A study on Distributed Power Control of Laptops

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Abstract

The contract power cost and power facilities of offices are determined by the maximum of power consumption. Therefore, it is very meaningful to cut the peak of power. In this work, we conduct the experiment and simulation to control the power consumption of multiple laptops using decentralized control.

独立分散制御を用いたノート PC の消費電力制御

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オフィスにおいて，契約電力コストや電力設備は，消費電力の最大値で決定される。従って、電力消費のピークカットを行うことは意義深い。本発表では、複数のノートパソコンの消費電力を，独立分散式によって制御した実験結果と数値シミュレーションによって示す。

1 Back Ground

1.1 Objection

Recently we are reconsidered that it is important to save energy and cut power consumption of peak with planned power outage in East Japan Great Earthquake. Power station facility and contract fee can be reduced according to cut power consumption of peak.

In this research, objection is cutting power consumption of peak of laptops in office. For example, at noon, there is time zone that has great power consumption. Power always has facility and fee on condition that power consumption is max. So in this time, if we want to reduce power consumption of laptops, total power consumption will be needed to cut down.

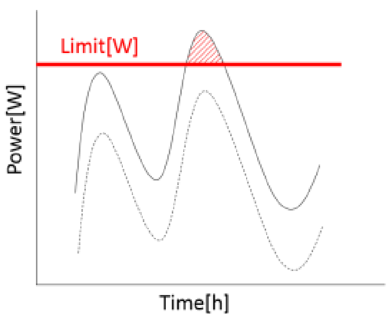

Figure 1 image of peak cut

Figure 1 is image of peak cut of power consumption. Full line is total power consumption and dotted line is total power consumption minus laptops's power consumption. Power consumption surrounded by oblique line reduce in time having highly power consumption, total power consumption can cut down.

1.2 Selection of control way

Deep space probe called "Hayabusa", was asked for distributing power efficiently. Space probe can't be supplied power once launching rocket. It is important to assign power to many heaters. This study's idea comes from space technology.

Control method of Hayabusa was "Sever-Client system". Sever is element of gathering heater information and calculates each power thinking about whole balance. Client is each heater. It needs two way communications and the system has many demerits. These examples write below.

(1) Too much communication time with increasing Client.

(2) Capital investment is high.

(3) Predetermined client can join because power control system is inconvenience to plug in or out.

So it is uncomfortable to use this system in office because there are many PCs and it is impossible to cut off these PCs.

Then in this study, we use "Distributed power control system". This way is that broadcasting sender element called transmitter broadcasts only whole power consumption to each Client. Broadcasted PCs calculate next condition own. For one communication, demerits of Sever-Client control system are eliminated.

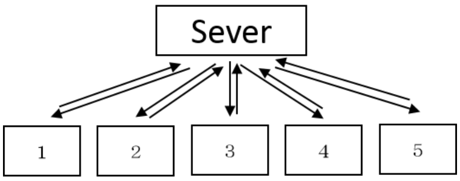

Figure 2 Sever-Client system

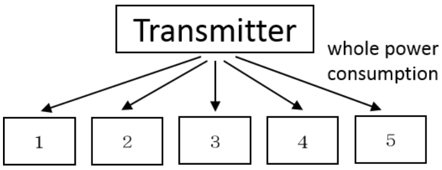

Figure 3 Distributed autonomous system

2 Distributed independence control

2.1 control way

It shows general control way. Figure 4 is block diagram of Distributed independence control. Pt is total power consumption, Pt^* is the limit of total power consumption, and P_i is individual power consumption. The diagram shows Z translation. ΔP is difference between total consumption and the limit, and it is broadcasted and feedback in whole system. System sensibility is *St* and individual priority is Q_i.

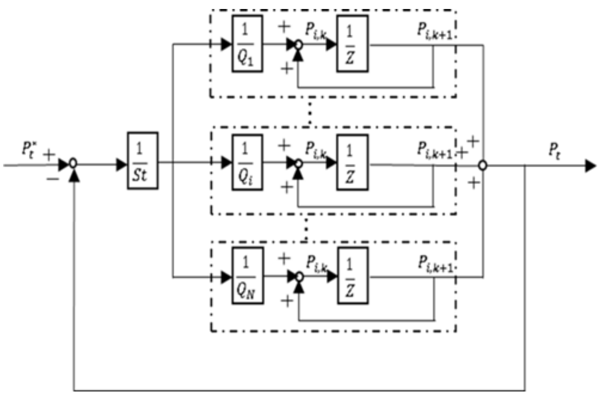

Figure 4 block diagram

2.2 Control system in Note PCs

In office there are many PCs connecting to AC adapter regardless of full battery. These PCs have difference priority that is taking out AC adapter by staying battery. The lower for priority, it can be taken off AC power source. This system aims peak cut of power consumption. No.*k*+1 power is calculated by feedback of No.*k* power. In general, Power's fee and facility are decided moving average of past 30 minutes called power demand. So ΔP is past moving average and *St* is 1.

$$P_{i,k+1} = P_{i,k} - \Delta P * \frac{1}{Q_{i,k}} \quad (1)$$

Priority depends on battery of individual PC and CPU, PCs calculate own. The lower priority is, the higher probability of taking off AC adapter is. The formula shows below. *N* is the imagination number of PCs, *blp*(%) is battery, *CPU* is CPU working rate.

$$Q_{i,k} = \frac{100}{blp_{i,k}} * \left(\frac{CPU_{i,k}}{100} + 0.1\right) * N \quad (2)$$

In particular Note PCs, it is not continuously because of ON-OFF control. So it can't be calculated by (1). This study is used Counter that is unreality figure. Counter's formula shows below.

$$C_{i,k+1} = C_{i,k} - \Delta P * \frac{1}{Q_{i,k}} \quad (3)$$

Counter have border that is C^*. If Counter is lower than these threshold, Note PC will be taken off AC power source. This is OFF.

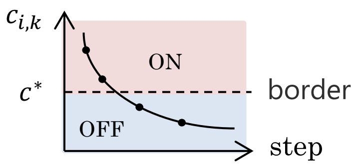

Figure 5 Counter and ON-OFF

Even client determine priority on their own, Stability condition of priority need to be satisfied. We search stability condition as Counter exchanging for power.

$$C_{i,k+1} - C^* = \left(C_{i,k} - C^*\right) - \Delta P * \frac{1}{Q_{i,k}} \quad (4)$$

Arranging (4) formula, it is (5).

$$\delta\Delta_{i+1} = \left(1 - \frac{P}{Q_{i,k}}\right) * \delta\Delta_i \qquad (5)$$

assuming that $Q^{-1} = \frac{1}{Q} K$,

Stability condition is

$$Q_{i,k} > 1 \qquad (6)$$

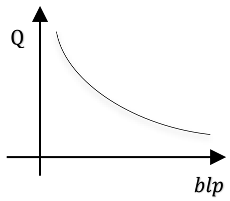

Figure 6 Relationship between battery and priority

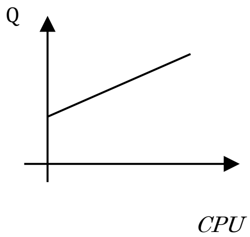

Figure 7 Relationship between CPU and priority

3 Experiment

3.1 Experiment conditions

Experiment is under this condition. There are the 5 PCs, one of them is broadcasting equipment. Others have the limit, thinking transition of total power consumption and battery condition. Each PC connects microcomputer between AC adapter and socket. This structure is that electricity can't be supplied if Counter is lower than threshold automatically.

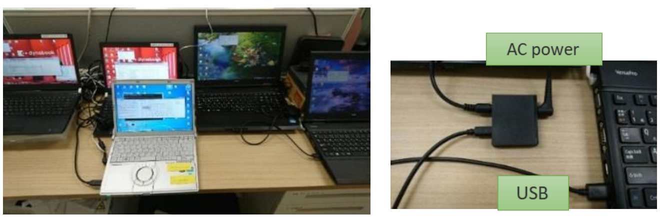

Figure 8 Experiment condition

The purpose of this experiment is that moving average of past 5 seconds is stable. PC usually moves by dummy programs.

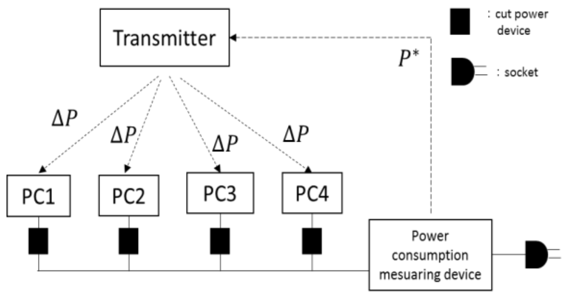

Figure 9 experiment condition

3.2 Experiment result

The experiment was conducted in the following five ways.

Table1 experiment pattern

		initial battery charges [%]	Target [W]
(1)	no control	100	
(2)	control	100	80
(3)	no control	60-100	
(4)	control	60-100	80
(5)	no control	100	65

(1) initial battery charges are 100[%] with no control

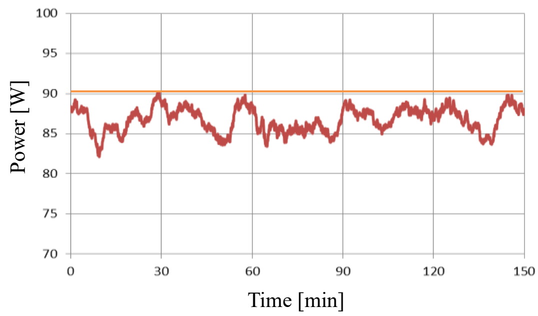

Figure 10 Power consumption (1)

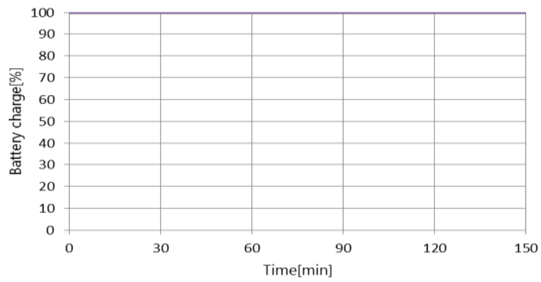

Figure 11 Battery charge (1)

This pattern shows no control. The maximum power is 91[W], and battery charges keep 100[%] by all means.

(2) initial battery charges are 100[%] with control

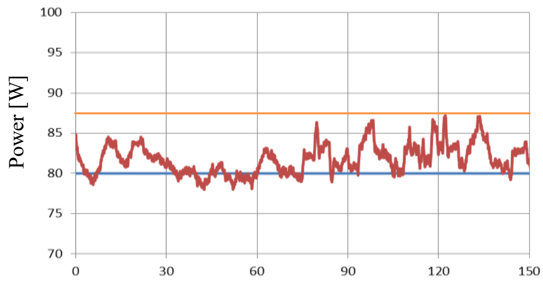

Figure 12 Power consumption (2)

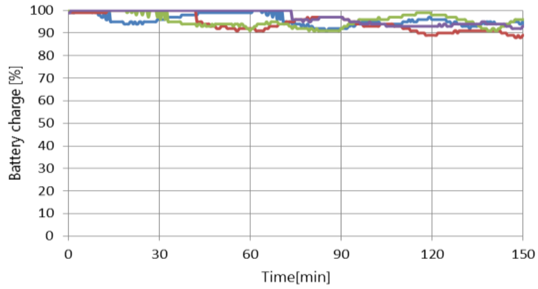

Figure 13 Battery charge (2)

Peak of power consumption decreases 5[w]. Therefore 1[w] decreases per one Note PC, and battery charge settle in one point.

(3) initial battery charges are 60-100[%] with no control

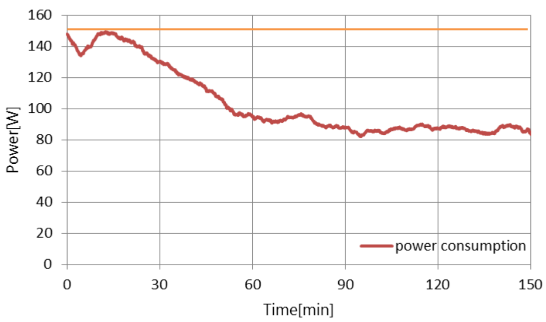

Figure 14 Power consumption (3)

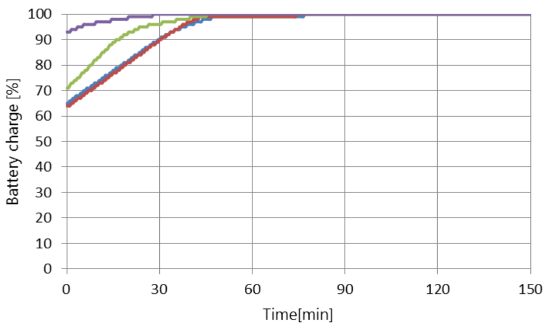

Figure 15 Battery charge (3)

This pattern shows no control with difference initial battery charge. The maximum power is 150[W], and battery charges rise 100[%].

(4) Initial battery charges are 60-100[%] with control

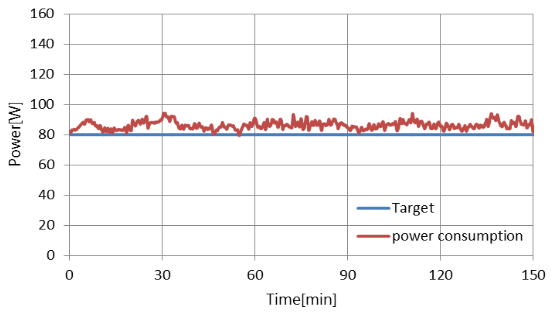

Figure 16 Power consumption (4)

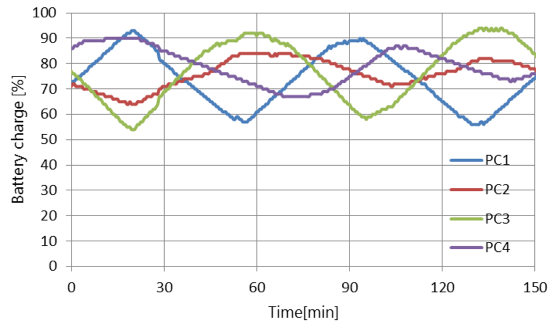

Figure 17 Battery charges (4)

Power consumption is controlled near target power consumption. Battery charges vibrates within the range from 50 to 90[%].

(5) initial battery charges are 100[%] with no control

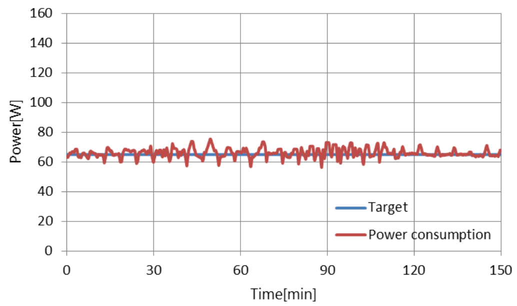

Figure 18 Power consumption (5)

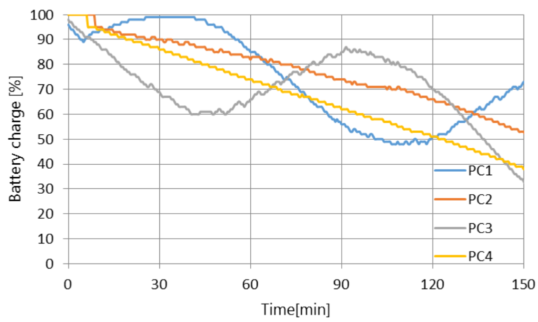

Figure 19 Battery charges (5)

The target power consumption is 65[W]. Power consumption settles in the target. Since each device decides on ON and OFF while considering the priority, the charge amount never decreases by only one.

4 Simulation

Simulation condition shows below.

Table2 simulation condition

The number of Note PCs	100
Target power [W]	1620
Each Note PCs power consumption [W]	12～15

Power consumption and CPU rate of operation are defined as random. Simulation results shows below.

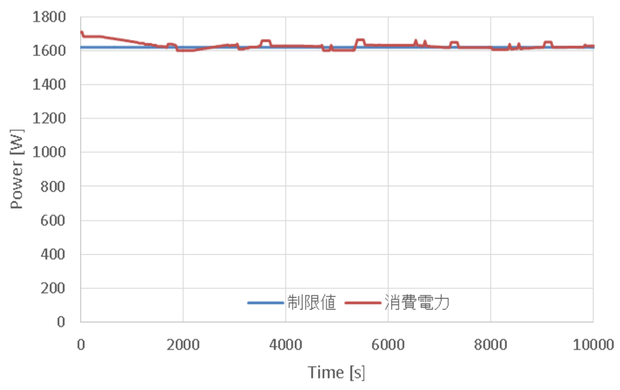

Figure 20 Power consumption

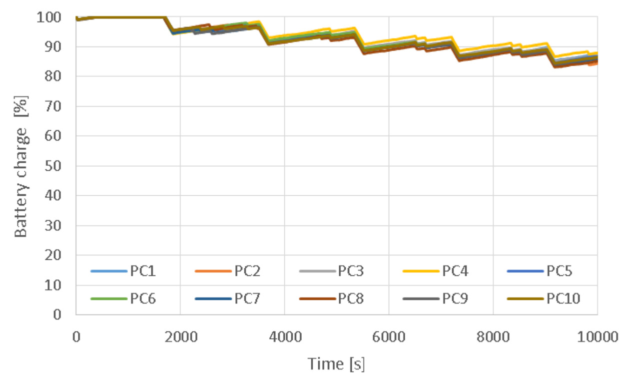

Figure 21 Battery charge

Power consumption settle in target like 4 Note PCs.

5 Conclusion

We attempt that power consumption of Note PCs is under control by limit by distributed individual control. We show that power consumption is stable by limit by experiment and simulation.

If it has limit, it can maintain charge of battery in good order.

6 Reference

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3. Oki, Yusuke, Tomoyuki Ogawa, and Junichiro Kawaguchi. "Train Power Demand Control Using Decentralized and Parallel Control Scheme." IEEJ Journal of Industry Applications 6.6 (2017): 482-489.