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Design of Energy Management System with Electric Power Dispatching and Optimization Management Mechanism

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Abstract: In this paper, we propose an energy management system (EMS) with electric power dispatching and optimization management mechanism that's different from other references which using load-shedding and optimal power scheduling method. Our proposed system prioritizes the positive value of profit within a period of time and provides the optimized data of power usage to the users for having the maximum profit. Firstly, EMS collects data from the database and process energy dispatching according to the simulated result of different season conditions in one year and the corresponding power price of Taiwan Power Company (Taipower). Then, the trading amount with the power grid is regulated to ensure the user's maximum profit. On the EMS dispatching interface, while adjusting the imbalance state of power generated, the trading amount with the power grid is regulated based on the condition of battery storage system. Then, the amount of power generated from every hour, every day and every month are analyzed by EMS to determine which period of time have the largest price difference between the supply and demand. Based on the result after analyzing supply and demand, EMS adjusts the data of the supply and battery storage system then makes an annotation of the analyzed data.

Key words: smart grid, distributed power generation, energy management system

1. Introduction

In recent years, countries around the world have been focusing on developing new energy technologies. Energy conservation and carbon reduction have become the focus of global attention. Many countries with advanced green energy and smart grid development technologies have planned for the development of a low-carbon economy in terms of energy policy and forward-looking targets, so that the green energy development ratio can increase in the whole industry in the country. In the future, smart grids and control technology will be established to improve the situation of electricity consumption, to combine electric equipment with technology, to manage electricity through two-way communication, and to popularize smart grid construction.

About the energy application, many research papers have been proposed features in different technical methods. One method is a Smart Grid Cyber-Physical System (SG-CPS) comprising sensors that link system to predict and analyze and then examine optimization algorithms result in electricity purchasing situation [1]. People could use the energy management controller and received demand response to adjust the system for the architecture of EMS in home based on the smart grid, and then users in the system will find an optimal start time and operating mode for the application in response to the varying electricity prices. The specific coordination function simulations show that the optimization method will result in lower cost for the consumers, lower peak load, and lower load fluctuations [2, 3]. A mixed integer linear

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programming formulation of the optimization problem has been applied because designed for scheduling various types of appliances in area. In addition to the load schedule, the work is devoted to extending the optimization method, including renewable generation sources and different types of loads and storage devices, to solve the electricity demand and power cost price [4]. In the hybrid micro-grid is made up of energy and battery model that explores the battery's response and economical benefit. Based on the state of the battery storage so that chooses the type of battery that is in keeping with micro-grid configuration. The advantage of the method is users mitigate energy waste. Besides, this method shows feasibility of a hybrid microgrid to support intermittent heavy loads, mitigating the demand for a dedicated power system [5].

According to the concept of smart grids, the system integrated into a regional grid in a microgrid form, and the EMS is used to do power dispatch control to record the information generated by the change. The platform interface is set up using MATLAB software and according to the Taipower Company's three-phase electricity costs and transaction prices for renewable energy, the power balance is adjusted and the microgrid power change is simulated through mathematical calculations. By adjusting the power supply state via the EMS, it can reduce costs, make a profit, improve the situation of excessive waste of electricity, and achieve the maximum economic benefit of self-generated power.

2. Architecture of the Proposed EMS

According to the smart grid concept, we learned about the relation between distributed energy, the storage system and the load. In Fig. 1, the PV parameter is P_{e1} = 10 kW, the wind parameter is P_{e2} = 80kW, the battery parameter is P_b = 10 kW, the load parameter is P_L = 100 kW. The simulation data are analyzed with random rate sampling test from actual electricity in Taiwan, and the equations of power output for PV, wind and battery is shown Eqs. (1)-(6).

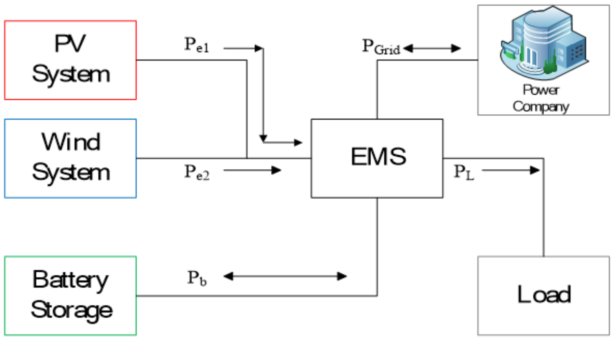


Fig. 1 Architecture for the proposed EMS of microgrid.

$$(P_{e1} + P_{e2}) + P_b \geq P_L \quad (1)$$
$$P_{e1}{}^{min} \leq P_{e1} \leq P_{e1}{}^{max} \quad (2)$$
$$P_{e2}{}^{min} \leq P_{e2} \leq P_{e2}{}^{max} \quad (3)$$
$$SOC = (Qr/Qrated) \times 100\% \quad (4)$$
$$SOC^{min} < SOC < SOC^{max} \quad (5)$$
$$P_{bn} = P_{br} + P_{e1n} + P_{e2n} - P_{Ln},$$
$$n \geq 2, 0 \leq P_{bn} \leq 10kW, P_{br} = 0, P_{br} = 0 \quad (6)$$

The best result is that the total energy supply has always been in excess of the demand in Eq. (1). The PV power capacity range is from 0 to 10 kW in Eq. (2). The wind capacity range is given by Eq. (3). Eqs. (4) and (5) are described battery capacity and condition, besides Q_r and Q_{rared} are remaining and rated capacity respectively. In Eq. (6) is battery power output conditional function.

3. Power Dispatching Control Methodology

In each time, we use the power dispatching algorithm to control the system for distributed energy, storage device and loads. Firstly, the amount of power generated from every hour is analyzed by EMS to calculate the data of variety. By the way, for the supply of energy priority is battery, wind and PV. There are two conditions, the result is selling from oversupply that the system must charge the battery for capacity before the remaining amount of energy is sold. On the other hand, the result of supply doesn't meet the demand, so the system carries out a task of buying as shown in Fig. 2.

The battery supply electricity to the load demand that is given by Eq. (7).

$$P_{xn} = P_{bn} - P_{Ln} \quad (7)$$

$$P_{e1r} = \begin{cases} P_{e1n} & , P_{xn} + P_{e2n} \geq P_b^{max} \\ P_{e1n} - [P_b^{max} - (P_{xn}) - P_{e2n}] & , P_{xn} + P_{e2n} < P_b^{max} \,\&\, P_{xn} + P_{e1n} + P_{e2n} \geq P_b^{max} \\ 0 & , P_{xn} + P_{e2n} < P_b^{max} \,\&\, P_{xn} + P_{e1n} + P_{e2n} < P_b^{max} \end{cases} \quad (8)$$

The parameter P_{e1r} is the remaining amount of energy for PV, according to the condition of battery storage system, wind system and load in Eq. (8).

$$P_{e2r} = \begin{cases} P_{e2n} & , P_{xn} \geq P_b^{max} \\ P_{e2n} - (P_b^{max} - P_{xn}) & , P_{xn} < P_b^{max} \,\&\, P_{xn} + P_{e2n} \geq P_b^{max} \\ 0 & , P_{xn} < P_b^{max} \,\&\, P_{xn} + P_{e2n} < P_b^{max} \end{cases} \quad (9)$$

$$P_{br} = \begin{cases} P_b^{max} & , P_{xn} + P_{e1n} + P_{e2n} \geq P_b^{max} \\ P_{xn} + P_{e1n} + P_{e2n} & , 0 \leq P_{xn} + P_{e1n} + P_{e2n} < P_b^{max} \\ 0 & , P_{xn} + P_{e1n} + P_{e2n} < 0 \end{cases} \quad (10)$$

$$P_{Lr} = \begin{cases} P_{Ln} - (P_{e1n} + P_{e2n} + P_{bn}) & , P_{e1n} + P_{e2n} + P_{bn} < P_{Ln} \\ 0 & , P_{e1n} + P_{e2n} + P_{bn} \geq P_{Ln} \end{cases} \quad (11)$$

The parameter P_{e2r} is the remaining amount of energy for wind, according to the condition of battery storage system and load in Eq. (9). P_{br} is the remaining amount of energy for battery, and that is the energy would not continue to supply charging the battery in the state. Moreover, P_{Lr} is load demand for every state is given by Eqs. (10) and (11), respectively.

According to Taipower offer residential time-of-use power price system on October 2016 version.

(Jun.~Sep., Mon.~Fri.)

$$T_p(x) = \begin{cases} 5.84\text{NT}, 10 \leq x < 12 \,\&\, 13 \leq x < 17 \\ 3.85\text{NT}, 7 \leq x < 10 \,\&\, 12 \leq x < 13 \,\&\, 17 \leq x < 22 \\ 1.71\text{NT}, 0 \leq x < 7 \,\&\, 22 \leq x < 24 \end{cases} \quad (12)$$

(Oct.~May, Mon.~Fri.)

$$T_p(x) = \begin{cases} 3.69\text{NT}, 7 \leq x < 22 \\ 1.65\text{NT}, 0 \leq x < 7 \,\&\, 22 \leq x < 24 \end{cases} \quad (13)$$

(Jun.~Sep., Sat.~Sun.)

$$T_p(x) = 1.71\text{NT}, 0 \leq x < 24 \quad (14)$$

(Oct.~May., Sat.~Sun.)

$$T_p(x) = 1.65\text{NT}, 0 \leq x < 24 \quad (15)$$

About $T_p(x)$ is time of use power price, (x): hr.

(a) PV(6.12NT$/kWh) (b) Wind(2.27NT$/kWh)

Buying fee:

$$T_P(x) \times [(P_{br} - P_{Lr}) + P_{e1r} + P_{e2r}] \quad (16)$$

Selling fee:

$$6.12\text{NT\$/kWh} \times P_{e1r} + 2.27\text{NT\$/kWh} \times P_{e2r} \quad (17)$$

In Eqs. (12)-(15), the user needs to buy the demand of electricity that is in the light of the time-of-use price from Taipower in June to September and October to next May. However, when the result of the battery capacity has met the maximum value, the system is going to calculate the trading price for the power. If the supply and the demand are imbalance, the system must check the value for power dispatching, and then one condition is buying state what get the remaining of the supply and demand, and the other condition is selling state what get the P_{e1r} and P_{e2r}, that total selling fee sum which is the product of P_{e1r} and PV unit fee as well as the product of P_{e2r} and wind unit fee in Eqs. (16) and (17). Finally, the data via calculus of algorithm will show the output waveforms illustrated in the Fig. 3 [13, 14].

Based on the result after analyzing supply and demand, the power dispatching state is shown in Table 1.

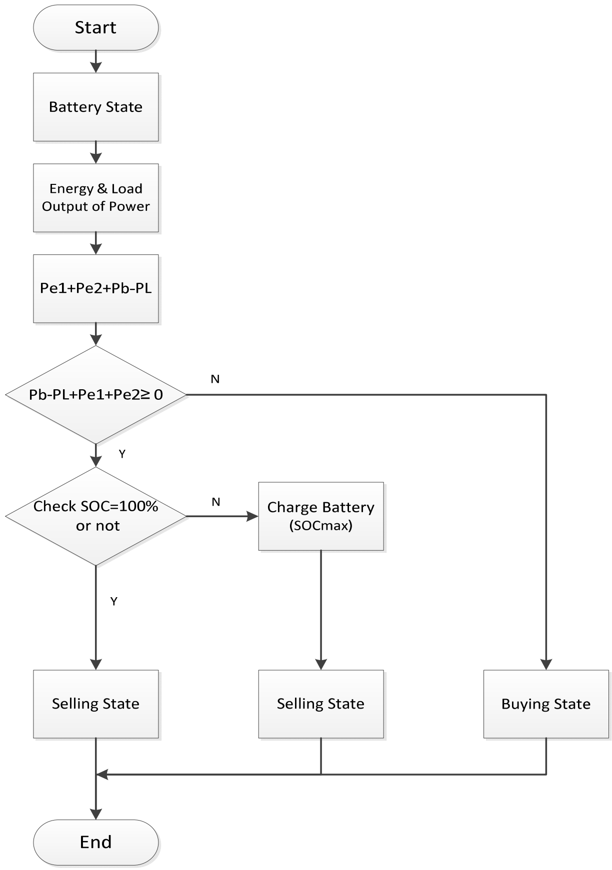


Fig. 2 Process flow diagram of power trading.

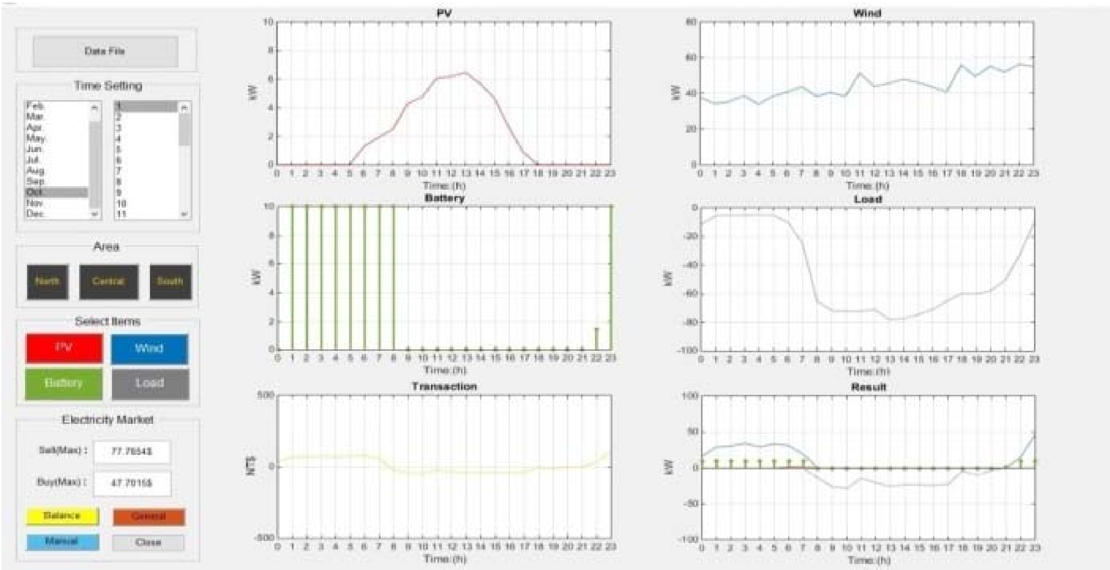


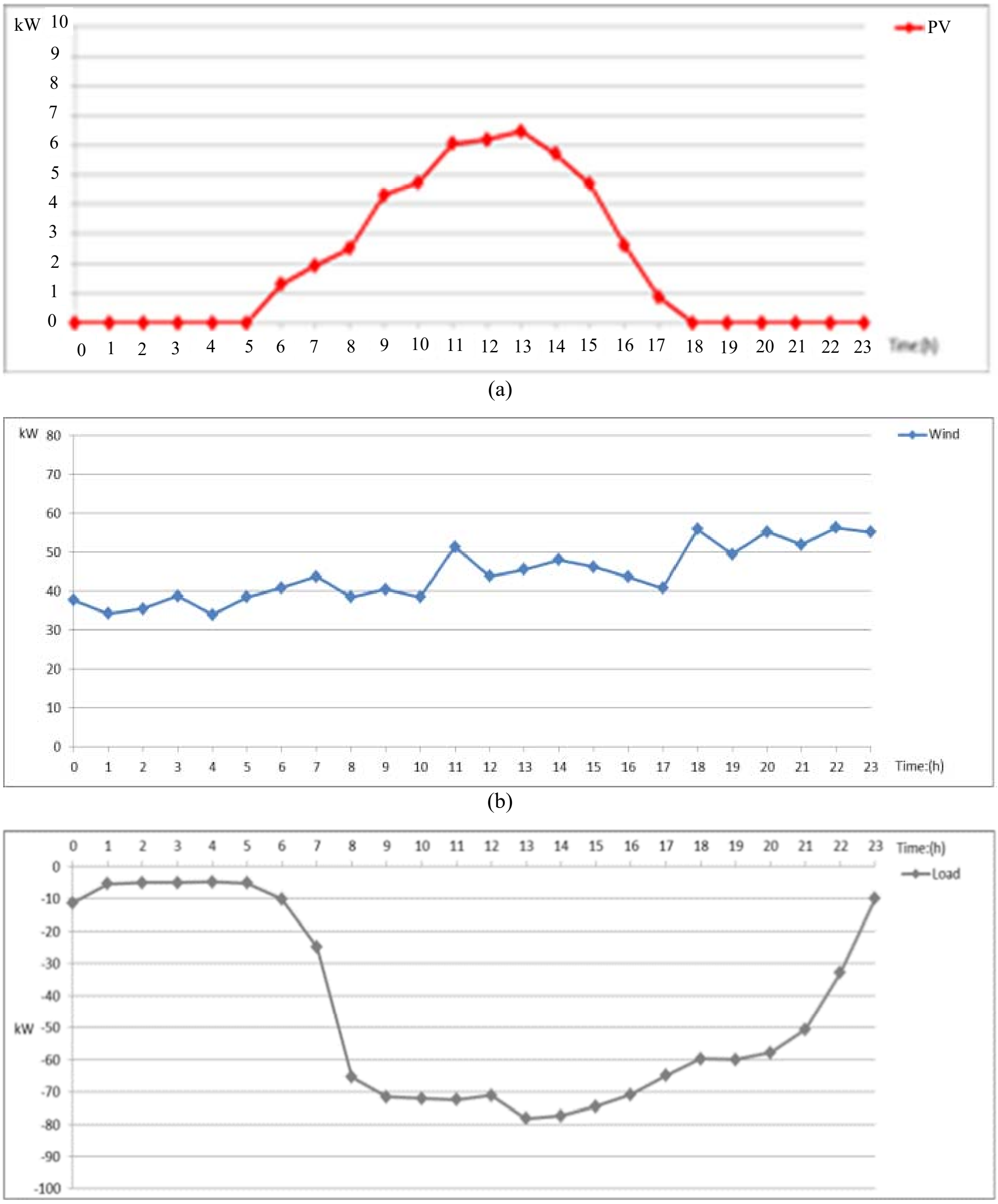
Fig. 3 Control interface of EMS.

Table 1 Supply and demand state of power.

Load / Supply	$P_L > P_{e1}+P_{e2}+P_b$	$P_L = P_{e1}+P_{e2}+P_b$	$P_L < P_{e1}+P_{e2}+P_b$	$P_L < P_{e1}+P_{e2}$
($P_{e1} \leq 10$ kW) + ($P_{e2} \leq 80$ Kw) + $P_b \leq 10$ kW	Buying	Not transacting	Not transacting (charging)	Selling

4. Simulation Results

The simulation in the light of the energy and battery storage system and load's condition of variety, and then the power dispatching calculates the data by EMS that will display the condition of power trading. The system gets the data for PV, wind and the load from every hour in Fig. 4. About state of the battery storage capacity, is representative of the result of supply to load of the discharge, and the result of energy storage are stored in the battery storage system by the wind and PV as shown in Figs. 5-7, the value of power trading is gotten in EMS, after the system calculates the result of total value which includes the residual energy and load.

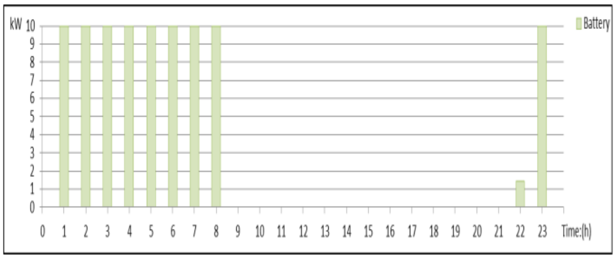


(a)

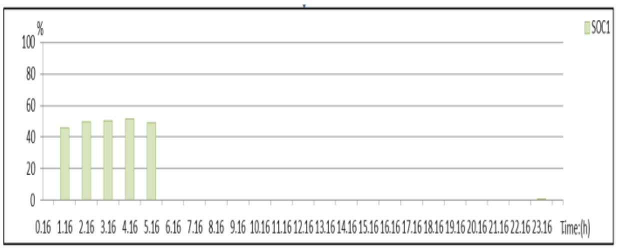
(b)

(c)

Fig. 4 Supply and demand (a) PV, (b) wind, and (c) load.



(a)



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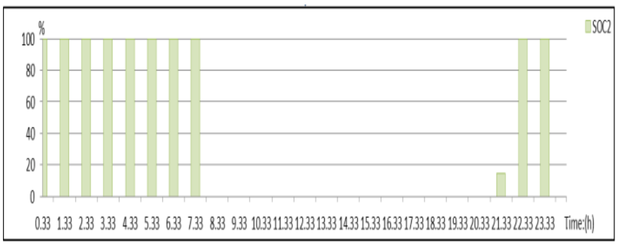

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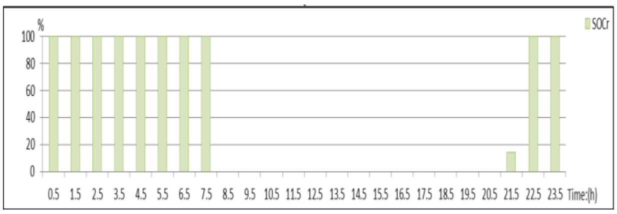
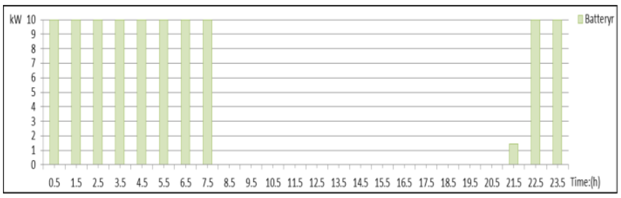


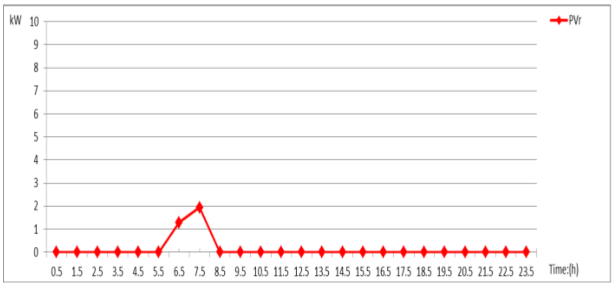
(d)



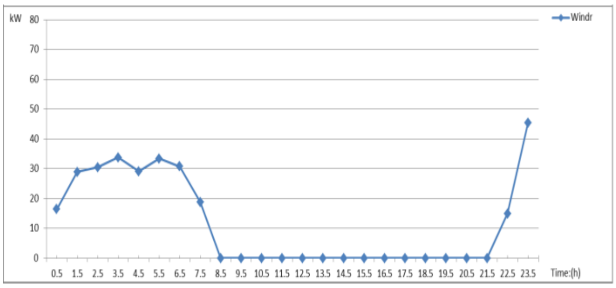
(e)

Fig. 5 State of the battery storage capacity: (a) electricity of the battery, (b) result of supply to load, (c) the result of energy storage for the wind, (d) the result of energy storage for PV, and (e) result of charge/discharge.

In the case of simulation, based on the specifications are recorded for PV, the wind, the battery and load, their parameter is $P_{e1} = 10$ kW, $P_{e2} = 80$ kW, $P_b = 10$ kW and $P_L = 100$kW respectively. If



(a)



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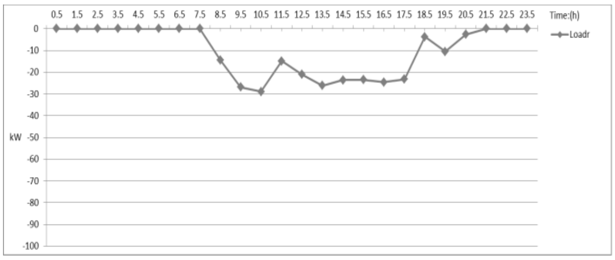

(c)

Fig. 6 The residual power (a) PV, (b) wind, and (c) load.

the power generations are producing more electricity than the load demands during the off-peak time at the same time, the battery has residual values of electricity; the result is the positive value of profit during the off-peak time. At the peak of time, the result is state of selling to get the positive value because it's oversupply. On the contrary, the EMS will prioritize the least price of power electricity which is the supply does not meet the demand. Finally, when the demand far exceeds supply for PV and the wind, we must upgrade the energy level and performance and then the system will balance supply and demand.

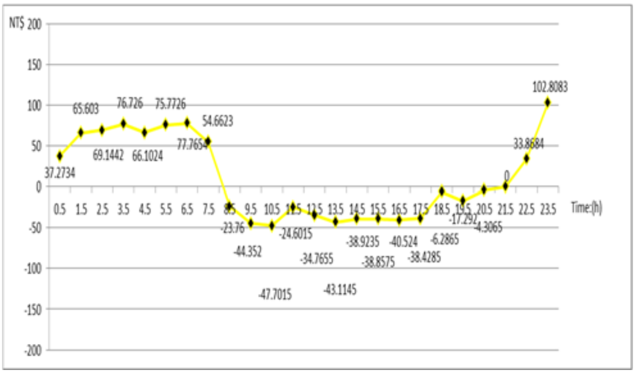

Fig. 7 Power trading price.

5. Conclusion

In the paper, the relationship between the supply of distributed energy and the energy storage device is coordinated to achieve optimum supply operation, and the energy management and dispatch are completed by cooperating with the supply of power demand in the next stage to make a profit from the trading of electric power. It can be verified the feasibility from the system simulation, the conditional configuration of the battery is performed by means of mathematical equations, and then it is judged that earning positive profits is a priority.

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