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Novel Concept for HEMS Apparatus

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Abstract

HEMS (Home Energy Management System) is widely recognized as the useful technology for saving energy. On the other hand HEMS is never influenced around common people. The reason is supposed coming from following three points. 1. High initial cost, 2. Location dependence (The present HEMS is mounted into the wall), 3. Personal unconcern for energy saving. Then I introduce the novel concept for HEMS apparatus . The idea is introducing sensor network technology taking place of the conventional wired system. In addition to that, by introducing energy harvesting technology into the power source of sensor network nodes, each node can continue to work without battery or AC power supply cable.
In order to examine this new idea, following step by step study procedure is necessary.
At first to examine the validity of sensor network HEMS, secondary to estimate consuming energy amount by using sensor network HEMS, thirdly to proof the continuity working sensor network node without battery.
Then we've described above study procedure in the case of using solar cell in this paper. Still we've added future perspective for using many kinds of energy harvesting (thermal, vibration, wireless power transmission).

Keywords: HEMS, sensor network; energy harvesting; wireless power transmittans; solar cell; Peltie element; viblation

1. Introduction

HEMS is the very useful technology for saving energy. On the other hand, it does not spread for all people at present. Then we analyze the reason for that and we've arrived at the following conclusion.

(1) High initial cost
(2) Location dependence (The present HEMS is mounted into the wall).
(3) Personal unconcern for energy saving

For overcoming those problems, we've propose following novel concept for HEMS apparatus.

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The concept is introducing sensor network nodes taking place of the conventional wired HEMS. In addition to that, the other concept is to introduce energy harvesting into the power source of sensor network nodes. As the results each sensor node can continue to work without battery or AC power cable. This novel HEMS will overcome the three problem inherent in conventional HEMS, because sensor network can be used for many kinds of object (human care, security, safety) except for saving energy, and sensor network node becomes location free, resulting in free from the installing construction.

In this paper we'll show the validity and future potential about our novel concept.

2. To examine the validity for sensor network HEMS

At first, we've developed the sensor network for HEMS. The job sequence of this sensor network system is following (Fig.1).

(1) To sense the room temperature, humidity, illumination, human motion, self power status (Voltage at the capacitor) at the end node, after that, to transmit those data toward the coordinator (router) node.

(2) In the router node, consuming energy is measured and the parameter by which we want to control electrical appliance (room light, air conditioner, and so on) in account for saving energy is derived using these data. And that control parameter is transmitted toward the end node.

(3) In the end node, the control parameter is received and transmitted toward the electrical appliance.

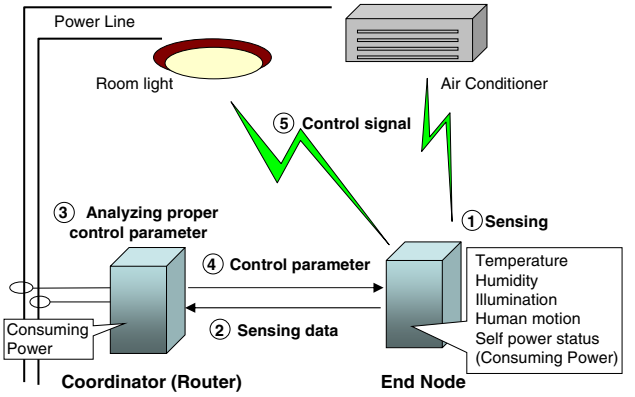

Fig.1 Job sequence for sensor network HEMS

In this system more than two sensor network node are used. Data communication between each node is used for blue tooth and appliance control signal is used for infrared data communication.

As the basic concept Coordinator and End Node has the same function except for data communication role is different (S/R).

Then the construction of each module is almost the same.

In common case the consuming power measurement is performed at the Coordinator side because such measurement points are usually concentrated at a certain place.

The block diagram and photograph of the sensor network HEMS are shown in Fig.2 and Fig.3.

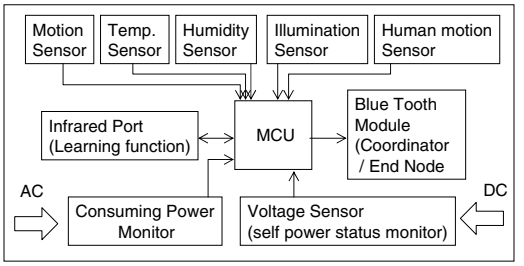

Fig.2 Block Diagram for Sensor network HEMS node

Fig.3 HEMS Module Photograph (80X80X110mm)

Using above module, simple measurement is performed

MEASUREMENRT

Energy saving value is measured by controlling the intensity of the light illumination referring to human existence in gradually wide area. (Because this system can be placed wherever one want to set.)

In this example room light and desk light control is performed with two HEMS module.

The control rule is that the light brightness is growing or reduced under consideration of the distance between person and the room or desk light regarding with the time by time information of every human motion sensors in the room.

The person go and back between desk and shelf frequently for 100 sec. Consumption power is monitored by each End Node. (In this measurement we've used the Personal Computer for the arrangement of the data via serial port sent by Coordinator.)

As the result the consumption power is reduced about 33% in this measurement. This result shows we can reduce energy consumption if we can set the monitoring system everywhere we want to watch at any time. The validity for sensor network HEMS can be clarified in this measurement.

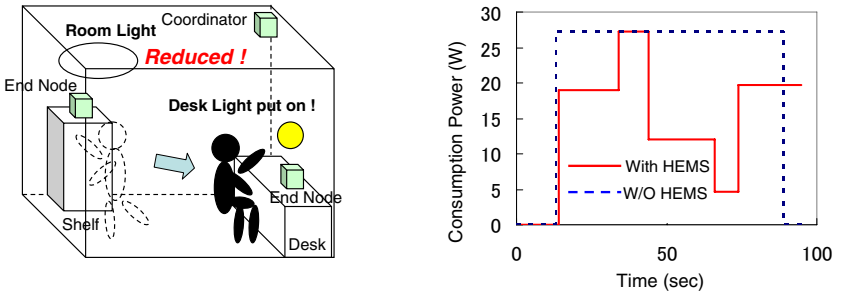

Fig.4 Measurement with sensor network HEMS module and result

3. To proof the continuity working for battery-less sensor network HEMS

We have to manage the energy in order that sensor network node can continue to work without battery or AC power supply via the cable.

(1) HEMS modeling

HEMS is categorized for each function. If we choose poor application HEMS (only energy consumption monitoring), the consumption energy for node is small, but if we choose rich application such as human motion tracking or continues data acquisition, the node needs much energy.

Model	Power(mW)	T(ms)	1	2	3	4	5	6		
Sleep	4.50E-03	—								
Comm.	42	3								
RF	22.5	30								
Temp. Sens.	22.5	1	○	○	○	○	○	○	○	○
Moist. Sens.	0.073	8000		○	○	○	○		○	
Illumi. Sens.	22.5	1	○	○	○	○	○	○	○	○
Motion Sens.	0.002	—	○	○		○	○		○	Location
Door Sens.	22.5	1	○	○		○	○		○	
Acc. Sens.	21.6	1000						○		○
Vital Sens.	10.1	1000			○			○		○
Used Pow Mon	43.5	10		○		○	○		○	
Control	200	24				○	○		○	
Comm times			1	1	1	2	2	3	2	30
Moni./Ctrl			Moni.	Moni.	Moni.	Ctrl.	Ctrl	Moni.	Ctrl	Moni.
Fix/Mov.			Fix	Fix	Mov.	Fix	Fix	Mov.	Fix	Mov.
Duty(min)			30	10	30	10	10	30	3	30
Ave. used Pow (μW)			6.98	9.65	10.91	18.98	18.98	23.47	48.10	35.49

Table1 Consumption power of sensor network node for each HEMS

Then we've modeled HEMS situation and summarized consumption power with sensor node for each HEMS model (Table1).

From model 1 to 3, HEMS is categorized as "Monitoring HEMS", and from model 4 to 6 HEMS is categorized as "Control HEMS". Control HEMS mean the controlling appliance referring to monitoring data. "Fix HEMS" or "Movable HEMS" means locating at any place or put on with human body for getting the vital and 3D vibration information.

The following results are clarified that Model 1 has the smallest energy consumption less than 10uW, and if we choose more than level 4 HEMS, at least 20uW is necessary (for Fixed node).

As the first trial we've tried to make Model 1 HEMS sensor nodes and examine whether those sensor nodes can continue to work under common life condition.

(2) Feasibility Study for HEMS sensor nodes with energy harvesting

We've designed the lasting workable sensor nodes referring to 10uW energy consumption.
The sensor node consumes power conditioning loss (regulator loss) in addition to above HEMS consumption power. This loss is relative large in this small energy [uW] region. More over we have to consider the leak current with Capacitor. Under all consideration we have to get average power more than 35uW from somewhat energy harvesting. Now we select amorphous-Si solar cell because amorphous –Si solar cell has high efficiency even under low illumination status. By using the solar cell as AM1815 (SANYO) (45mmX56mm) under 500lux, 11%duty (ref. Fig.6) condition, the converted energy is greater than the consuming energy results in sensor node can work externally. Then we've made the small battery less sensor node having solar call and Capacitor as EDLC (Electric Double Layered Capacitor) as energy reservoir. Bloc diagram is shown in Fig.4 and photograph is shown in Fig.5.

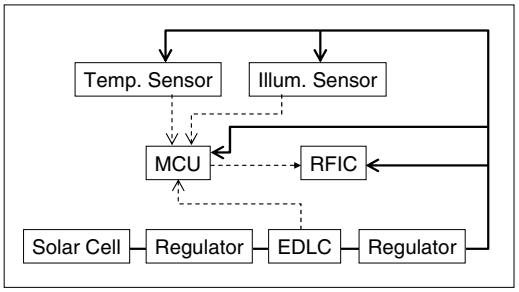

Fig.4 Block Diagram for HEMS node with Solar

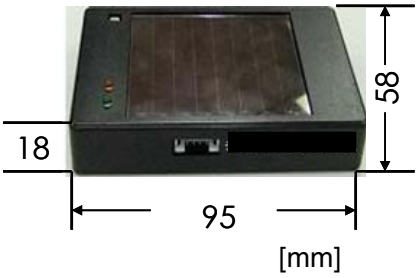

Fig.5 Photograph for HEMS node with Solar

For our measurement we've defined common life condition which is account for illumination duty: light on duration is 4hour per day and going out duration (black condition) is 2days per week, and total light on duty is calculated as 11% (Fig.6).

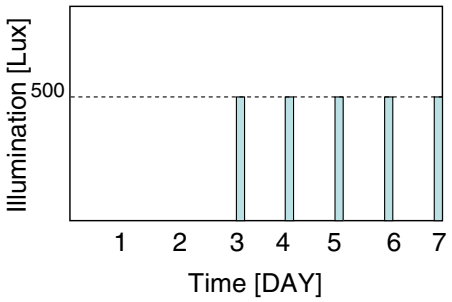

Fig.6 Common Life Condition definition

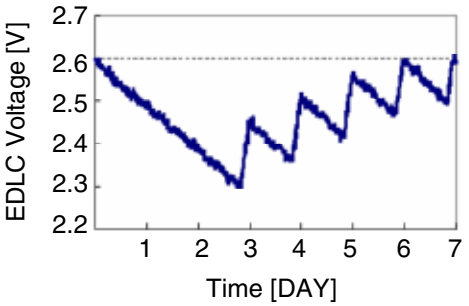

Fig.7 1week energy budget monitoring result

Under above condition, one week test is performed. The result is shown in Fig.7. Initial EDLC Voltage is as the same as EDLC Voltage after 7days. This result shows energy balance between generated energy and consuming energy is keeping. As the result we've proofed our battery-less sensor network node can work continuity forever in the extent for Model 1 HEMS.

5. Future perspective for using many kinds of energy harvesting

Next we've examined the possibility of realizing (more than Model 4 HEMS). Referring to Table1 and considering power conditioning loss and leakage loss, we have to generate more than 100uW average power. Solar cell can generate 35uW or so under 11% duty condition. Then we have to include the new energy harvesting in addition to solar cell. Thermal power generation using the temperature difference between body and atmosphere, vibration power generation using at the walking vibration is considered.

Thermal Power Generation

Thermal power generation using Peltier element is hopeful even if the temperature difference is from 5 degree to 10 degree. Because common commercialized Peltier can generate more than 1mW/cm2 under 10 degree difference. But the device reducing thermal conduction is necessary. Fig.8 shows the experiment model to examine the effect of thermal conduction. We've measure the generated power along with the difference of temperature between both sides of Peltier element. In case 1 Peltier can generate

more than 400uW while in case 2, case 3 generated power is restricted around 1uW (Fig.9). These results show we can get more than 100uW by giving ideal thermal device. Here our target value is set as 35uW.

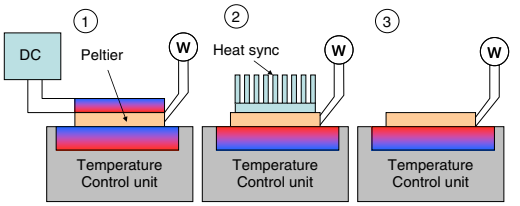

Fig.8 Experiment Model for 3type thermal conduction

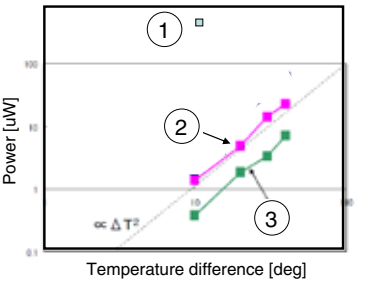

Fig.9 Results for generated power

Vibration Power Generation [1]

PIEZO element, electrical magnet element, electret element is used for vibration power generation. Generated power by vibration is decided by mainly frequency and stroke with less influenced by the kind of generation element. Then we've calculated generated power in referring to HEMS scene. HEMS scene means human walking step, i.e. one step per second and its acceleration is 1g. Still giving stroke as 2cm we can obtain 3mW by walking energy. 1.8mW is our target value considering AC/DC converting loss.

Wireless Power Transmission [2]

When there is no light, no difference of temperature, and no vibration, wireless power transmission is effective method. In our study it is clarified that 27mW can be received referring to ICNIPR guideline under the condition of 10cm diameter of harmonic coil, 20cm of transmitting distance. Now in considering AC/DC converting loss, about 15mW is our target value.

Energy harvesting power amount is shown is Table2. Table2 shows average generated power is nearly 100uW combined with many kinds of energy harvesting in account for Fixed and Movable (human status is both Active and Sleep) HEMS. This consideration shows the possibility of realizing more than Model 4 HEMS only with energy harvesting.

Table2 Energy Harvesting Power Amount

TYPE	HEMS Scene		Illumination	Temp.	Vibration	Wireles Power Transmission	Generated Power (AVE.)
		Peak Power (uW)	320	35	1800	15000	
Fixed		Duty	11%	—	—	0.4%	95uW
Movable	Active		—	100%	3%	—	89 μW
	Sleep		—	100%	—	0.4%	95 μW

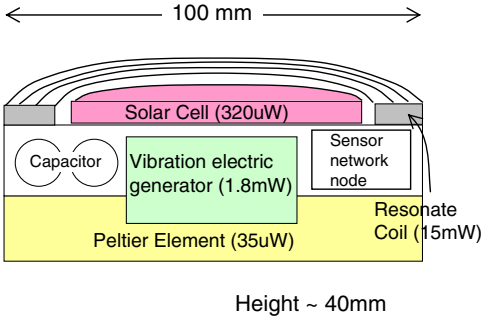

Fig.10 Conceptual View for our Future Work

6. Conclusion

We've shown the novel concept for HEMS. That is introducing sensor network and energy harvesting technology into HEMS apparatus. And we've made prototype for HEMS sensor node and performed feasibility test for HEMS by sensor network to examine its validity. Next we've made sensor network node with solar cell in order to examine the energy budget between generated power and consuming power. That result shows energy budget is balanced. But this test is restricted by only monitoring HEMS (Model 1). Then we've examined future perspective in the case of using many kinds of energy harvesting. In this estimation, we can realize more rich HEMS (more than HEMS MODEL 4) by combination of many kinds of energy harvesting. Now we are planning to design the hybrid energy harvesting sensor network node (fig.10) based on the results in table2.

"I believe this approach opens the new load for future HEMS".

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