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# Dispatching Strategy for New Energy Output Uncertainty

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***Abstract:***

Aiming at the shortcomings of traditional microgrid dispatching, this paper takes wind-light-diesel-storage system as the research object, and puts forward a new energy output composite forecasting model. At the same time, aiming at the uncertainty of new energy output such as wind power and photovoltaic in microgrid, a new microgrid system scheduling model is proposed. Then, the (Load Loss Rate, LLR) and confidence probability are used to evaluate the system model scheduling. The results show that the wind-light-diesel-storage system scheduling model considering the uncertainty of new energy output proposed in this paper can reduce the impact of the uncertainty of new energy output on the system, and this method can effectively balance the economy and security of the system.

***Keywords****: Microgrid, Wind power, Photovoltaic, Uncertainty, Scheduling model.*

## I. INTRODUCTION

In recent years, in some areas where power grid access is difficult, such as mountainous areas and islands, wind power, photovoltaic and other distributed energy sources have gradually become the main means of power supply by virtue of their economic reliability and easy installation. In addition, the establishment of micro grids in areas rich in renewable energy can balance power locally and avoid long-distance transmission. Research shows that a micro grid system composed of multiple distributed energy sources can further improve the energy utilization efficiency of the system after reasonable scheduling [1, 2].

With the gradual popularization of micro-network technology, how to economically and reliably schedule micro-networks has become a hot issue studied by scholars at home and abroad [3]. There are many kinds of micro grid scheduling methods, but most of the scheduling strategies can be transformed into nonlinear programming problems with multiple constraints. For example, in the literature, an in-depth analysis of the output characteristic curve of a diesel engine was conducted and the curve was linearized to propose a multi-time scale micro grid scheduling strategy. Although this strategy can further improve the safety and economy of the system, it does not consider the impact of new energy output uncertainty on the

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system. The literature [4-6] considered the impact of new energy output uncertainty on the system, but ignored the impact of load volatility. The literature [7] analyzed the power output characteristics of the battery and then determined the optimal operation of the micro grid. However, this strategy only considers the economy of the system and does not fully consider the safety and environmental protection of the system. In the papers [8, 9], a robust optimal control is used to schedule the micro grid system based on the uncertainty of the new energy output, and the safety of the system is greatly improved. However, this method requires more economic cost. In reference [10], a model of wind-light-water-fire multi-energy complementary stochastic optimal scheduling is proposed on the basis of the uncertainty of wind and photovoltaic power output, and the model is solved by a mixed integer programming algorithm, however, the solution process is too complicated.

In view of the problems existing in the above scheduling strategy, the wind-light-wood-storage system is constructed in this study. In order to better describe the impact of new energy output uncertainty on the system, a new energy output composite prediction model is proposed.

## II. MATERIALS AND METHODS

### 2.1 Experiment

The structure of the wind-light-diesel-storage independent microgrid system studied in this paper is shown in Figure 1. The electrical load of the system is mainly supplied by wind turbines, photovoltaic arrays, diesel engines and batteries. In addition, wind turbines, photovoltaic arrays, and diesel engines can store excess electricity in batteries.

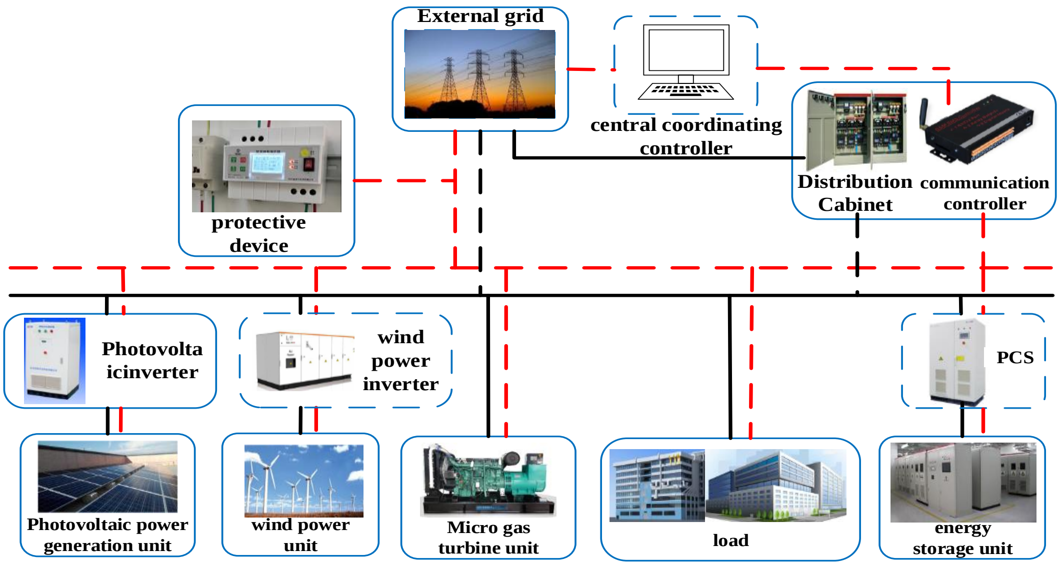


Fig 1: Microgrid structure

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## 2.2 Methods

### 2.2.1 Wind power output mathematical model

(1) Fan output power

Enter the wind speed to make the fan start generating electricity, the rated speed is the one that makes the fan reach the rated power, if the power generation is not satisfied, the output wind speed . The relationship between the predicted output of the fan and the wind speed is shown in formula 1:

$$P_{wt}(t)=\begin{cases} 0 \\ v_f^{\,3}-v_{ci}^{\,3} & v_{ci}\le v_f<v_r \\ P_{\mathrm{r}} & v_r\le v_f<v_{co} \end{cases} \tag{1}$$

where $P_{wt}(t)$ is the predicted output of the fan. $v_f$ is the predicted wind speed. $P_r$ is the rated output power of the wind turbine. $v_r$ is the rated wind speed. $v_{ci}$ is the input wind speed. $v_{co}$ is the output wind speed.

(2) Wind speed probability distribution

Common wind speed probability distributions include Ray Leigh distribution, Weibull distribution, exponential distribution, lognormal distribution, etc. Among them, the two-parameter Weibull parameter can be obtained at any height after obtaining the Weibull distribution parameters of the wind frequency at a certain height. It can be seen that the variation law of wind energy can be better described. Its probability distribution density function is shown in formula 2:

$$f(v_{w,i})=\frac{k_{w,i}}{c_{w,i}}(\frac{v_{w,i}}{c_{w,i}})^{k-1}.\exp[-(\frac{v_{w,i}}{c_{w,i}})^{k_{w,i}}] \tag{2}$$

where $v_{w,i}$ is the wind speed. $k_{w,i}$ is the Weibull shape parameter. $c_{w,i}$ the distribution parameter.

Once the shape and scale parameters are known, the fractional velocity sequence can be fitted. The Weibull cumulative probability distribution is shown in formula 3:

$$F(v_{w,i})=1-\exp[-(\frac{v_{w,i}}{c_{w,i}})^{k_{w,i}}] \tag{3}$$

The expected value and variance expressions of the Weibull distribution of wind speed are shown in formulas (4) and (5), respectively:

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$$u(v_{w,i}) = c_{w,i}\Gamma(1+\frac{1}{k_{w,i}}) \tag{4}$$

$$\delta(v^{w,i}) = c_{w,i}^2\Gamma(1+\frac{2}{k^{w,i}}) - [E(v^{w,i})]^2 \tag{5}$$

Where $\Gamma$. is the Gamma function, which is the mathematical expectation operator. The smaller the variance, the better the stability of the wind speed, and the smaller the randomness of wind power generation.

2.2.2 Photovoltaic output mathematical model

In order to facilitate the calculation, the photovoltaic output is usually regarded as a function of the two variables of ambient temperature and light intensity. As shown in formula 6.

$$P_{pv}(t) = AI\eta_{mpt}\eta_{inv}(1-0.005(t_0+25)) \tag{6}$$

where $A$ is Effective area of photovoltaic panels. $I$ is light intensity. $\eta_{mpt}$ is is the maximum power point tracking efficiency. $\eta_{inv}$ is inverter efficiency. $t_0$ is ambient temperature.

2.2.3 Modeling of energy storage device characteristics

The discharge power of the battery is shown in Formula 7.

$$P_{bat}(t) = \frac{SoE(t+1) - SoE(t)\times(1-\beta_{bat})}{\Delta t\times\eta_d} + \frac{P_c(t)}{\eta_c\times\eta_d} \tag{7}$$

where the $SoE(t)$ is the remaining energy of the battery at time $t$; $P_{bat}(t)$ is the discharge power of the battery at time $t$; $P_c(t)$ is the charging power of the battery at time $t$; $SoE(t+1)$ is the residual energy of the battery at $t$+1; $\eta_c$ battery charging efficiency; $\eta_d$ battery discharging efficiency; $\beta_{bat}$ is the self-discharge ratio of the battery.

2.2.4 Diesel generator fuel consumption model

Diesel generators require diesel fuel to operate. The consumption of diesel oil directly affects the economy and environmental protection. Therefore, in the optimal configuration of microgrid capacity, the focus is on the mathematical relationship between the operating power of the diesel generator and the fuel consumption. Referring to the relevant literature, the fuel consumption has a linear relationship with the output power of the diesel generator. The output power of diesel engine is expressed as follows:

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$$\begin{aligned} &P_{dg}(t)=a_{dg}\times F_{DE} \\ &F_{DE}=c_{f1}P_{DER}+c_{f2}P_{DE} \end{aligned} \tag{8}$$

where the $P_{dg}(t)$ is the output power; $a_{dg}$ is the fuel coefficient of oil extractor; $F_{DE}$ is the fuel consumption, and the unit is L. $c_{f1}$ is the intercept coefficient of diesel generator fuel curve, the unit is L/kW. $c_{f2}$ is the slope of the fuel curve in L/kW. $P_{DE}$ and $P_{DER}$ are the operating power and rated power of the diesel generator, respectively, the unit is kW.

2.2.5 A wind-light-diesel-storage system scheduling model considering uncertainty of new energy output

In the process of microgrid scheduling, the main consideration is the economy, environmental protection and safety of the system. Taking these three characteristics of the microgrid system into consideration, and considering the influence of the uncertainty of new energy output on the system scheduling, the following wind-solar-diesel-storage system scheduling model is constructed.

(1) Objective Function

In order to make the wind-light-diesel-storage system operate more economically, environmentally friendly and safe, the objective function is to take the fuel cost $f_1$, equipment maintenance cost $f_2$ and pollutant treatment cost $f_3$ in one scheduling cycle of the system, namely:

$$\min f = f_1 + f_2 + f_3 \tag{9}$$

$$f_1 = \sum_{t=1}^{24} c_{fuel} \times V_{dg}(\mathrm{t}) \tag{10}$$

$$f_2 = \sum_{t=1}^{24} \left( c_{dg} \times P_{dg}(t) + c_{wt} \times P_{wt}(t) + c_{pv} \times P_{pv}(t) + c_{bat} \times P_{bat}(t) \right) \tag{11}$$

$$f_3 = \sum_{t=1}^{24} V_{dg}(t) \times \left( \gamma_{NO_X} \times c_{NO_X} + \gamma_{SO_X} \times c_{SO_X} + \gamma_{CO_2} \times c_{co_2} \right) \tag{12}$$

where $c_{fuel}$ is the fuel cost, ￥; $c_{dg}$, $c_{wt}$, $c_{pv}$, and $c_{bat}$ are the maintenance cost of diesel engine, wind turbine, photovoltaic array and battery, ￥/kW; $P_{dg}(t)$, $P_{wt}(t)$, $P_{pv}(t)$ and $P_{bat}(t)$ are respectively the output power of diesel engine, wind turbine, photovoltaic array and battery at time $t$, kW; $\gamma_{NO_X}$, $\gamma_{SO_X}$, $\gamma_{CO_2}$ is pollutant emission factor, g/L; $c_{NO_X}$, $c_{SO_X}$, $c_{CO_2}$ is pollutant treatment cost ￥/g.

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(2) Constraints

a. Power Balance Constraints

In order to describe the security of the system, the load loss rate (LLR) and confidence probability $\alpha$ of the system are used as indicators, and the calculation formula of the LLR is as follows:

$$LLR = \frac{E_{loss}}{E_{tot}} \tag{13}$$

where, $E_{loss}$ is the maximum load loss allowed by the system, kW; $E_{tot}$ is the total load of the system, kW. On the basis of considering the system LLR and confidence probability $\alpha$, the power balance constraint of the system is:

$$\Pr\left\{ \frac{E_{tot}(t) - \left( P_{dg}(t) + P_{wt}(t) + P_{pv}(t) + P_{bat}(t) \right)}{E_{tot}(t)} \le LLR \right\} \ge \alpha \tag{14}$$

where $\Pr\{\cdot\}$ is the distribution probability description of the predicted wind power and photovoltaic power.

b. Wind Turbine Output Constraint

$$0 \le P_{wt}(t) \le P_{pwt}(t) \tag{15}$$

where, $P_{pwt}(t)$ is the predicted power of wind power, kW.
c. Photovoltaic Array Output Constraint

$$0 \le P_{pv}(t) \le P_{ppv}(t) \tag{16}$$

where, $P_{ppv}(t)$ is the predicted photovoltaic power, kW.

d. Diesel Engine Output Constraint

$$P_{dg,\min} \le P_{dg}(t) \le P_{dg,\max} \tag{17}$$

where, $P_{dg,min}$ and $P_{dg,max}$ are the minimum and maximum output power of the diesel engine, kW.

(3) Genetic Algorithm Based on Monte Carlo Simulation

Most of the objective functions and constraints in the established wind-light-diesel-storage system

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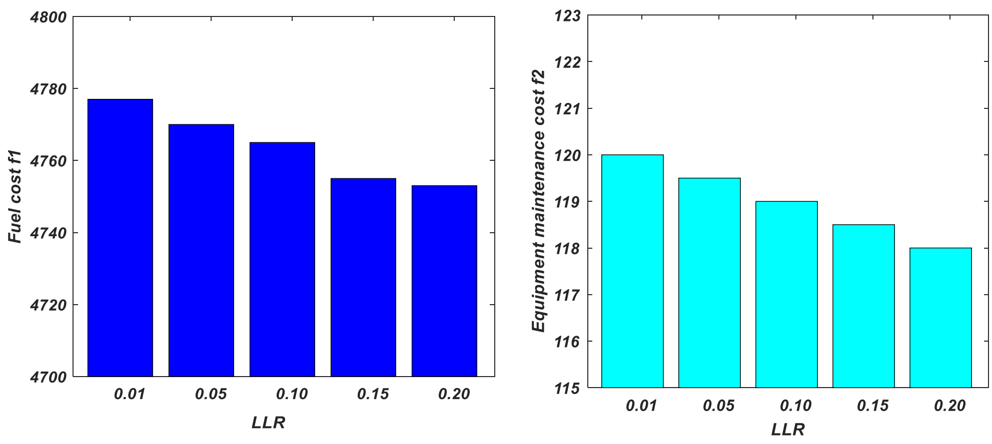
scheduling model are linear and do not need special treatment. Equation 14 is a chance constraint, and a genetic algorithm with Monte Carlo simulation was used to solve the scheduling model.

## III. RESULTS

In order to verify the superiority of the scheduling strategy proposed in this paper, taking Pinghu City, Jiaxing, Zhejiang Province as the research object, the following wind-light-diesel-storage system is constructed, in which the installed capacity of diesel engines is 4×100 kW, and the installed capacity of wind turbines is 6×30 kW, the installed capacity of the photovoltaic array is 120 kW, the capacity of the battery is 300 kW·h, the load missing rate is 0.05, and the confidence probability is 0.99.

### 3.1 Influence of Different Load Missing Rates on Scheduling Results

In order to study the impact of different load missing rates on the scheduling results, the paper sets the load missing rates as 0.01, 0.05, 0.10, 0.15 and 0.20 (confidence probability is 0.99), respectively. The scheduling results under different load missing rates are shown in Fig 2. It can be seen from Fig 2 that with the increase of the load missing rate, the scheduling costs of the system are reduced to varying degrees, but at this time, the improvement of the system economy is at the expense of the system stability. In addition, it can be seen from Fig 2 that in the case of higher confidence probability, the system load missing rate has less impact on the system economy. In the case of a certain confidence probability, the economy and safety of the system can be adjusted in a small range by adjusting the load missing rate.




(a) (b)

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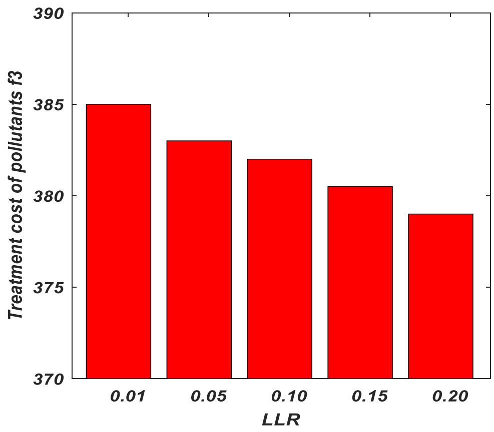
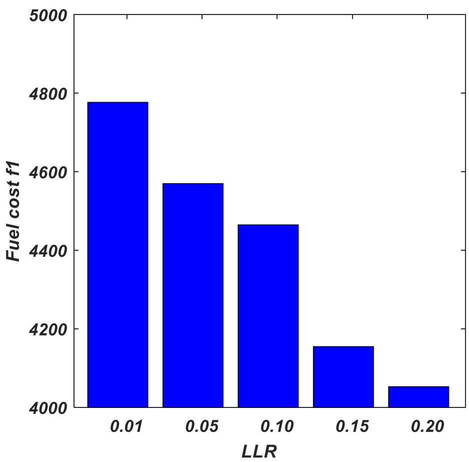



(c)

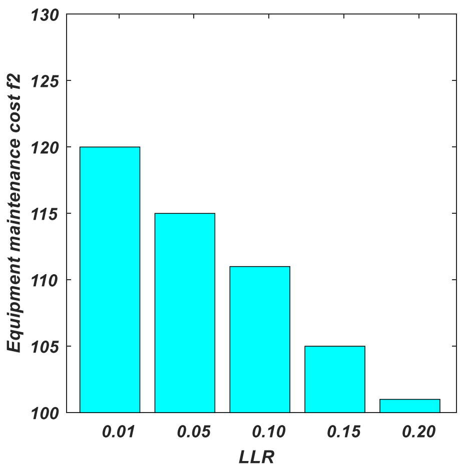
Fig 2. Scheduling results under different composite missing rates. (a) fuel cost; (b) equipment maintenance cost; (c) treatment cost of pollutants.

3.2 Influence of Different Quantiles on Scheduling Results

In order to study the influence of different confidence probabilities on the scheduling results, this paper sets the confidence probabilities as 0.99, 0.95, 0.90, 0.85 and 0.80 (load missing rate is 0.05), respectively. The scheduling results under different confidence probabilities are shown in Fig 3. It can be seen from Fig 3 that with the gradual decrease of the confidence probability, the scheduling cost of the system decreases gradually. Compared with the scheduling costs reduced by different load missing rates, the scheduling costs reduced by different confidence probabilities are more. This shows that the confidence probability can be greatly adjusted in the scheduling process that balances system economy and security.




(a)




(b)

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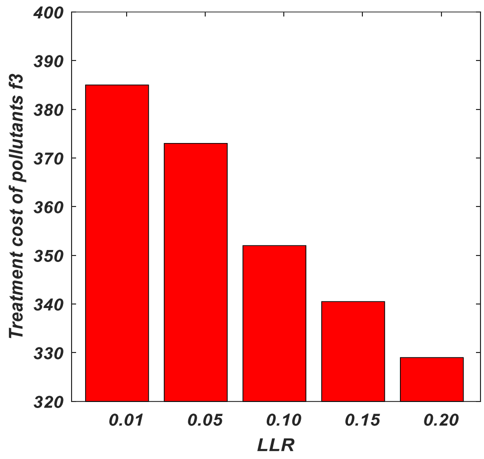
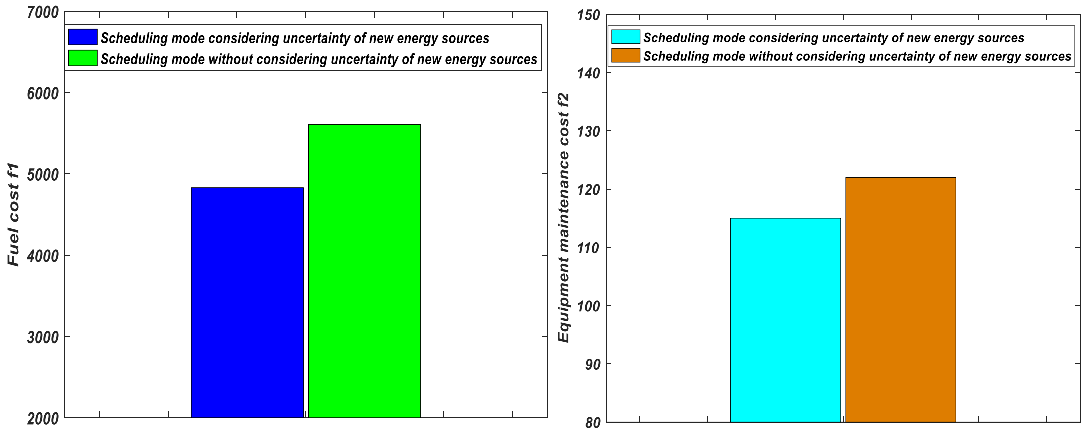



(c)

Fig 3: Scheduling results under different confidence probabilities. (a) fuel cost; (b) equipment maintenance cost; (c) treatment cost of pollutants.

3.3 Scheduling Results of Different Optimization Methods

In order to verify the superiority of this scheduling method, traditional scheduling strategies are selected for comparison. And the method 1 (Scheduling mode without considering uncertainty of new energy sources) is a conventional dispatching method, that is, the uncertainty of the output of new energy sources is not considered, and the load shedding situation does not occur in the dispatching process at this time. Method 2 (Scheduling mode considering uncertainty of new energy sources) is the proposed scheduling method, the load loss rate is 0.01, and the confidence probability is 0.95. The results of the three scheduling methods are shown in Fig 4.




(a) (b)

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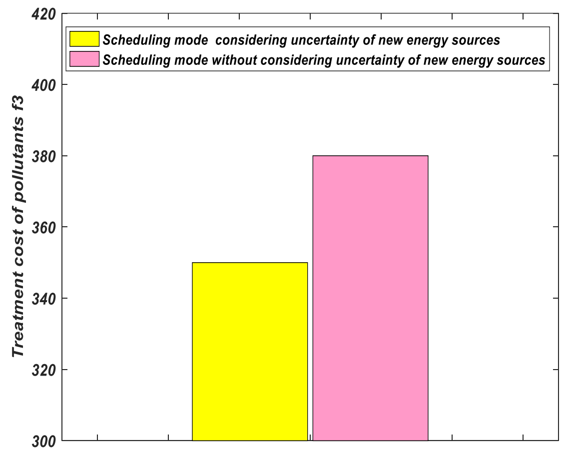


(c)

Fig 4: Scheduling results of two different scheduling methods. (a) fuel cost; (b) equipment maintenance cost; (c) treatment cost of pollutants.

It can be seen from Fig 4 that the proposed method 2 has better economy than method 1. Compared with method 1, the proposed scheduling strategy (Scheduling mode considering uncertainty of new energy sources) is more secure and can further reduce the impact on the system caused by the uncertainty of new energy output.

## IV. CONCLUSION

Based on the comprehensive consideration of the economy, safety and environmental protection of the system, a scheduling model of wind-light-wood-storage system was established considering the uncertainty of new energy output, and the genetic algorithm with Monte Carlo simulation was used to solve the model. The results show that this scheduling strategy can effectively balance the economy, environmental protection and security of the system. At the same time, the effects of load loss rate and confidence probability on system scheduling are analyzed. The superiority of the proposed scheduling strategy is verified by comparing it with other scheduling strategies.

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