

# Distributed Generation planning Research based on Timing Characteristics

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**Abstract.** In this paper, considering the load, wind power and photo voltaic timing characteristics, establishes a planning model containing distributed power energy storage device. In the planning model, the minimization of the total cost including the initial investment, fuel costs, net loss costs, environmental damage costs, operation and maintenance costs and power purchase costs. To improve the acceptance ability of the distribution network, and to ensure the economy. Then, using the particle swarm optimization algorithm to solve a typical example, to show that the model and the proposed method is correct and effective.

## 1. Introduction

Wind turbines generator (WG), photo voltaic power generation (PV) as the mainly distributed power generation (DG) supply studied in this paper, and the use of sodium sulfur battery energy storage (BS) as energy storage device.

Due to the characteristics of the output of DGs is random and volatility, resulting in when DG access to the distribution network, the power output of DGs can't achieve good matching in the time scale with the load demand, so limited the capacity of the distribution network to DGs. The energy storage can make up for the lack of volatility and intermittent of the distribution network after DG access to the power grid. Therefore, more and more people considering installing energy storage device in the near of the DG. In this environment, by fully considering the timing of the complementary characteristics of the load, distributed generation and energy storage, optimize the allocation of WG, PV and BS. To ensure the economy of distribution network, and also improve the capacity of distributed power distribution network.

## 2. Timing characteristics

The timing characteristic of power load and DG, are shown in Figure 1 and 2. The 2 typical load just as industrial (I) and residential (II) load.

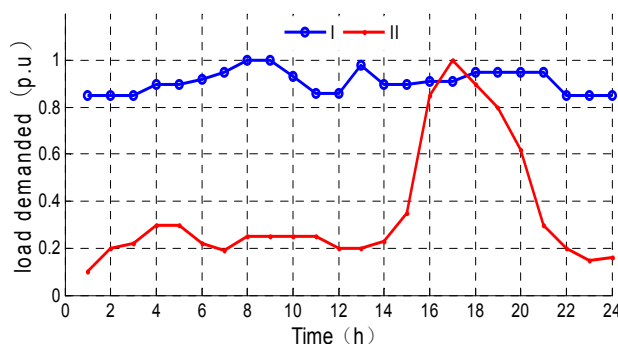


Fig 1 Timing characteristic curves of power load

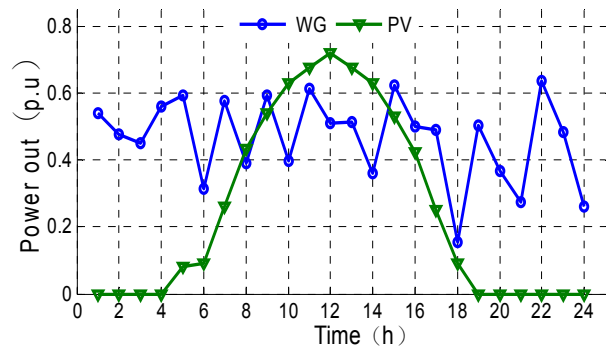


Fig 2 Output curve of DG

Without considering the timing characteristics of the load, the load demand must be calculated according to the maximum load. If not considering the timing characteristics of DG output, according to the rated power of constant power output, the annual generating capacity of

a total conversion to full power operation under general DG hours, the maximum output of the number of hours ranging from 2000~3000, and we take 2000.

### 3. To construct the objective function

#### 3.1 The objective function

In this paper, the cost of the distribution network in the minimum as the objective function:

$$BS \text{ and DG contained: } f_{\min} = C_0 + C_1 \times p_1 + C_g + C_e \quad (1)$$

Where  $C_0$  is the costs of operation and maintenance of DG (million);  $C_1$  is the total costs of DG and BS (million);  $C_m$ ;  $C_g$  is the power purchase cost of the system (million);  $C_e$  is the environmental cost of the system (million);  $p_1 = \frac{r(r+1)^n}{(1+r)^n - 1}$ ;  $r$  is interest rate;  $n$  is life expectancy.

#### 3.2 The constraint conditions

1) Power flow constraints

$$\begin{cases} P_i = U_i \sum_{j=1}^N U_j (G_{ij} \cos \theta_{ij} + B_{ij} \sin \theta_{ij}) \\ Q_i = U_i \sum_{j=1}^N U_j (G_{ij} \sin \theta_{ij} - B_{ij} \cos \theta_{ij}) \end{cases} \quad (2)$$

2) Voltage constraints

$$U_i^{\min} \leq U_i \leq U_i^{\max}, i \in N \quad (3)$$

Where  $P_i$  and  $Q_i$  are the active and reactive power of node  $i$ ;  $U_i$  is the voltage amplitude of nodal  $i$ ;  $N$  is the number of the nodes;  $G_{ij}$  and  $B_{ij}$  are admittance;  $\theta_{ij}$  is the voltage phase angle difference of node  $i$  and node  $j$ ;  $U_i^{\max}$ ,  $U_i^{\min}$  are the highest and lowest voltage of node  $i$ .

#### 3.3 Kinds of Costs

1) Operation and maintenance loss:

$$C_0 = e_l \sum_{k=1}^4 T_k \sum_{j=1}^{24} \sum_{i=1}^l \frac{p^2 + q^2}{u^2} R_i + C_m \quad (4)$$

Where  $T_k$  is the number of days;  $e_l$  is loss electricity price;  $p, q$  is the active and reactive power of node  $i$ ;  $R_i$  is the resistance value of the  $i_{th}$  branches. Load time series characteristics directly affect the size of the network loss cost.  $C_m = \mu_i P_i$ ,  $\mu_i$  is the operation and maintenance costs of the  $i_{th}$  kind distributed power supply unit.

2) Costs of DG and BS:

$$C_1 = \sum_{i=1}^n c_i \times S_{DG_i} + C_B \quad (5)$$

Where  $c_i$  is The unit capacity cost of distributed power supply,  $c_{wg}$ ,  $c_{pv}$ , stand for WG, PV,  $S_{DG_i}$  is the  $i_{th}$  kind of distributed power total installed capacity.  $C_B = c_{bs1} \times S_{BS} + c_{bs2} \times P_{BS}$ , it means cost of the BS. Where  $c_{bs1}$  is the unit energy cost of BS,  $S_{BS}$  is the capacity of the BS.  $c_{bs2}$  is the unit power cost of BS,  $P_{BS}$  is the rated power of the energy storage.

3) Power purchase cost:

$$C_g = (E_{total} - E_{dg}) \times e_g \quad (6)$$

Where  $E_{total}$  is the electricity consumption of the whole network one year ( $MW \cdot h$ );  $e_g$  is the purchase electricity price.

4) Environmental cost:

$$C_e = (E_{total} - E_{dg}) \sum_{i=1}^N K_i (V_i + R_i) \times 10^{-4} \quad (7)$$

Where  $K_i$  is emission intensity per unit of electricity produced  $i_{th}$  kinds of pollutant;  $V_i$  is the greenhouse gases environmental value standard;  $R_i$  is the expropriation price of greenhouse gas.

#### 4. Method for solution

##### 4.1 The swarm intelligence optimization algorithm—Particle swarm optimization algorithm

The speed of updating and position updating formula is as follows:

Where  $r_1, r_2$  rand from 0~1;  $c_1 = c_2 = 2$ ;  $v_{id} \in [-v_{max}, v_{max}]$   $x_{id}^t \in [x_{min}, x_{max}]$ .

$$\begin{cases} v_{id}^{t+1} = \omega \times v_{id}^t + c_1 r_1 (p_{id}^t - x_{id}^t) + c_2 r_2 (p_{gd}^t - x_{id}^t) \\ x_{id}^{t+1} = x_{id}^t + v_{id}^{t+1} \end{cases} \quad (8)$$

##### 4.2 Power flow calculation

The traditional radial distribution network, the line power flow generally from the side to the user side. When the DG is connected to the distribution network, the direction and the size of the line power flow can be influenced by the capacity of DG and access location. In the case of low DG penetration, the distributed power supply is relatively small, not enough to meet the load demand, network flow one-way circulation; high DG penetration cases, distributed power can meet the load demand at the same time, but also flow to the other main distribution grid nodes. So this paper uses forward and backward substitution method.

##### 4.3 The planning of energy storage device

1) According to the time sequence characteristic curves of equivalent load, when it reduce, energy storage device must be able to store excess energy quickly. On the contrary, the energy storage device must be able to release energy quickly. So that to ensure the power supply of system to the node is stable, and reduce the volatility of the distribution network.

2)  $P < 0$  that means distributed power supply is greater than the demand. At this time, BS device must be able to store excess power to ensure one-way flow of the distribution network.

#### 5. Example analysis

The paper uses the typical distribution network grid of 10kV as a calculation example. The initial grid is shown in Fig.3, with 14 nodes, 13 branches. In node 5 has WG and node 13 have PV and WG.

There have three schemes, scheme 2 and scheme 3 considering the timing characteristics and scheme 1 without. Scheme 2 do not contained BS, but scheme 1 and scheme 3 contained.

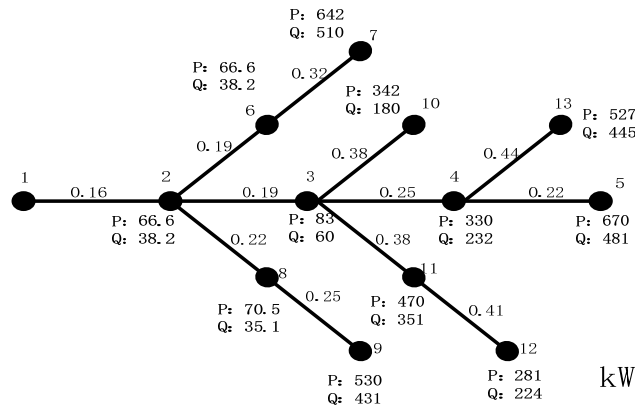


Fig.3 Distribution network grid structure diagram of IEEE13

##### 1) Economic comparison of the mounting conditions

Tab.1 Cost of planning schemes

/10K ¥	$C_0$	$C_g$	$C_e$	$C_1$	$C_m$	Total
Scheme 1	8.67	925.30	136.99	1281.5	87.60	1287.99
Scheme 2	3.46	894.08	98.846	694.6	39.36	1105.9
Scheme 3	2.66	731.71	85.426	1513.4	61.42	1033.73

2) The installed capacity of WG, PV, BS programming:

Tab.2 Position and capacity of DG

Schemes	DG type	Location	Capacity
Scheme 1	WG	5,13	400kW,200 kW
	PV	13	200kW
	BS	5,13	150*12kWh,120*12kWh
Scheme 2	WG	5,13	600 kW,300 kW
	PV	13	300kW
Scheme 3	WG	5,13	400kW,400 kW
	PV	13	450kW
	BS	5,13	100*8kWh,150*10kWh

In Tab.1 and Tab.2 can be concluded: ①Comparison with scheme 1 and 3, the network loss cost of the scheme 3 is significantly lower than that of scheme 1.② Comparison with scheme 1 and 3,scheme 3 has the lower capacity of BS.③Scheme 3 has the lowest total cost.

## 6. Conclusion

In this paper, established DG and storage device capacity allocation planning model based on timing characteristics of DG and load. Then using the particle swarm optimization algorithm to solve the model, finally obtains the best cost of distribution network optimal planning. The main conclusions are as follows:

- ①Taking into account the planning scheme of the time characteristic of load and DG, the network loss cost of the distribution network can be reduced obviously.
- ②Considering the timing characteristics of DG and load has the lower capacity of BS.
- ③can make the distribution network has the lowest total cost.

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