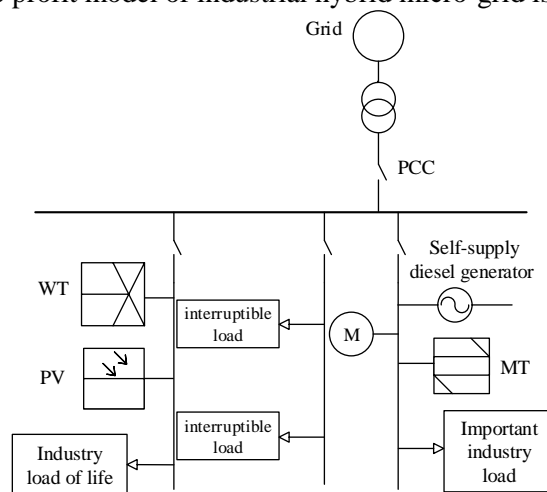

Figure 2. Profit Model of Industrial Hybrid Micro-grid

2.2 Load Micro-grid of Urban City Proper

The power consumption loads in urban city proper are relatively splitting. The power consumption habits of urban complex, public facilities, residential user and other users are different, and the population density of urban city proper us regional. Thus, the regional energy network construction aiming at energy saving to regulate and control the power can reduce the cost of power consumption. The typical profit model of urban micro-grid is shown in figure 3.
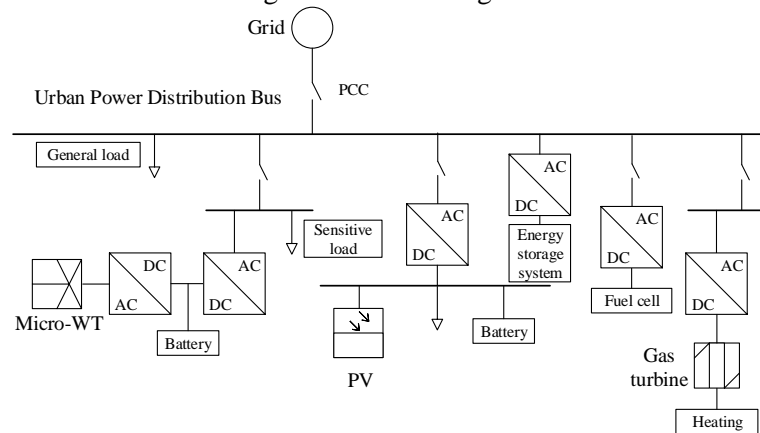

Figure 3. Typical profit model of urban micro-grid

The power supply side of load micro-grid at urban city proper tends to choose the trinity supply system of power supply, cold and hot in most cases, which acts as the main power supply for residential living with distributed photovoltaic. Resident users are more obvious to the elasticity of power price, incentive mechanism and subsidy policy, and the power consumption is highly flexible. Thus, the electric cars, power restore system, and stoppable constant temperature loads (like air conditioner, water boiler and etc.) can friendly interact with power grid to form a good micro-grid operational model. Its micro-grid structural diagram is shown below.

2.3 Load Micro-grid in Countryside

The characteristic of power consumption for load micro-grid in countryside is that the residential power consumption is of small load. If only aiming at construction photovoltaic system on rooftop for living power consumption, the power consumption and absorption will not be guaranteed. Thus, it is more suitable to build micro-grid network in countryside. In addition, countryside has the characteristics of large spaces in farmlands and fish farms, the construction for 'fish farm photovoltaic complementation', 'farmland photovoltaic complementation' and other models of micro-grid to proceed scale power generation (if any) does not only make best use of land resource and provide good cover for fish farming and farming, but also bring considerable benefits to power grid. The typical profit model of rural micro-grid is shown in figure 4.
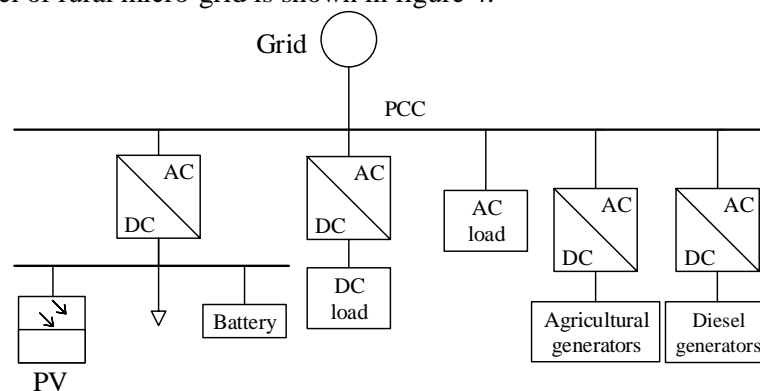

Figure 4. Typical Profit Model of Rural Micro-Grid

For the eastern mountainous area, there maybe relatively abundant water resources, and the micro-grid construction with small hydropower stations as foundation can be considered. For western jumping-offs, considering the village in Tibet region as a model, its natural resources are very suitable for distributed photovoltaic micro-grid, and the geothermal power generation and biomass power generation can be considered under allowable conditions.

2.4 Load Micro-grid for Islands

The load micro-grid for islands is very special. Its geographic location is always far away from mountain area or islet in the ocean. If constructing power transmission and distribution system, the cost will be largely increased; the micro-grid construction to satisfy the demand of power consumption will solve the problem of regional difficulty of power consumption. However, its off-network characteristics and abundant natural resources decide its diverse constitution forms of power generation [7]. To satisfy the reliability of power supply for users, it usually builds the complementary micro-grid of 'wind + light + storage'. Due to the higher cost of diesel generators and trinity supply system, these distributed power generations only can be introduced in areas easy to obtain fuel to ensure the economic operation. Meanwhile, the technology of power generation by using ocean energy resources and tide resources is increasingly progressive day by day. Once it is applied to the micro-grid for islands to complement with 'wind + light + storage', adding some subsidy and incentive mechanism by governments, the micro-grid for island will form a considerable profit model. Its micro-grid structural diagram is shown below. The typical AC / DC island micro-grid profit model is shown in figure 5.
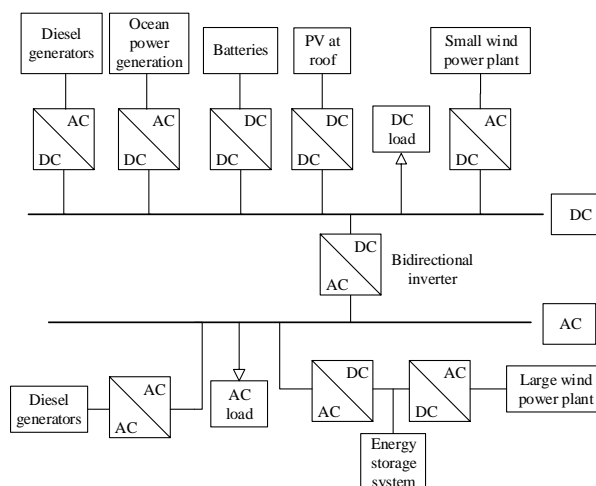

Figure 5. Typical AC / DC island micro - grid profit model

3. Research on Business Model of Micro-grid

3.1 Operation Sensitivity Factors of Micro-grid Operation

3.1.1 Electricity Price. There are numerous types of distributed power generations in micro-grid. Different regions have different scarcity levels of energy sources, which lead to the difference in electricity price for distributed energy resources. The users' behaviors are closely linked to the price constituted by grid companies in marketing environment and the price of distributed power generation. At present, the electricity pricing mechanism in the market is mainly formed by the menu type electricity price, valley electricity price, peak electricity price and two-part electricity price [8]. After the Electric Reform Document 9 is published, the real time electricity pricing mechanism will become the sensitive factor influencing operation of micro-grid. The new electric reform still proposes to open the competition of the power sales side to allow the large users to buy electricity directly, encourages capital investment to establish electricity sellers to allow these sellers to buy electricity from power

generation enterprises and sell it to customers, allows the users (including distributed power generation or micro-grid construction) to participate in market dealing [9].

3.1.2 Incentive Mechanism. The management of power consumption side will be the main trend for power market development. It is one of incentive mechanisms to prompt users to participate in friendly interaction with power grid for the micro-grid including distributed power generation to participate in power grid peak-shaving, frequency modulation, reservation, and stoppable service. For the power generation side, fully combining the incentive mechanism based on management of power consumption side, it calculates and analyzes investment cost and economic profit for power grid with distributed power generations, and puts forward the complex charging mechanism considering reserve capacity payment, assistant service payment, transmission fees and other fees to stimulate rational distribution of time and space for distributed power generation with diversified transmission fees.

3.1.3 Government Subsidy Mechanism. Due to the high investment cost of distributed energy resource, some subsidy in investment cost should be provided as well besides normal power generation subsidy. Secondly, the new technology used to build micro-grid should be provided with power generation subsidy according to requirements of national policy. Thirdly, the whole micro-grid should be provided with subsidy. It is analyzed in Some Opinions of Propelling Construction of New Energy Micro-grid Demonstration Project published by the National Energy Administration [10]. The meaning of micro-grid construction including distributed power generation is fully realized. Even though the subsidy to the whole micro-grid is not mentioned in the document. [11] There are 1-2 demonstration projects have been implemented in various provinces in 2015. In the propelling process of micro-grid construction and operation, the whole subsidy mechanism for micro-grid will be introduced in succession.

3.2 Adapt with operation cost and benefit analysis of micro-grid for new electricity reform
The equitable distribution of cost and profit among relevant entities is precondition of micro-grid's effective operation, so that it has the positive influence on sustainable development for micro-grid system to macroscopically recognize the cost and benefit of micro-grid and proceed scientific measurement. Judging from the analysis on positive economic effects brought by operation of micro-grid, according to regulations of local government, the loss of power generation can be reduced and efficiency of power grid can be improved by distributed power generation to realize the goal of energy conservation and emission reduction. The reduction in cost of transmission losses correspondingly reduces the users' electricity fees. Analyzing from the whole power grid, the micro-grid has certain controllability. It not only can operate independently to satisfy users' power consumption demands, but also can respond to demands of power distribution network's peak-shaving, frequency modulation, stopping ability and standby application. Thus, a virtuous circle of benefiting users and cost-efficiency for grid companies is generated.

Seeing from the other side, the micro-grid brings some negative influence to economy in the operation. The main reason is due to intermittent contribution of distributed power generation in micro-grid. Because of the intermittent feature of distributed power generation during power generation, it causes the intermittent changes in electric energy [12]. At this time, if the micro-grid is connected to external power distribution network, it will cause extra operation cost for external distribution network due to the instability of electric energy. The specific negative influences include the extra losses due to intermittent contribution of distributed power generation [13], voltage instability caused by intermittent contribution of distributed power generation, upgrading and reconstruction of power distribution/ power grid influenced by intermittent contribution of distributed power generation, and extra costs of balance power and auxiliary service caused by intermittent contribution of power generated by distributed power generation cause (especially for wind power, solar power and other intermittent uncontrollable power generations).

According to the analysis above, the operation model of micro-grid has an interest relationship with relevant bodies. Through fees apportion calculated fairly and reasonably and the benefit sharing mechanism of user, the mutual benefit and win-win result among micro-grid operators will be realized to finally prompt the popularization and development of micro-grid.

4. Construction of Technical Economy Model and Empirical Analysis of Different Types of Micro-grid Operation

At the background of the reformation of electric power system, the sufficient consideration against various factors influencing operation of micro-grid in future is needed, the actual operation conditions of micro-grid should be combined, and the operational economical status of micro-grid in a period of time should be checked .

Profit= （$b_1 + b_2 + b_3 + b_4 + b_5 - a_1 - a_2 - a_3 - a_4 - a_5 - a_6 - a_7 - a_8$）*N

a_1: Annual value of equipment investment fees; a_2: Operation and maintenance cost; a_3: Fuel cost; a_4: Reserve capacity fees; a_5: Transmission fees; a_6: Sewage fees; a_7: Contamination treatment fees; a_8: Power cut compensation costs; b_1: Electricity selling benefit; b_2: Government subsidies benefit; b_3: Energy-saving benefit; b_4: Auxiliary service benefit; b_5: Coal trade benefit; N: Years of operation.

According to the basic model construction above and analysis on micro-grid's commercial operational cost and benefit, the operational conditions and basic operational data of different micro-grids with distributed power generation should be stimulated in background of industry, business, islands and countryside.

Firstly, the valid operation years, equipment investment and operation and maintenance fees of distributed power generations should be defined, and the distributed power generation includes solar power, wind power, gas turbine and storage battery, etc. The distributed power supply of micro-grid constitutes the basic data of each parameter is shown in table 2.

Table 2. The distributed power supply of micro-grid constitutes the basic data of each parameter

	PV	Wind power	Gas Turbine	Energy system
Annual operating time(h)	1500	1000	6500	500
Equipment investment (RMB/kW）	7500	8750	10000	600
Price (RMB/kW·h）	0.81	0.87	0.70	0.60
Heating area(10000m^2)	10	7.3	0	2
Capacity cost （RMB/KW/h）	0.0443	0.0469	0	0.0526

Attention: Wind and solar subsidies are 0.28 RMB /kWh,0.42 RMB / kWh.
The first year of operation and maintenance fee is 5% of the total investment. Then this fee of the next year becomes 102% of the previous year.
When PV installed capacity greater than 4MW, equipment investment will become 7,000 RMB / KW.

Secondly, the price of natural gas is 2.7 Yuan/ m^3 (generating 9 kwh of electricity by burning 1 m^3 of natural gas), and the heat meter is charged as per the two-part calculation with area accounting for 30% and heat meter. The price of public buildings' heat supply is 33 Yuan/m^2, and the measured heat price 183 Yuan/MWh. The yearly heat cost index is 30w/ m^2 with heat supply for 120 days. Thus, the unit consumption of heat supply is 0.311GJ/m^2 [14], and the planned energy conservation can reach 10%. The energy supply efficiency of the triple combined unit is shown in table 3.

Table 3. Energy Supply Efficiency of the Triple Combined Unit

Power generation efficiency	50%		

| Heating efficiency | 37% | Heating fee(RMB/kW·h) | 0.17 |
| Cooling efficiency | 20% | Cooling fee(RMB/kW·h) | 0.22 |

The distributed power supply ratio of different types of micro-grid is shown in table 4.

Table 4. Distributed power supply ratio of different types of micro-grid

		Industry	Commercial	Island	Country
Gas Turbine		2.50	1.80	0.00	0.50
Capacity cost （MW）	WP	0.20	0.20	2.40	0.40
	PV	2.30	3.00	2.60	4.10
	FC	0.00	0.00	0.00	0.00
	BE	0.00	0.00	0.00	0.00
Ocean Energy		0.00	0.00	0.00	0.00
Total		5.00	5.00	5.00	5.00

According to the basic data above, the relevant empirical analysis is carried out, and details are shown in the table 5.

Table 5. Technical and Economic Table of 20-year Operation Period for Different Types of Microgrids

	Industry	Commercial	Island	Country
1.Operating costs	20149.03	16384.22	6865.76	9063.86
(1) Invest costs	4454.00	4291.00	4230.00	3810.00
(2) Fuel costs	12150.66	8748.47	0.00	2430.13
(3) Operating and maintenance costs	2775.33	2673.77	2635.76	2374.05
(4) Transmission fees	To be determined			
(5) Reserve capacity fees	769.04	670.98	0.00	449.68
2.Operating profit	24762.01	22232.28	8374.61	11246.07
(1) Electricity selling benefit	20087.84	17781.08	5495.83	7327.78
(2) Cooling/Heating income	1692.99	1218.95	0.00	338.60
(3) Government subsidies benefit	1875.56	2425.15	2878.77	3358.57
(4) Energy-saving benefit(10%)	1105.62	807.10	0.00	221.12
(6) Auxiliary service benefit	To be determined			
3.Net profit	4612.98	5848.06	1508.85	2182.20
4.Investment profit margin	1.14%	1.78%	1.10%	1.20%

According to the data calculation shown above, the investment profit margins for different type of micro-grids (from large to small) with certain construction installed capacity are business micro-grid of 1.78%, countryside micro-grid of 1.20%, industrial micro-grid of 1.14%, and island micro-grid of 1.10% in 20 years' operation. Analyzing from the view of cost, the gas turbine is widely used in industrial field due to easy obtainment of fuel and high efficient usage of resource. However, its construction in islands and countryside is few due to its high equipment investment cost, and the easily approachable clean energies (like solar and wind power) are applied more; the storage capacity is increased correspondingly. Analyzing from the view of benefit, the influence of electricity price is most prominent. The business electricity price is much higher, and its benefit is considerable comparing with electricity selling. Meanwhile, the clean energy power generation subsidy provided by relevant national policy accounts for 10%-20% of the benefit. In addition, the energy development carries out clean substitution, energy consumption carries out electrical power substitution to enhance the benefit of energy-saving. The friendly interaction between power grid and user can enhance orderly power utility at user side so as to increase the demand response benefit.

5. Conclusion

This paper studies the operation model of micro-grid including distributed power generation in fields of urban industry, urban business, islands and countryside in the background of new power reform, and analyzes sensitivity factors influencing its operation to further study the operational cost and benefit of micro-grid under different scenarios. The technical economical model including reserve capacity fees and energy-saving benefit should be constructed innovatively, and the empirical analysis with basic data should be carried out. Taking advantages of constructing distributed power generations of micro-grid in different scenarios as the analyzing proof, the promotion model for micro-grid operation is finally obtained.

Acknowledgments

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