Expansion Planning of Wind-Biomass Co-generation System in The Micro-grid

Xiong Changquan[1],Chen Qiang[1],Wang Song[2], Qiu Xiaoyan[2], Xu Jian[2], Xia Lily[2] ,Wei hongfen[2]

(1.Dazhou Electric Power Bureau,Sichuan Electric Power Company,China;
2.School of Electrical Engineering and Information
Sichuan University
Chengdu, China)
E-mail: wangsong_scu@sina.com, xiaxing726@163.com

Abstract— Based on the improved genetic algorithm, a wind-biomass co-generation system (WBCS) planning model is put forward. The expansion plan which minimize the total cost is introduced to increase the reliability of Micro-Grid(MG) and meet the nonlinear constraints of system planning and operation. In the process of planning the total cost, not only the unit construction cost and operation cost are considered, but also the outage loss cost of demand side caused by power supply shortage. Adaptive weight method is adopted to construct dual objective function and the relationship between unit cost and reliability are well balanced. the test results shows that the proposed model and algorithm are feasible, and can provide some theoretical basis and technical support for the planning and designing of smart grid and distributed generation.

Keywords- micro-grid ， wind-biomass energy system ， expansion planning，sum of adaptive weighted，improved genetic algorithm

I. INTRODUCTION

At present, with growing environmental pressure improvement of electric power system in safe operation, energy, environmental protection, market competition and the enterprise management entered into people's field of vision. The research on distributed generation and microgrid has become a new hotspot at home and abroad. The distributed generation near the loads provides users with higher power supply reliability and better quality of power. The distributed power supply meets user requirements, while external power grid failure or power quality cannot meet user requirements ,and then microgird is separated with great power grid and turn to the isolated network running mode[1][2].

Wind power has strong intermittently, so the wind generator operation often combines with other units includes wind - diesel generator, the wind - solar power etc [3].

Considering the installation costs, operating costs, loss of power outages and reliability of MG composit, the model of expansion and plan in the wind-biomass power generation systems is built. In addition, based on the simple genetic algorithm (SGA)，simulated natural disaster phenomena， and adopted catastrophic genetic algorithm(CGA), the improved Genetic Algorithm (IGA) is put forward to accelerate the convergence speed of genetic algorithm obviously[4][5].

Project supported by a grant from the Ph.D. Programs Foundation of Ministry of Education of China (No. 20070610109), National Key Technologies R & D Program of China (No. JS20080113506594).

II. OBJECTIVE FUNCTION AND CONSTRAINT CONDITION

A. *Objectives*

1) *Cost ojective:*

The objective of expansion planning of wind-biomass: It meets the load, and safety operation system planning, at the same time making the minimum total cost. Objective function is given by

$$\min C_k = \sum_{t=0}^{T} (I_{kt} - R_{kt} + O_{kt} + M_{kt} + U_{Ekt})(1+i)^{-t} \qquad (1)$$

where, *Ck* is the total cost of scheme. T is the time of planning is discount rate; I_{kt} is the total investment of new unit of the year *t* plan *k*.O_{kt} is the operating cost. M_{kt} is the maintenance costs. R_{kt} is the surplus value of the year *t* plan *k*.U_{Ekt} loss as the power cut.

Because each place has slightly different natural environment and load characteristics in MG, and a distributed power supply in different places with different configurations cost, and biomass also has a different configuration costs in the same location with wind power[6].

$f_1(x)=minC_k$ is the first optimization objective for the model.

2) Reliability ojective:

It describes the micro-grid reliability by using the distribution system reliability indices which can be divided into load point indices and system indices. Load point indices used to reflect the degree of power supply reliability of load point,，include load point failure rate λ(time/a)、load point outage duration of each fault *r*(h/time)、outage time annual mean of load point *U*(h/a)[7].

The indexes of system include system average interruption frequency index(SAIFI) 、 system average interruption duration index(SAIDI)、average supply available indicators(ASAI).Calculations are[8]：

$$SAIFI = \frac{\sum_{i=1}^{N_L} N_i \lambda_i}{\sum_{i=1}^{N_L} N_i} \quad (2)$$

$$SAIDI = \frac{\sum_{i=1}^{N_L} N_i U_i}{\sum_{i=1}^{N_L} N_i} \quad (3)$$

$$ASAI = \frac{\sum_{i=1}^{N_L} N_i \cdot 8760 - \sum_{i=1}^{N_L} N_i U_i}{\sum_{i=1}^{N_L} N_i \cdot 8760} \quad (4)$$

where, N_L is the number of load points in MG. N_i is the number of users which connect the load point *i*.

Power-up should compensate the losses caused by the lack of electricity, beacuse of system reliability. But for users, the protection system reliability is more important. In order to consider the interests of both of supply and user , the paper established a two-goal programming model：

This paper just calculate the reliability index of structural，$f_2(x)=maxASAI$ is the second optimization objective of installation location for the distributed power.

Objective function *f(x)* change into the fitness function *Fit (f (x))* by boundary construction method：

$$Fit(f(x)) = \begin{cases} f(x) - c_{\min}, f(x) > c_{\min} \\ 0, f(x) \le c_{\min} \end{cases} \quad (5)$$

where，c_{min} is the minimum estimate of *f(x)*.

B. *Dual objective function:*

To deal with the dual-objective optimization problem of lower cost and higher reliability, it uses method of the sum of adptive weighted to deal with fitness function. *zk (x)* is the q objective functions, $z_k^{\max}$ and $z_k^{\min}$ are the maximum and minimum values for each target. If *zk (x)* is the benefit type, that is the maximum optimization objective. Target value after the linear normalization[9]:

$$z_n(x) = \frac{z_k(x) - z_k^{\min}}{z_k^{\max} - z_k^{\min}} \quad (6)$$

If *zk (x)* is the cost-based, that is the minimum objective function. Target value after the linear normalization:

$$z_n(x) = \frac{z_k(x) - z_k^{\max}}{z_k^{\min} - z_k^{\max}} \quad (7)$$

Dual objective function:

$$z(x) = \omega_1 \cdot z_{1n}(x) + \omega_2 \cdot z_{2n}(x) \quad (8)$$

where, weighting factors ω_1， $\omega_2>0$and $\omega_{1+}\omega_{2=1.}$

C. Constraints

1) *Inequality constraints:*

Building in the unit, the constraints of wind and biomass units number in financial terms and schedule of the year *t* must be considered.In actual operation, the wind power penetration should be limit in total load of the system[10]. Including biomass and wind turbine unit maximum and minimum output limits.

$$\begin{cases} 0 \le N_{BGt} \le \max N_{BGt} \\ 0 \le N_{WTGt} \le \max N_{WTGt} \\ P_{BGi\min} \le P_{BGi} \le P_{BGi\max} \\ P_{WTGi} \le P_{WTGi\max} \\ \sum P_{WTGI} \le \lambda P_{LD} \end{cases} \quad (9)$$

Where N_{BGt} is the number of biomass generating units under construction. N_{WTGt} is the number of wind generating units under construction. λ is power factor of wind power penetration. P_{BGI}、P_{WTGi} are the developed power of the biomass and wind power units.

2) *Equality constraints:*

For safe operation of the system,active power of units equal active power of loads,and some of the load must be cut while the power in short supply.

$$\sum P_{BGi} + \sum P_{WTGi} = P_{LD} - P_{DF} \quad (10)$$

where,P_{BGi} is output power of biomass units.P_{WTGi} *is* output power of wind units.、P_{LD} is active power of load.P_{DF} is the removal of the load power[11].

D. *Handle the constraints*

The above problem is transformed into a non-binding by constructing a penalty function to handle the constraints.

The penalty function is：

$$P_{FK} = C_K + \sum_{j=1}^{l} \beta_j F_{kj} \quad (11)$$

where,P_{Fk} is the penalty function for proposal *k*. $\beta_j F_{kj}$ is punishment in the constraints on the program *k*. *l* is the number of constraints. $\beta_j >> 0$， is the penalty factor.

III. APPLICATION OF GENETIC ALGORITHMS

A. *Improved GA*

This paper uses genetic - catastrophic algorithm, based on simple genetic algorithms, simulated natural disaster phenomena, to improve the performance of GA. It can implement disaster while successive generations of the best chromosomes do not evolve,or group of infectded body are very similar.This method can break the monopoly of the original genetic advantages, and increase genetic diversity, genetic algorithm can speed up the convergence rate[12].

B. *Construct the fitness function of GA*

According to the basic principles of GA, the fitness function value used to evaluate the individual.The fitness function is larger, the indivedual is better.Type (11) can not serve as the genetic algorithm fitness function,it could build a fitness function according to equation(11),

$$A_{Fk} = \sum_{i=1}^{N} P_{Fi} - P_{Fk} \qquad (12)$$

where， N is the population size.By the formula (12) known,the penalty function PFk is smaller,the fitness function AFk is greater,and the probability of being selected is higher.

C. *Flow chart of genetic algorithm*

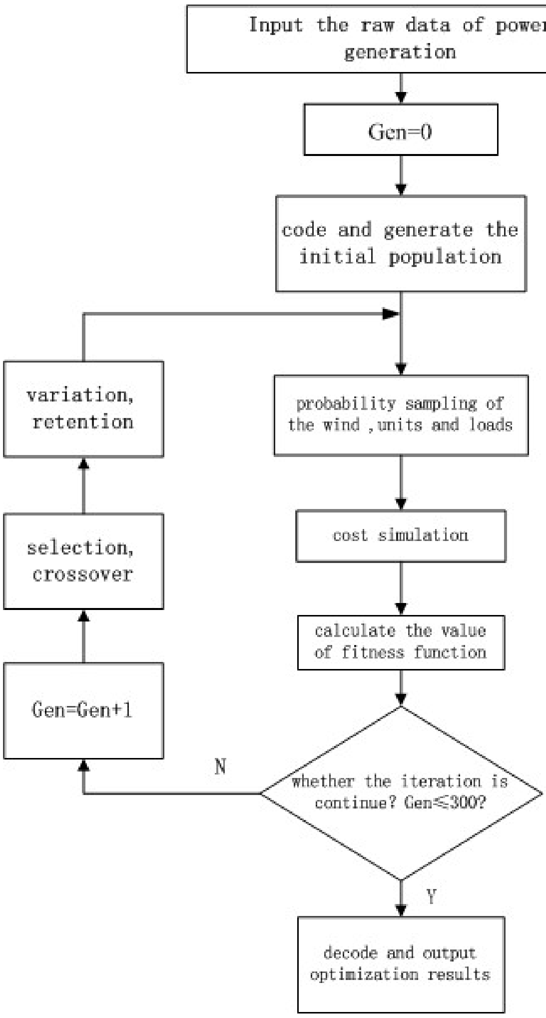

Fig. 1 Procedure for expansion planning of wind-straw energy system

IV. THE SUMULATION CALCULATION AND ANALYSIS

According to this model,using MATLAB to achieve an independent power system planning and design of the next decade. Shown in Figure 6 with radial nodes of the MG optimization test.Node 1 is connected large power grid,others is load nodes,wind and biomass generators connected in these five nodes respectively. In the system,lines length are $l_1=l_2=\ldots=l_{10}=l$=3km,the distance between each node and the local load is 0.01l=30m.The reliability index of line is λ=0.25(time/km·a)， r=5(h/time). The loads of node 2 to 6 are 150kw, 300kw, 450kw, 100kw, 150kw.SAIFI=2.85SAIDI=14.25ASAI=99.84%.

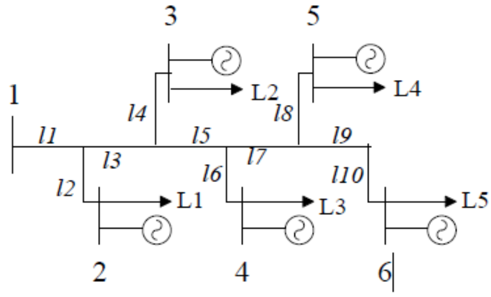

Fig. 2 Test system structure[13]

Capacity of the units to be selected and the model shown in Table 1 ,The region is rich in wind resources and straw resources, the average wind speed is about 7.09m / s.Because of rapid economic development, 10% load increase every year in planning period,due to economic constraints, each unit can not exceed two per year,10% annual discount rate.Economic indicators of unit operation in Table 2, straw price of 200 yuan / t.

Tab. 1 Cost data of candidate units[14]

node	node 2 （yuan/kw）	node 3 （yuan/kw）	node 4 （yuan/kw）	node 5 （yuan/kw）	node 6 （yuan/kw）
Straw unit	6500	6800	6800	7000	6250
wind unit	9750	10000	9850	9500	10000

Wind speed sequence and load sequence have no necessary link in this model.Optional sampling of the wind speed produce wind speed value sequence, and then generate random load value.

The generation is 0.9,mutation rate is 0.05, individuals of the population are 50 in GA.The weighting factors of ω1 and ω2 determine the importance of cost and reliability.Finding the optimal solution by IGA.

It supposes the importance of cost and reliability is same,$\omega 1 = \omega 2 = 0.5$. The following conclusions can be drawn:

Tab. 2 Planning scheme （$\omega_{1=}\omega_{2=0.5}$）

year	plan	year	plan
1	2W-6	2	W-4
3		4	B-4
5		6	W-6,B-4
7	W-2	8	W-2
9	W-3,W-5	10	B-3,W-5

Note:mW-K ,m wind units were installed in node k.B-K， a straw unit was installed in node k.

At this point, MG configuration cost 7.82 million yuan, the reliability of indicators: SAIFI=0.7553， SAIDI=3.7635， ASAI=99.96%. Distributed generation improved the reliability of MG remarkable. The figure shows the convergence of SGA and IGA ,IGA can converge to the optimal solution more uickly, with high optimization efficiency.

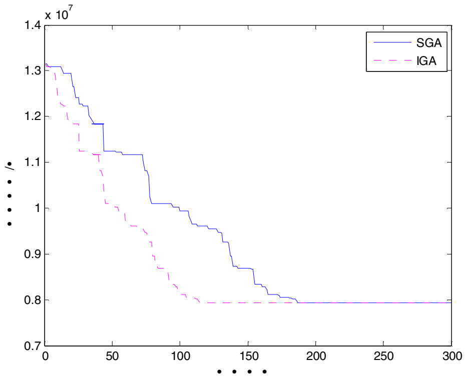

Fig.3 Convergent curves of IGA

If the importance of cost be increased, $\omega_{1=0.1}$, $\omega_{2=0.9}$. Calculation of available:

Tab. 3 Planning scheme ($\omega_{1=0.1}$, $\omega_{2=0.9}$)

year	plan	year	plan
1	2W-6	2	W-2
3		4	B-4
5		6	W-2
7	W-4,B-3	8	W-4
9	W-3,B-4	10	W-3,W-5

Note:mW-K ,m wind units were installed in node k.B-K , a straw unit was installed in node k.

Based on the optimization results suggest, that the first install the lowest cost of the corresponding node,the validity of the algorithm is verified. MG's total configuration costs 7.62 million yuan, then ASAI=99.88%.

If the importance of reliability be increased, $\omega_{1=0.9}$, $\omega_{2=0.1}$. Calculation of available:

Tab. 4 Planning scheme ($\omega_{1=0.9}$, $\omega_{2=0.1}$)

year	plan	year	plan
1	W-6,B-4	2	W-6
3	B-3	4	
5	W-6	6	
7	W-5,B-4	8	W-4
9	W-5,W-3	10	W-4,W-2

Note:mW-K ,m wind units were installed in node k.B-K , a straw unit was installed in node k.

At this point,micro-power first installed in the heavy load of nodes and the end of line,this may help to improve system reliability,consistent with the actual operation of MG,the validity of the algorithm is verified.MG's total configuration costs 8.14 million yuan, then ASAI=99.98%.

V. CONCLUSION

1) Theoptimal allocationproblem of the micro-power installed capacity and location is solved by IGA.Using sum adaptive weights method to combine the two objectives, cost is minimum and reliability is highest, into one fitness function. Through several generation of genetic algorithm, the optimal capacity configuration and optimal installation location of wind generator and biomass power units can be reached. According to different requirements of MG operation, the optimal results will be impacted by the cost and the weight of reliability.

2) The MG planning would be impacted by the increasing awareness of the society environmental protection, and the adjustment and improvement on environment law. The environmental benefits of wind power generation and the financial burden of the straw seasonal harvest are not considered in this paper.

REFERENCES

[1] Lasseter B. Microgrids [C] // Power Engineering Society Winter Meeting. Columbus, Ohio, USA, 2001 : 146-149.

[2] Lasseter R H.. Microgrids [C] // Power Engineering Society Winter Meeting. NewYork, USA, 2002 : 305-308.

[3] Yu Ying,Tian Guo-zheng. Biomass And Power Generation.[M] Beijing,China Electric Power Press.2008.

[4] Vallem, M.R., J. Mitra. Siting and sizing of distributed generation for optimal microgrid architecture [C] // Power Symposium, Proceedings of the 37th Annual North American. 2005 : 611-616.

[5] Vallem, M.R., J. Mitra, and S.B. Patra. Distributed Generation Placement for Optimal Microgrid Architecture [C] // Transmission and Distribution Conference and Exhibition, 2005/2006 IEEE PES. 2006 : 1-5.

[6] Agalgaonkar,A.P.,et al.Optimal sizing of distributed genertators in microgrid[C]//Power India Conference,IEEE.2006:1-8

[7] Qiu Xiao-yan,Xia Li-ly,Li Xing-yuan. Planning of Distributed Generation in Construction of Smart Grid[J]Planning of Distributed Generation in Construction of Smart Grid. Power System Technology, 2010(4): 34- 4.

[8] Zhang Zi-jian, Qiu Xiao-yan.. Multi-Objective Reactive Power Optimization Based on Improved Genetic-Interior Point Algorithm[J].Power System Technology,2009,33(13):27-05

[9] Wang Xing-wang, Qiu Xiao-yan. Distributed generation planning in distribution system based on modified particle swarm optimization algorithm.[J]Power System Protection and Control, 2009 (7) , 37-14.

[10] Wang Jian,Li Xing-yuan,Qiu Xiao-yan.Power System Research on Distributed Generation Penetration.[J]Automation of Electric Power Systems, 2005, 29 (24):90-97.

[11] Li Bin, Liu Tian-qi, LiXing-yuan. Impact of Distributed Generation on Power System Voltage Stability.[J]Power System Technology, 2009, 33 (3) : 84-88

[12] Ding Ming, Wu Yi-chun. Expansion Planning of Wind-diesel Energy System Based on Genetic Algorithm[J]Proceedings of the CSEE, 2006 , 26 (8) : 470-40

[13] Lu Zong-xiang,Wang Cai-xia.Overview on Microgrid Research.[J]Automation of Electric Power Systems,2007,31(19)

[14] Zheng Zhang-hua , AI Qian ,Present Situation of Research on Microgrid and Its Application Prospects in China.[J]Power System Technology, 2008,32(16)