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# Day-Ahead Optimized Dispatch for the Micro-grid Containing Accumulator

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**Keywords:** micro-grid; quantum particle swarm; optimal dispatch; storage battery.

**Abstract.** An optimally economical dispatch scheme for the operation of micro-grid is proposed in order to solve the micro-grid dispatch problems caused by large quantities of approved construction of micro-grid projects. And it analyzes the issue of a micro-grid system in micro-grid that whether the storage battery works or if there is a constraint between the micro-grid with the grid in switching power and thus calculates the power supply structure in each period and the total power supply cost per day as well as the average unit price of electricity purchase under these four different conditions by considering various cost and both the constraints of battery parameters and different rules in different durations. Then the utilization of renewable energy along with the produced influence of storage battery after adjustment is analyzed. The optimized dispatch model is established using the quantum-behaved particle swarm optimization and ultimately an optimized dispatch scheme with maximum economic benefits is determined for the significant improvement of economic benefits and better satisfaction for the requirements of real-time dispatch, which plays the role of peak load shifting of storage battery.

## Introduction

With the increasingly prominent problems of energy and environment, the renewable energy based on the power generation with wind and optics has entered a period of rapid development which can be divided into large-scale centralized access and distributed access according to different power system mode, and the distributed access is mainly used in micro-grid. Micro-grid is a small-scale power generation and distribution system consisting of distributed power supplies, energy storage devices, energy conversion devices, load, monitoring and protection devices, etc. Thereupon, the affairs that how to properly manage the operation of internal distributed power supplies and energy storage devices in micro-grid and to achieve the maximization of economic, technical and environmental benefits of micro-grid have become an important research topic.

The TOU price mechanism divides the 24hours of the whole day into the periods of peak, flat, low ebb, etc. according to the load change of grid for setting up different price levels on each period[1]. The implementation of TOU price can not only reflect the power cost in different periods, but also guide the residents to use electricity scientifically, peak load shifting and improve the utilization efficiency of electric resources, which has obtained high recognition. And the charging and discharging of storage battery leads the micro-grid to peak load shifting at the same time. The core of current optimization of economic dispatch problem for micro-grid with storage battery under the TOU price mechanism is to coordinate wind power, PV, storage battery and power grid to gain the lowest total cost in the premise of guaranteeing the smooth operation of each part and requirements of load, and various cost, constraints of battery parameters along with different rules in different time periods are the mainly considered to determine the optimal dispatch model[2].

A day-ahead economic dispatch model is established in this paper by taking the micro-grid containing fans, PV, storage battery and conventional load as the object, that is, to consider the TOU price on the side of grid on the basis of predicting day-ahead fan output, PV output and conventional load (next 24 hours) and make full use of the controlled means such as the battery in micro-grid to optimize the economic efficiency of the operation of micro-grid. And the power supply structure in each period and the total power supply cost (Yuan) all day long as well as the average unit price of electricity purchase (Yuan/kWh) under these four different conditions of that whether the storage battery of micro-grid works or if there is a constraint between the micro-grid with the grid in switching power are calculated, and the utilization of renewable energy and the produced influence of storage battery after adjustment are analyzed and finally, the model is evaluated.

## Dispatch Strategy of Micro-grid

The undulatory property renewable energy has impacts on the balance of power supply between the micro-grid with electric system, and the battery has the capacity to peak load shifting, so classified investigations on different periods of power using and different power outputs of wind and PV are conducted in order to achieve the minimum average load power supply unit price[3]. Furthermore, charging and discharging status of battery as well as the interaction with the main grid should be reasonably arranged under the conditions that meeting the requirements of discharge rate, capacity, start-stop times constraints, the constraints of purchase and sale of electricity, and the constraints of interaction capacity between the micro-grid with main grid. The dispatch circle is set as 15min in this paper and the whole day is divided into three periods of peak, flat and low ebb according to the load level of the grid, which is shown in table 1.

Table 1. Distribution and corresponding power purchase price of three periods of peak, flat, low ebb.

| Period | Low ebb | Flat | Peak | Flat | Peak | Flat |
|---|---|---|---|---|---|---|
| | 0:00~7:00 | 7:00~10:00 | 10:00~15:00 | 15:00~18:00 | 18:00~21:00 | 21:00~0:00 |
| Selling price of electricity [Yuan/kWh] | 0.22 | 0.42 | 0.65 | 0.42 | 0.65 | 0.42 |
| Electricity purchasing price [Yuan/kWh] | 0.25 | 0.53 | 0.82 | 0.53 | 0.82 | 0.53 |

The highest purchase price of electricity appears in peak hours and thus the battery should discharge preferentially under the premise of meeting the load in this period, and selling the electricity as much as possible; it shall try to sell electricity if the outputs of wind and PV are insufficient, and it might purchase electricity from the grid unless it is really inadequate; The lowest purchase price of electricity appears in the low ebb hours, and thus the battery should save electricity preferentially; the outputs of wind and PV, battery, cost of electricity sales and electricity purchase should be comprehensively considered in the process of degree of electric utilization. The dispatch rule strategy diagram is shown in table 2.

Table 2. Dispatch rules of micro-grid.

| Period | Rules |
|---|---|
| Peak | To sale the electricity as far as possible and the battery should have the priority to discharge, wind power is preferentially used by the internal load in micro-grid; to sale the surplus as far as possible when wind power is sufficient, and PV is preferentially used when wind power is insufficient, when PV is insufficient as well, it may use storage battery preferentially. |
| Flat | The storage battery should have the priority to be charged, selling the surplus to main grid; when the output of wind power is sufficient, purchasing from external grid preferentially and charging the battery at the same time. |
| Low ebb | The storage battery should have the priority to be charged and the outputs of wind and PV are dispatched, selling the electricity to main grid as far as possible under the premise of meeting the demand of micro-grid; if the outputs of wind and PV are still far from the demand of micro-grid load, purchasing electricity from main grid. |

## Optimization Dispatch Model of Micro-grid

### Determination of the Objective Function and Constrained Condition

(1) Objective function：The object is the minimum average unit price of power supply of load and thus the formula is as follow:

$$\min C = \frac{\sum_i \left( C_w P_{wi} + C_s P_{si} + C_{buyi} P_{buyi} U_{buy} + C_{bi} P_{bi} U_b - C_{selli} P_{selli} U_{sell} \right)}{\sum_i P_{nli}} \quad (1)$$

(2) Constrained condition

A. Balance constraint of system power:

$$P_{wi} + P_{si} + P_{disi} + P_{buyi} - P_{selli} - P_{chai} = P_{nli} \quad (2)$$

B. Mutual capacity constraint of micro-grid and main grid:

$$0 \le P_{selli}, P_{buyi} \le 150kW \quad (3)$$

C. The constraints of power purchase and sale as well as the charging state of battery cannot appear simultaneously: The charging state of battery (SOC i.e. the ratio of remaining battery power and battery capacity) should meet the constraint of bound value in order to prevent the battery from overcharge and over-discharge: where $S_t$、$S_{\min}$、$S_{\max}$ are values of the SOC states in t period of the battery and its bound respectively. That is, the battery stops charging when SOC reaches the maximum ($S_{\max}$ ＝0.9) of the battery; and when the SOC reaches the minimum ($S_{\min}$ ＝0.3) , the battery stops discharging. The numerical value variation formula of SOC is:

$$S_t = S_0 + \frac{\sum_{i=1}^{96} P_{chari} X_i \Delta t - \sum_{i=1}^{96} P_{disci} Y_i \Delta t}{E_b} \quad (4)$$

D. The same constraints in the first and last states of the cycle: it is in view of the data considers that it cannot perform any charging and discharging operation when reaching 0.4 from 22:00 in actual calculation. Charge / discharge rate constraints: The maximum charge and discharge power is 20% of the rated capacity of the storage battery unit per unit time, i.e., 15min.

E. Charge and discharge times constraint: Frequent charge, discharge and the discharge depth can affect the battery life in a dispatch cycle, so it is necessary to limit the times of charge and discharge.

### Quantum Behaved Particle Swarm Optimization Algorithm

The model is solved with quantum particle swarm optimization algorithm in this part. QPSO algorithm establishes the quantum potential well based on introducing quantum behaviors to the particle evolutionary population to make the particles in the solution space converge to the center of the potential well in accordance with the probability[4]. And because the state of particles in this quantum space is uncertain, the velocity and position of particle cannot be obtained simultaneously, so the probability density function in a certain point of particles can be achieved by solving the Schrodinger equation and then the equation of position of particles can be obtained with Monte Carlo algorithm as:

$$F_j(i) = P_j(i) \pm \frac{L_j(i)}{2} \ln \frac{1}{u} \quad (5)$$

where i is the current iterations; $F_j(i)=\left[F_{j1}, F_{j2}\cdots F_{jd}\right]$ is the current position of the particle, $d$ is the number of particle dimension, $P_j(i)$ represents the random point position of particle j; $L_j(i)$ is the characteristic length of the potential well of a quantum; $u$ is the uniformly distributed random number in [0,1].

$$P_j(i+1)=\vartheta P_{jbest}(i)+(1-\vartheta)P_{gbest}(i) \tag{6}$$

$$L_j(i+1)=2\beta\left|P_{mbest}-X_j(i)\right| \tag{7}$$

$$\beta=m-(m-n)\times i/T_{\max} \tag{8}$$

where $\vartheta$ is the random number in [0,1]; $P_{gbest}(i)$ is the best global position after the iteration of particle; $P_{jbest}(i)$ is the best position of particle $j$; $P_{mbest}$ is the mean value of the best positions of all particles in populations; $\beta$ is the contraction factor, $\beta$ decreases progressively and linearly from $m$ to $n$ with iteration, in general, $m$=0.9, $n=0.5$; $T_{\max}$ is the maximum number of iteration of the particle. Therefore, the equation is obtained as:

$$X_{jk}(i+1)=P_{jk}(i+1)\pm\beta\left|\beta_{mbestk}(i)-X_{jk}(i)\right|\ln\frac{1}{u} \tag{9}$$

$$P_{jk}(i+1)=\vartheta P_{jbest}(i)+(1-\vartheta)P_{gbest}(i) \tag{10}$$

$$P_{mbest}(i)=\frac{1}{96}\sum_{i=1}^{96}P_{jbest}(i)=\left[\frac{1}{96}\sum_{i=1}^{96}P_{jbest1}(i),\frac{1}{96}\sum_{i=1}^{96}P_{jbest2}(i),\cdots,\frac{1}{96}\sum_{i=1}^{96}P_{jbestd}(i)\right] \tag{11}$$

**Example Analysis**

The power supply structure in each period has changed, which is shown in figure 1.

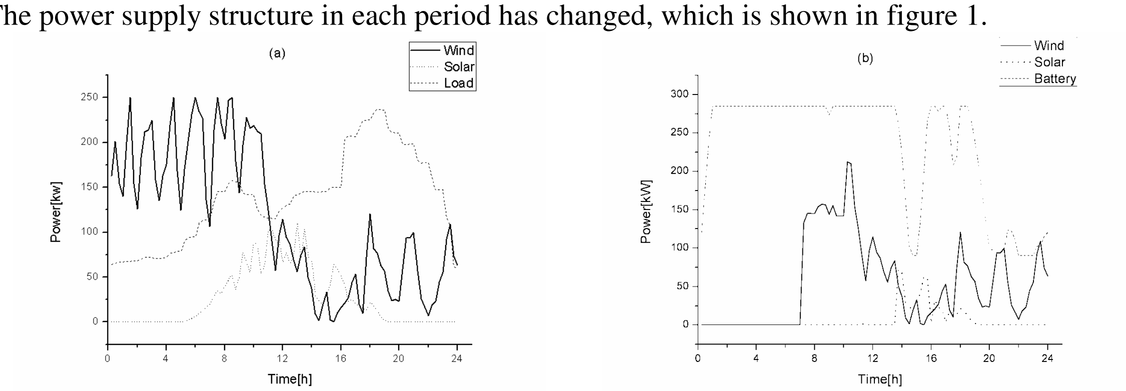


Figure 1. (a) (b) respectively show the power supply structure before the dispatch and after the dispatch.

The calculation results indicate that the total power supply cost and average unit price of electricity purchase per day decreases when the utilization rate of renewable energy is not limited, but the rates of -rejecting the wind and PV are extremely high and reach 0.54 and 0.69 respectively. When the battery is added, the average cost decreases and the economic benefits of the system is improved compared to the case of limiting full utilization of renewable energy but without energy storage; and at the same time, the battery stores electrical energy when the wind and PV generate more, and it will release energy when the wind and PV generate less, which peaks load shifting. When the battery is added, the wind-rejection rate is 0.54 and the PV-rejection rate is 0.57. Compared with the case of no battery, the PV-rejection rate decreases obviously, which indicates that the utilization of renewable energy will be improved after connection of micro-grid system with grid. At the same time, the times of charge and discharge also decreases when the utilized amount of renewable energy is not limited, which manifests that this scheme can prolong the service life of the battery.

## Conclusion

The core problem of daily dispatch of micro-grid caused by the output of the undulatory property of renewable energy, which plays the role of peaking load shifting of battery to the greatest extent and can favorably improve the output characteristic curve of micro-grid, alleviate the phenomenon of wind-rejection and PV-rejection. The fundamental reason for the complexity of daily optimal dispatch of micro-grid is that the renewable energy such as wind and PV has the characteristics of intermittence, instability, anti-peaking and rapid variation of output curve. While the fan and PV system are greatly affected by the light, wind speed, temperature and other external environmental factors, the primary energy power at the input side cannot actively regulate and control within the technical range, which can only attempt to achieve the maximum output of generating system directly resulting in its output characteristics inferior to the traditional thermal generation in the aspect of placidity, and the complexity increases when conducts the dispatch because the power production is planned and continuous. There is still space for improvement during the actual application of this model, and thus improvements can be carried out with the following four aspects and many details of the problem could be carefully considered in order to make the model more practical, it should be considered as: the optimization of power prediction model; the impact of accessing new energy on dispatch and operation of power system; national policy and social impact and the environmental benefits.

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