Development of Demand Controller Using Power line

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Abstract

In this paper, an intelligent demand control system was introduced. This system are composed of demand controller, RTU, power line modem and HMI program. The proposed demand controller was capable of synchronizing with watt-hour meter recommended by KEPCO(Korea Electrical Power Corporation). To control remote loads, network function using powerline communication is implemented in RTU with HMI program and novices are able to operate system easily. Additionally using the power line, the cost and time of installation can b saved. The system performance was proved with a several experiments.

1. Introduction

Recently according to economic growth and rise of a living standard, energy demand is increased rapidly.
Because of investment, space of power generator and environmental problems, demand power management is more complex.
The increase of power supply capacity as well as demand power management are more necessary nowadays.
The demand controller (the maximum demand power management system) is an equipment for demand power management. The demand controller watches and predicts the variable maximum power consumption per hour.
When the contract power will be expected to exceed, the demand controller sounds an alarm and turns off the temporary loads in turns. And then power consumption is maintained under the maximum demand power level.
The RTU is developed for controlling the remote loads. The RTU receives the control commands generated in demand controller, and then controls loads.
Especially, in this papehe power line cables are used for communication between the demand controller and the RTU .
Power line communication method which is coupled the high frequency communication signal with a power line is adapted. In this paper, the power line communication to control loads is introduced and is installed in distribution line.

2. Main discourse

2.1 Demand controller

80C196KC which is 16bit μ -controller is used for proposed demand controller. Measured voltage and current from sensors are filtered and transmitted to A/D converter of μ -controller. Watt-hour is calculated with these data in μ -controller. The demand controller performs the demand power management with demand management program, and then displays many measurement values such as communication condition, loads condition etc. The block diagram of demand controller is shown in Fig.1.

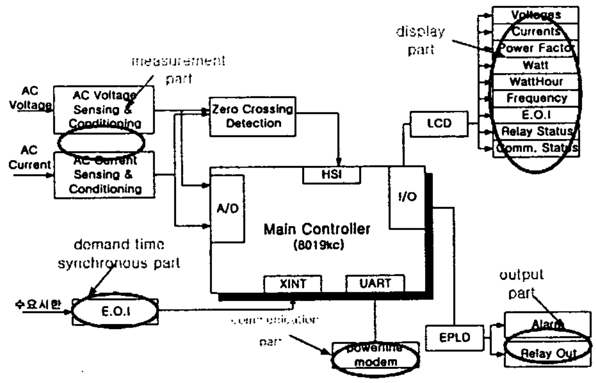


Fig. 1 Block diagram of demand controller

In this paper, demand controller has the following characteristics:
To reduce the calculation error between demand controller and Korea Electric Power Corporation watt-hour meter, the synchronization of demand time is prerequisite.
For exact measuring, the low pass filter reduces the noise of voltage and current acquisited from the input sensor. Also for reducing the error, power calculation algorithm and compensation algorithm are developed
A communication part communicates to RTU with power line modem, PC with RS-232C and demand controller has output part to control the relays.

2.1.1 Basic theory

The basic principle of demand controller is to maintain the maximum demand power during demand time. When average power exceeds a maximum power, loads are turned off during a rest demand time.
Residual power $P_r[kW]$ is the power that present power is subtracted from contract power.
A adjustment power is the different value between present power and residual power.
Maximum demand power $P[kW]$ is the value that is divided power consumption into demand time. The

demand controller predicts the power consumption. Maximum demand power is described in eq.(1).

$$p[kW] = \frac{consumption\ power(Kwh)}{demand\ time} = \frac{Q}{T} \quad (1)$$

The demand controller calculates a power consumption during one sampling time using the acquisition data from CT(current transformer) and PT(potential transformer). Rate of power consumptionΔ $Pa[kW]$ is described in eq.(2).

$$\Delta Pa[kW] = \frac{\Delta Q}{\Delta t} \quad (2)$$

A preestimated maximum demand power(Pu) is sum of present consumption power and following power from present time till last time.

Present watt-hour (Qt) and preestimate watt-hour (Qu) are calculated in eq.(3), (4)

$$\begin{aligned} Qu[kWh] &= Qt + Pa(T-t) \\ &= Qt + \frac{\Delta Q}{\Delta t}(T-t) \end{aligned} \quad (3)$$

$$Pu[kW] = \frac{Qu}{T} \quad (4)$$

An adjustment power $Pc[kW]$ is power that demand power maintains with the below contract power.

A adjustment power is calculated in eq.(5).

$$Pc[kW] = \frac{Qu - Qs}{(T-t)} \quad (5)$$

Contract watt-hour is maximum power consumption during demand time. Residual watt-hour(Qr) is the watt-hour that present watt-hour (Qt) is subtracted from contract watt-hour. Residual watt-hour(Qr) is calculated in eq.(6).

$$\Pr[kW] = \frac{Qr}{(T-t)} = \frac{Qs - Qt}{(T-t)} \quad (6)$$

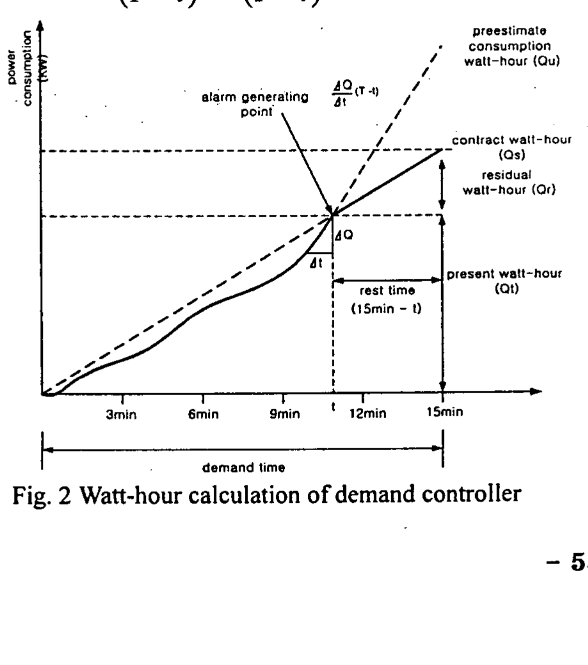


Fig. 2 Watt-hour calculation of demand controller

Fig.2 shows maximum watt-hour, power consumption and preestimated maximum watt-hour.

2.1.2 Loads management & warning system

A priority method is chosen for load control. If power consumption exceeds a contract power, the demand controller sounds an alarm and then turns off loads in turns.

Procedure of warning system is two step.

At the first step, warning system sounds an alarm when loads power exceeds residual power.

And the second step, warning system sounds an alarm when loads are controlled.

2.1.3 Structure of system

Fig.3 shows an architecture of whole system.

This system divides into four parts which are HMI program, demand controller, RTU, power line modem. A HMI program provides the function of report, printing, control and statistics. And the program watches demand power and controls loads power.

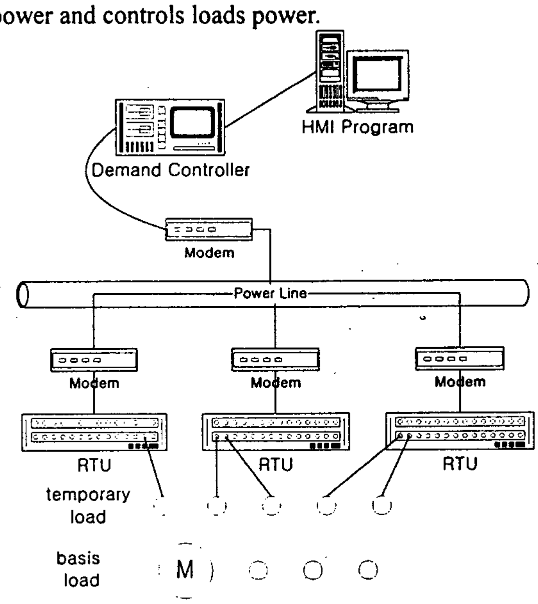


Fig. 3 Architecture of whole system

Whole system is controlled by demand controller. Demand controller makes a packet and send it to other unit for controlling loads. A power line modem controls data signal. RTU receives the command signal of demand controller and controls loads.

2.2 RTU(Remote Terminal Unit)

Signal lines must be installed from demand controller to remote loads in convention system, so the system has disadvantage of high installation cost.

In this paper, RTU is developed so as to save cost and the demand controller sends control signal to RTU for controlling loads and the RTU controls load sharing directly.

The block diagram of RTU is shown in Fig.4.

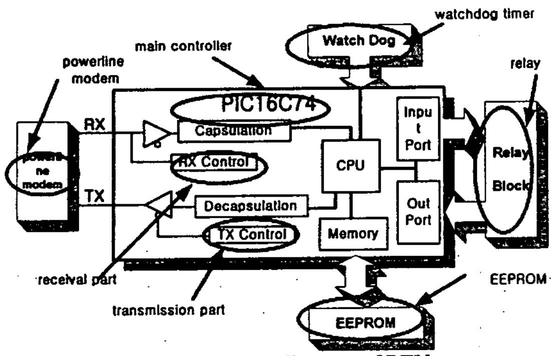


Fig.4 Block diagram of RTU

The RTU which is installed nearby remote loads is the agent of the demand controller. The RTU is connected with the demand controller through the power line modem. Because of using power line communication, the system cost can be decreased.

The RTU board is consisted of PIC16C74 which is 8-bit μ -controller, so the board can be designed with low cost. And EEPROM is used for storage of important information in this system. A watch dog timer watches the system for stable operation.

The RTU watches the state of loads and controls load sharing. The RTU sends informations of various load state to demand controller through power line.

2.3 Power line modem

The block diagram of power-line modem is described in Fig.5.

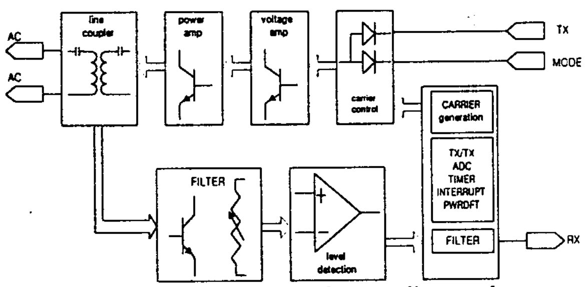


Fig.5 Block diagram of power line modem

Micro-controller generates carrier frequency and the signals of Tx(transmission) and Rx(reception) are controlled by MODE pin state. The power line modem is consisted of three parts which are line coupler, modulation part and signal amplifier.

Line coupler is used for coupling control and data signals with AC power line. Modulation part converts a digital signal to analog signal. FSK modulation is used for converting digital signal to analog signal.

The digital signal is amplified to 15V analog signal with amplifier.

2.4 HMI program

We developed the program that is monitoring, controlling, and storing the every measurement values. We noted the program HMI program which is based on the GUI. This program is loaded in PC and the PC is connected to the demand controller with RS-232C.

We developed the MHI program with visual basic/control. SQL server is used for storing and reporting data.

User can check the every information status through tool bar easily.

Fig.6 describes the main window of HMI program.

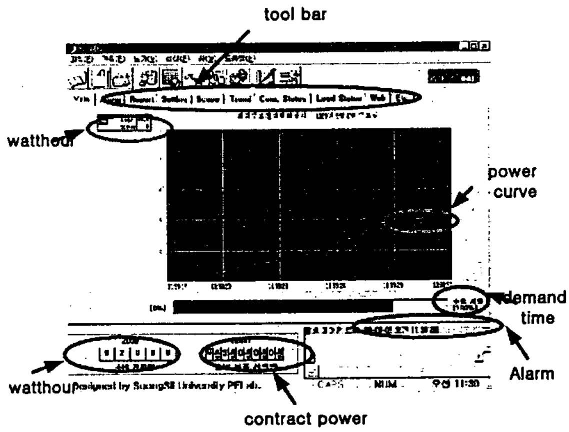


Fig.6 Main window of HMI program

3. Result of experiment

Fig.7 shows the graph that loads are added during the operation. The first broken point shows that loads are added and the second point shows that loads are controlled.

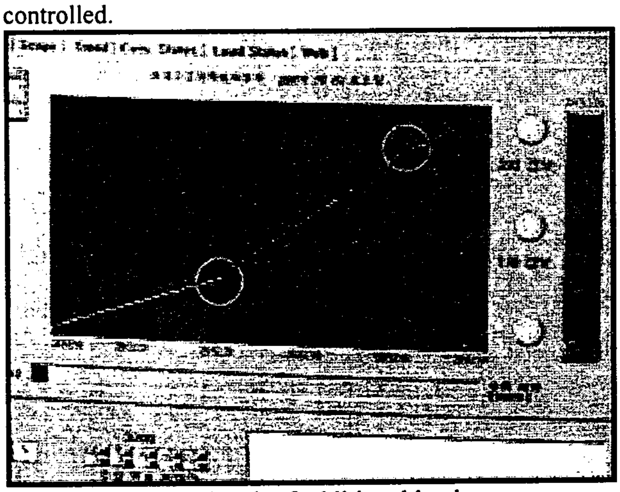
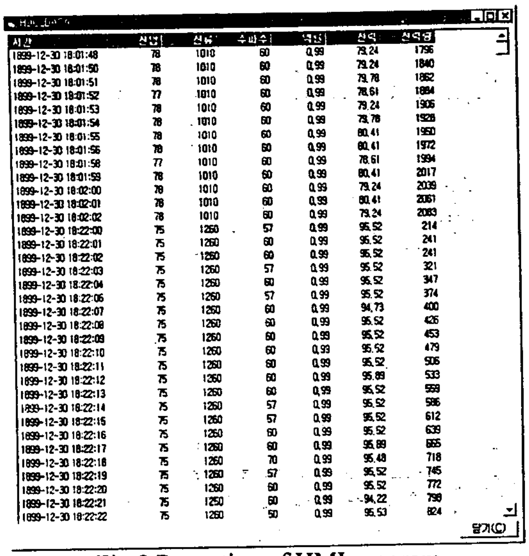


Fig.7 Graph of additional loads

Fig.8 shows the reporting function of HMI program is of the values of voltage, current, frequency, power factor etc.



시간	[illegible]	[illegible]	주파수	[illegible]	[illegible]	[illegible]
1899-12-30 18:01:48	78	1010	60	0.99	79.24	1796
1899-12-30 18:01:50	78	1010	60	0.99	79.24	1840
1899-12-30 18:01:51	78	1010	60	0.99	79.78	1862
1899-12-30 18:01:52	77	1010	60	0.99	78.61	1884
1899-12-30 18:01:53	78	1010	60	0.99	79.24	1906
1899-12-30 18:01:54	78	1010	60	0.99	79.78	1928
1899-12-30 18:01:55	78	1010	60	0.99	80.41	1950
1899-12-30 18:01:56	78	1010	60	0.99	80.41	1972
1899-12-30 18:01:58	77	1010	60	0.99	78.61	1994
1899-12-30 18:01:59	78	1010	60	0.99	80.41	2017
1899-12-30 18:02:00	78	1010	60	0.99	79.24	2039
1899-12-30 18:02:01	78	1010	60	0.99	80.41	2061
1899-12-30 18:02:02	78	1010	60	0.99	79.24	2083
1899-12-30 18:22:00	75	1260	57	0.99	95.52	214
1899-12-30 18:22:01	75	1260	60	0.99	95.52	241
1899-12-30 18:22:02	75	1260	60	0.99	95.52	241
1899-12-30 18:22:03	75	1260	57	0.99	95.52	321
1899-12-30 18:22:04	75	1260	60	0.99	95.52	347
1899-12-30 18:22:06	75	1260	57	0.99	95.52	374
1899-12-30 18:22:07	75	1260	60	0.99	94.73	400
1899-12-30 18:22:08	75	1260	60	0.99	95.52	426
1899-12-30 18:22:09	75	1260	60	0.99	95.52	453
1899-12-30 18:22:10	75	1260	60	0.99	95.52	479
1899-12-30 18:22:11	75	1260	60	0.99	95.52	506
1899-12-30 18:22:12	75	1360	60	0.99	95.89	533
1899-12-30 18:22:13	75	1260	60	0.99	95.52	559
1899-12-30 18:22:14	75	1260	57	0.99	95.52	586
1899-12-30 18:22:15	75	1260	57	0.99	95.52	612
1899-12-30 18:22:16	75	1260	60	0.99	95.52	639
1899-12-30 18:22:17	75	1260	60	0.99	95.89	665
1899-12-30 18:22:18	75	1260	70	0.99	95.48	718
1899-12-30 18:22:19	75	1260	57	0.99	95.52	745
1899-12-30 18:22:20	75	1260	60	0.99	95.52	772
1899-12-30 18:22:21	75	1250	60	0.99	94.22	798
1899-12-30 18:22:22	75	1260	50	0.99	95.53	824

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Fig.8 Reporting of HMI program

Fig.9 shows the internal and external figure of the proposed demand controller system.

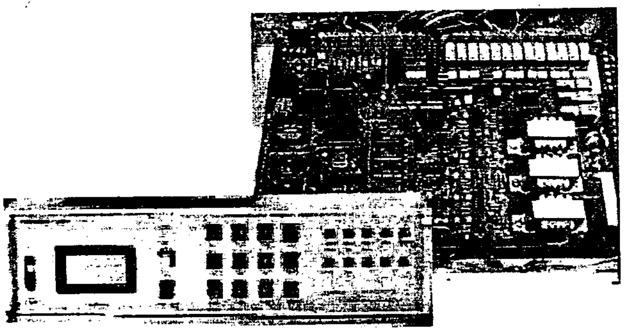

Fig.9 Figure of demand controller

4. Conclusion

We developed the demand controller with predictable function and accurate watt-hour calculation function. The accurate watt-hour calculation is performe with synchronization of demand time provided with KEPCO watt-hour meter.

For decreasing the system cost, power line modem was used and then effective load control was performed.

Using the HMI program, it was possible that remote loads were controlled in central computer.

And we can prove that this system can be applied to other remote control systems such as UPS, emergency power generator etc,

Reference

[1] A.J. Hoffman, "Peak Demand Control in Commercial buildings with target peak adjustment based on load forecasting," IEEE ICCA Conf., pp 1292-1297, 1998.

[2] Andres Fortino, " Networking Technologies" McGraw-Hill, pp.267～299 ,1996

[3] Fred Halsall, " Data Communications, Computer Networks and Open System," Addison Wesley, pp.62～70, 1995

[4] J. R. Jordan, "Serial Networked Field Instrument-ation," John Wiley & Sons, 1995

[5] Andres Fortino, Arnold Villeneuve, "Networking Technologies", Mcgraw-Hill, 1996

[6] Fred Harsell, "Data Communications, Computer Networks and Open Systems ", pp.769

[7] T.Esmailian, P.G. Gulak, and F.R. Kschishcang, "A discrete multitone power line communications system" IEEE pp 2953～2956, 2000.8