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Non-Intrusive Appliances Load Monitoring (NILM) for Energy Conservation in Household with Low Sampling Rate

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Abstract

This paper presents a design and construction of measuring system to measure the power consumption of a split type air conditioning unit and refrigerator in household for energy conservation without having to install any instrument directly to appliances. The system will be only using aggregate power consumption data from only one instrument installed at main power distribution board and using proposed algorithm to disaggregate power consumption data of selected appliances, it is called Non-Intrusive Load Monitoring (NILM). It can significantly reduce cost and time in home energy audit. In this paper authors have used 3 points of monitored data to detect any change of power signal that obtained a 1 Hz sampling rate of active power from energy meter. The proposed method uses basic knowledge about specified air conditioning and refrigerator to establish criteria of disaggregation. Significant saving in air conditioner and refrigerator energy consumption can be achieved by real-time information on their in use. The results showed that the proposed system can disaggregation energy of air conditioner in accuracy 90.71% and refrigerator in accuracy 89.95% from total consumes energy.

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Keywords: NILM; Load Disaggregate; Smart Meter

1. Introduction

Significant savings in energy consumption can be achieved by improved energy management in buildings[1]. Other advanced control algorithms, real-time information on appliances in use. Components of an air conditioner are

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evaporator and condenser with fans plus a compressor. Replacing a dirty, clogged filter with a clean one can lower air conditioner's energy consumption by 5% to 10%[2]. Real time energy consumption of refrigerators can be used to plan to defrost. Frost in refrigerator increases the amount of energy needed to keep the motor running. Manual defrost refrigerators is necessary to realize the energy savings. A continuous feedback on the air conditioner and refrigerator power draw can lead to significant energy saving. The system uses a single energy meter of main point to obtain a 1 Hz sampling rate of active power.

2. Non-Intrusive Load Monitoring

The main idea of Non-Intrusive Load Monitoring (NILM) is to obtain appliance-specific information non-intrusively[3]. The information is collected at the main input, and then disaggregated to obtain operational time and power draw information. Fig.1 shows an example of an aggregated power signal and the corresponding NILM solution. The main signal consist with refrigerator LED TV and fan signal. In this illustration, the reconstructed operational time of fan is from 6:30 AM to about 9:30 AM with the power draw is about 46 W and LED TV is from 6:05 AM to about 8:35 AM with the power draw is about 58 W. In this example, the appliances are modeled as on/off load that consume constant active power at a single steady state. NILM system elements can be divided into four parts as follows:

Hardware, this element used to measure and record data including a power meter that install at main circuit. The method of read data from meter can be used low sampling rate (equal or less than 1 Hz) or high sampling rate (equal or greater than 1000 Hz).

Event Detection is software that detects the change of power or other changes in parameter of electricity. That represents a change in operating conditions of the equipment. A transition of active power from a high to low, can determine whether the machine is turned on or active power transition from a low to high can indicate that the machine is turned off. It can be mathematically expressed as Eq. 1:

$$\Delta P = P_{t2} - P_{t1} \tag{1}$$

where ΔP is a change of active power, P_{t1} is the steady-state active power at time t_1 and P_{t2} is the steady-state active power at time t_2.

Data disaggregation is software that acts as disaggregation or grouped the electrical equipment that on or off. The supervised disaggregation algorithm for Non-Intrusive Load Monitoring can be categorized into pattern recognition methods or optimization methods[4].

-Optimization Methods: In the case it compares the extracted feature data of an unknown appliances to that of known appliances present in the cluster of the database and search the closest match by minimization the error between them. It can be expressed as a mathematical Eq. 2:

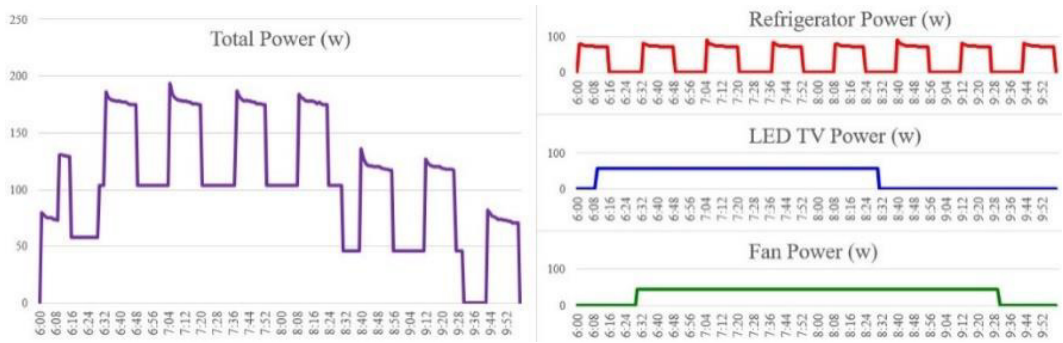

Fig. 1. NILM classified an input signal into individual appliances

$$\min P(t) - \sum_{i=1}^{n} (a_i P_i) + e(t) \quad (2)$$

where P(t) is a total active power that read from meter at time t, a_i is a status of load i (0: on, 1:off), P_i is active power of load i, n is number of load in system and e(t) is the error tolerance.

-Pattern Recognition Methods: Pattern matching method that is most often used by researchers for load disaggregation. The database of appliance contains many unique features that are used to define the structure and parameters of the recognition algorithm. For load identification, the transition of steady-state active power are mapped to a space of P-Q plane. It can be mathematically expressed as Eq. 3:

$$(\Delta P - P_k) + (\Delta Q - Q_k) = e \ \ if\ \Delta P > 0 \text{ (load on)}\ , (\Delta P + P_k) + (\Delta Q + Q_k) = e \ \ if \Delta P < 0 \text{ (load off)} \quad (3)$$

where ΔP is a change of active power, ΔQ is a change of reactive power, P_k is the active power database of load k, Q_k is the reactive power database of load k and e is the error tolerance.

Information presentation is the display of power consumption of electrical devices from data disaggregation module. The way of presentation can be divided into home display or internet display.

- Home display: The home display is showing the data through a device installed inside the house.

-Internet display: The Internet of Things (IoT) devices can be used to monitor and control the electrical and mechanical systems. Besides home based energy management, the IoT is relevant to the smart grid with the aim to improve the economics, efficiency, reliability, and sustainability of the electrical systems. ThingSpeak[5] is the Internet of Things application platform. Each channel has eight fields that can hold any type of data.

3. Design of System

The step changes in real power of system is detected. These algorithms match these changes with the air conditioner and refrigerator being turned on or off. The system uses a single point of power meter as shown in Fig.2. This system consists of power meter, microcontroller, WIFI module, LCD, SD-card and RTC. Test system can be divided into four parts as follows:

-Hardware, using power meter with RS485 communication connect to microcontroller. Microcontroller obtained active power sampling rate at a 1 Hz from energy meter and save data in memory of microcontroller.

-Event Detection have used 3 points of monitored data to detect any change of real power signal. Data of 3 point (P1, P2 and P3) be divided into 9 patterns shown in Fig.3. If the power is in the Flat-Flat mean all loads in a steady state. If the pattern is not Flat-Flat means either a change of status. When the Flat-Flat pattern in two close range saves a change real power (ΔP).

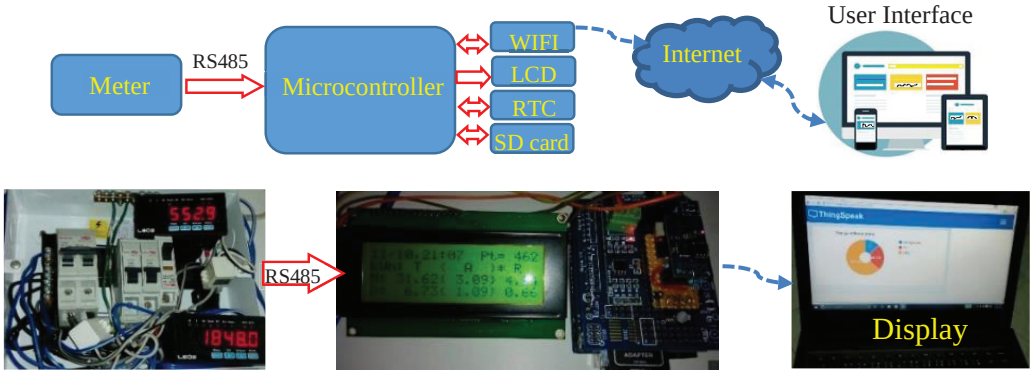

Fig. 2. Test system

-Data Disaggregation. Pattern recognition methods use to data disaggregation. This article interest the 12,000 BTU of air conditioner and 5.8 cu.ft. of refrigerator. Eq.3 is identified load.

-Information Presentation. The system is displayed via LCD 20x4 characters and using the ThingSpeak to store and display data shown in Fig.4.

4. Test Result

This result was test on September 1-30, 2015. Fig.5 shows result of energy daily load profile of air conditioner. Fig.6 shows result of energy daily load profile of refrigerator. The results showed that the proposed system can disaggregation energy of air conditioner in accuracy 90.71% and refrigerator in accuracy 89.95% from total consumes energy.

5. Conclusion

The paper proposed a design and construction of measuring system to measure the power consumption of a split type air conditioning unit and refrigerator in household for energy conservation without having to install any instrument directly to appliances. From the results, the system can disaggregate energy of air conditioner and refrigerator from total consumes energy. This information which is continuous data on the air conditioner energy consumption can plan to replace or clean filters to save air conditioner's energy consumption. Moreover this real time energy consumption of refrigerators can plan to defrost system and for energy savings.

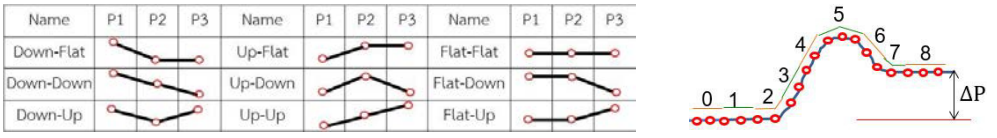

Fig. 3. Patterns of 3 point method

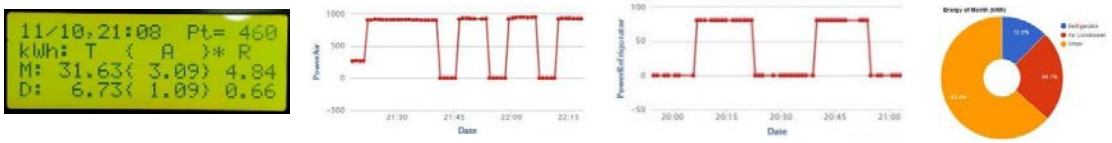

Fig. 4. Information presentation

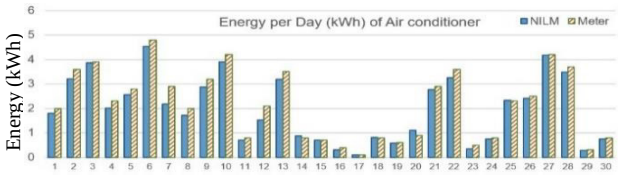

Fig. 5. Energy per day of air conditioner

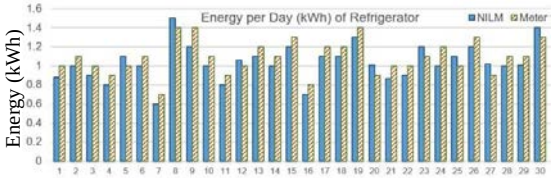

Fig. 6. Energy per day of refrigerator

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