

SPECIFICATION

A Non-intrusive Microwave Oven Operating Identification Method Based on Hybrid Criteria

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Technical Field

The present invention belongs to the technical field of intelligent power consumption, and relates to a non-intrusive microwave oven operating identification method based on hybrid criteria.

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Background

At present, the residential electricity consumption in China has the following characteristics: first, the growth rate is high, and the proportion of residential electricity consumption in the new electricity consumption is as high as 38% in 2016; second, the behaviors are complicated, and the residential customers' electricity consumption behaviors are very complicated due to numerous individuals and a great variety of domestic appliances; third, the comprehensive energy consumption is high, and the comprehensive energy consumption of residential customers is much higher than the levels in Japan and other developed countries. Residential power load monitoring and decomposition technology is an emerging basic supporting technology for smart grids. Different from the current smart meters which only measure the total power of users, it aims at monitoring and decomposing the starting time, working state and energy consumption of all appliances in a household, thus achieving more reliable and accurate electric energy management. The electric power load monitoring and decomposition technology makes the user's electricity charge list like a cellphone charge list, the electricity consumption of various household appliances are clear at a glance, so that the user knows his electric power consumption in time, providing a reference for the reasonable distribution of the electricity consumption time and the corresponding electricity consumption of each appliance. Finally, the money spent on electricity and electric energy waste can be effectively reduced. Statistical data shows that the monthly electric charge can be reduced by 5%~15% if home users can get the detailed information on electricity consumption of residential electric appliances in time. If half of all U.S. households save so much money every month, the reduction in carbon emissions is equivalent to reduction of 8 million cars.

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Currently, the residential power load monitoring and decomposition technology is mainly divided into two categories: Intrusive Load Monitoring and decomposition (ILMD) and Non-intrusive Load Monitoring and decomposition (NILMD):

(1) Intrusive Load Monitoring and Decomposition (ILMD): Sensors with the digital communication function are installed at the interface between each electric appliance and the power grid by intrusive load monitoring to allow accurate monitoring of the operating state and power consumption of each load. However, the cost for construction and maintenance is high due to the installation of a large number of monitoring sensors. Above all, the intrusive load monitoring requires installation and debugging in residents' homes, which easily results in the users' emotional resistance.

(2) Non-intrusive Load Monitoring and Decomposition (NILMD): A sensor is installed only at the user's entry to judge the power consumption and working state (for example, a washing machine has different working states such as washing, rinsing and dewatering) of each or each type of electric appliance in the house by collecting and analyzing the total current, voltage and other information at the entry, thus arriving at the law of the resident's electricity consumption. Since only one monitoring sensor is to be installed, both the construction cost and the difficulty of maintenance in the later period of the non-intrusive load decomposition scheme are greatly reduced compared with the intrusive load decomposition; in addition, the sensors are selectively installed at the user's meter box without invading into the household for construction at all. It can be considered that NILMD using the decomposition algorithm instead of the sensor network of the ILMD system has the advantages of simplicity, economy, reliability, data integrity and easy and fast popularization and application. It is expected to develop into a new generation of core technology in the Advanced Metering Infrastructure (AMI) (after it becomes mature, the NILMD algorithm can also be integrated into smart meter chips) and support the demand side management, custom power and other advanced functions of intelligent power consumption, and it also applies to the temporary monitoring and investigation of load power consumption details.

The microwave oven is a cooking utensil which uses food for absorbing microwave energy in the microwave field to heat itself. The microwave generated at the microwave generator of the microwave oven sets up a microwave electric field in the microwave oven cavity, and certain measures are taken to make the microwave electric field evenly distributed in the cavity. The food is put into the microwave electric field, and the cooking time and the intensity of the microwave electric field are controlled by the control center to carry out various cooking processes. The power range of the microwave oven is generally 800~1500 watts.

To sum up, NILMD technology has gradually become a research focus, and the breakthrough and industrialization of related technologies are of great significance to the energy conservation and emission reduction of the whole society. However, the research of NILMD technology is still in the stage of theoretical research, and key technologies such as the decomposition identification method of the intermittent operating load, especially the microwave oven, have yet to be broken through.

Therefore, a non-intrusive microwave oven operating identification method is needed to solve the above problems.

Summary of the Invention

The present invention aims at solving the problem by providing a non-intrusive microwave oven operating identification method based on hybrid criteria.

The present invention achieves the above purpose through the following technical scheme:

A non-intrusive microwave oven operating identification method based on hybrid criteria, comprising the following step:

1). sampling voltage and current signals of a main power inlet line at the sampling frequency f , and forming a voltage signal sampling sequence $u(i)$ and a current signal sampling sequence $i(i)$, wherein, i is the sampling point number;

2). scanning the collected the voltage signal sampling sequence $u(i)$ and the current signal sampling sequence $i(i)$ in a first time window, and calculating a real-time average active power sequence $P(k)$ and a real-time average reactive power sequence $Q(k)$, wherein, the first time window comprises m power frequency cycles, each power frequency cycle comprises n sampling points, and k is the sampling point number of the average power sequence;

3). scanning the real-time average active power sequence $P(k)$ and the real-time average reactive power sequence $Q(k)$ in a second time window, and calculating an active power variation $\Delta P(k)$ and a reactive power variation $\Delta Q(k)$;

4). detecting the reactive power variation sequence $\Delta Q(t)$ in the t th time window: if $\Delta Q(t) > 700$, determine that the power rises, with the rising time of $T_{on}(i)$ and the active power rising value of ΔP_u , record the reactive power rising value as ΔQ_u , record ΔP_u , ΔQ_u and $T_{on}(i)$ into the started electric appliance list, and go to Step 5); otherwise go to Step 2);

5). detecting the active power variation $\Delta P(t)$: if $\Delta P(t) < -1200$, determine that the power falls, with the falling time of $T_{off}(i)$, the active power falling value of ΔPd and the reactive power falling value of ΔQd , and go to Step 6); otherwise go to Step 2);

6). traversing the started electric appliance list: when $|\Delta Pd|/|\Delta Pu| > 3$ and $|\Delta Qu|/|\Delta Qd| > 2$, go to Step 7); otherwise go to Step 2);

7). calculating the time interval between two power changes $\Delta T_i = T_{off}(i) - T_{on}(i)$: if $10s < T_i < 30s$, determine that the microwave oven operates; otherwise return to Step 2).

Further, the range of the sampling frequency f in Step 1) is 0.5kHz~2kHz.

Further, the real-time average active power sequence $P(k)$ and the real-time average reactive power sequence $Q(k)$ described in Step 2) are calculated by the following formula:

$$P(k) = \frac{1}{mn} \sum_i^{i+mn} u(i) * i(i)$$

$$Q(k) = \frac{1}{mn} \sqrt{\sum_i^{i+mn} u(i)^2 * \sum_i^{i+mn} i(i)^2 - (\sum_i^{i+mn} u(i) * i(i))^2}$$

wherein, m is the number of power frequency cycles contained in the first time window, i is the sampling point number, and n is the number of sampling points contained in a power frequency cycle.

Further, the duration of the second time window described in Step 3) is $n \times T$, wherein, n is the number of sampling points contained in a power frequency cycle, and T is the power frequency cycle.

Further, $w = 1000 \times (f/50)$.

Further, the voltage and current signals of the main power inlet line are sampled with a voltage sensor and a current sensor in Step 1).

Further, the active power variation $\Delta P(k)$ and the reactive power variation $\Delta Q(k)$ are calculated by the following formula in Step 3): $\Delta P(k) = P(k+1) - P(k)$, $\Delta Q(k) = Q(k+1) - Q(k)$.

The present invention has the advantages that: The non-intrusive microwave oven operating identification method based on hybrid criteria of the present invention takes full account of the features of active power and reactive power changes and the characteristics of operating time during starting and stopping of the microwave oven, thus the microwave oven can be accurately distinguished from inductive working appliances (such as electric cookers and the like), and the accuracy of non-intrusive microwave oven identification is improved.

Brief Description of the Drawings

FIG.1 is the flow diagram of the present invention;

FIG.2 is the calculation result diagram of the real-time average active power of the non-intrusive identification method of microwave oven based on hybrid criteria;

5 FIG.3 is the calculation result diagram of the real-time average reactive power of the non-intrusive identification method of microwave oven based on hybrid criteria.

Detailed Description of the Preferred Embodiments

The technical schemes in the embodiments of the present invention will be illustrated clearly and
10 completely below in combination with the accompanying drawings in the embodiments of the present invention. Apparently, the described embodiments are merely some of the embodiments of the present invention, not all of them. Based on the embodiments in the present invention, all other embodiments obtained by those of ordinary skill in the art without any creative effort belong to the scope of protection of the present invention.

15 As shown in FIG.1, the specific process steps of the non-intrusive identification method of microwave oven based on power stage change characteristic disclosed in the present invention are as follows:

(1) Taking the sampling frequency $f=0.8\text{kHz}$, and sampling voltage and current signals of a main power inlet line with a current sensor and a voltage sensor to form a voltage signal sampling sequence $u(i)$ and a current signal sampling sequence $i(i)$, wherein, i is the sampling point number.

20 (2) Taking the calculation time window $m=5$ power frequency cycles, with the number of sampling points $n=16$ included in one power frequency cycle, and calculating the real-time average active power sequence $P(k)$ and the reactive power sequence $Q(k)$ of the main power inlet line, wherein

The calculation formula of $P(k)$ is $P(k)=\frac{1}{80}\sum_i^{i+80}u(i)*i(i)$,

The calculation formula of $Q(k)$ is $Q(k)=\frac{1}{80}\sqrt{\sum_i^{i+80}u(i)^2*\sum_i^{i+80}i(i)^2-(\sum_i^{i+80}u(i)*i(i))^2}$,

25 (3) Scanning the real-time average active power sequence $P(k)$ and the real-time average reactive power sequence $Q(k)$ in a certain time window, calculating the active power variation $\Delta P(k)$ and the reactive power $\Delta Q(k)$, for which the calculation formula of $\Delta P(k)$ is $\Delta P(k)=P(k+1)-P(k)$, and the calculation formula of $\Delta Q(k)$ is $\Delta Q(k)=Q(k+1)-Q(k)$, wherein, $k=1,2,3...$

As shown in FIG.2, The power of the microwave oven is always changed during operation, the step change process of the active power and reactive power intermittently occurs twice, the active power rises by 220W in the first stage, and the reactive power rises by about 800Var; the active power rises by 1020W in the second stage; the reactive power falls by about 500Var, and subsequently, the active power is stabilized around 1300W, the reactive power is stabilized around 300Var, and the values of $\Delta P(k)$ and $\Delta Q(k)$ are calculated according to the calculation formula.

(4) Detecting the reactive power variation sequence $\Delta Q(t)$ in the t th time window: if $\Delta Q(t) > 700$ is satisfied, determine that the power rises, and record the rising time as $T_{on}(i)$, record the active power rising value as ΔP_u , record the reactive power rising value as ΔQ_u , and record ΔP_u , ΔQ_u and $T_{on}(i)$ into the started electric appliance list; otherwise go to Step (2);

Specifically, identifying whether it is power rising for the load by detecting the $\Delta Q(t)$ value: if it is not power rising, return to Step (2); otherwise record the rising time as $T_{on}(i)$, record the active increment as ΔP_u , and record the reactive increment as ΔQ_u .

As shown in FIG.2 and FIG.3, the reactive power of the microwave oven instantaneously rises by 845Var at the starting time, which is greater than the threshold value 700Var in the criteria, so it can be determined as power rising, record the rising time as $T_{on}(1)$, $\Delta P_u = 400W$ and $\Delta Q_u = 845Var$.

(5) Detecting whether active power variation $\Delta P(t)$ meets $\Delta P(t) < -1200$: if yes, record the falling time $T_{off}(i)$, the falling value ΔP_d of active power, the falling value ΔQ_d of reactive power, traverse the started electric appliance list, and when the following criteria are met: $|\Delta P_d|/|\Delta P_u| > 3$, $|\Delta Q_u|/|\Delta Q_d| > 2$, go to Step (6);

Specifically, identifying whether it is power falling for the load by detecting the $\Delta P(t)$ value: if not, return to Step (2); otherwise record the change time as $T_{off}(i)$, record the active increment as ΔP_d , record the reactive increment as ΔQ_d , and add ΔP_d , ΔQ_d and $T_{off}(i)$ into the started electric appliance list.

As shown in FIG.2 and FIG.3, the active power at the time of $T_{off}(i)$ falls by 1360W, while the reactive power at the same time falls by 295Var, record the active increment as $\Delta P_d(1) = -1360W$, record the reactive increment as $\Delta Q_d(1) = -295Var$, resulting in $|\Delta P_d(1)|/|\Delta P_u(1)| \approx 3.4 > 3$, $|\Delta Q_u(1)|/|\Delta Q_d(1)| \approx 2.86 > 2$, which meet the criteria: $|\Delta P_d|/|\Delta P_u| > 3$, $|\Delta Q_u|/|\Delta Q_d| > 2$, and go to Step (6).

(6) Calculating the interval duration $T_i = T_{off}(i) - T_{on}(i)$: if it meets $10s < \Delta T_i < 30s$, $\Delta T_1 \approx \Delta T_2 \approx \dots \approx \Delta T_n$, determine the operation of the microwave oven, and calculate the similar rated power of the microwave oven; otherwise return to Step (2).

Specifically, calculating the period in which the electric appliance operates according to the formula, $T_1=T_{off}(1)-T_{on}(1)$, $\Delta T_2=T_{off}(2)-T_{on}(2)$: as shown in FIG.2, if the electric appliance operates at similarly equal intervals and the duration of each operation is 10s to 30s, then it can be determined as the operation of the microwave oven, and the similar rated power P_s of the microwave oven can be obtained.

5 As shown in FIG.2 and FIG.3, $10s < \Delta T_1 = \Delta T_2 = \dots = \Delta T_n \leq 30s$, then it can be determined as the operation of the microwave oven, and the similar rated power of the microwave oven is 1300W.

CLAIMS

1. A non-intrusive microwave oven operating identification method based on hybrid criteria, characterized by comprising the following steps:

5 1). sampling voltage and current signals of a main power inlet line at the sampling frequency f , and forming a voltage signal sampling sequence $u(i)$ and a current signal sampling sequence $i(i)$, wherein, i is the sampling point number;

2). scanning the collected the voltage signal sampling sequence $u(i)$ and the current signal sampling sequence $i(i)$ in a first time window, and calculating a real-time average active power sequence $P(k)$ and a
10 real-time average reactive power sequence $Q(k)$, wherein, the first time window comprises m power frequency cycles, each power frequency cycle comprises n sampling points, and k is the sampling point number of the average power sequence;

3). scanning the real-time average active power sequence $P(k)$ and the real-time average reactive power sequence $Q(k)$ in a second time window, and calculating the active power variation $\Delta P(k)$ and the
15 reactive power variation $\Delta Q(k)$;

4). detecting the reactive power variation sequence $\Delta Q(t)$ in the t th time window: if $\Delta Q(t) > 700$, determine that the power rises, with the rising time of $T_{on}(i)$, the active power rising value of ΔP_u and the reactive power rising value recorded as ΔQ_u , record ΔP_u , ΔQ_u and $T_{on}(i)$ into the started electric appliance list, and go to Step 5); otherwise go to Step 2);

20 5). detecting the active power variation $\Delta P(t)$: if $\Delta P(t) < -1200$, determining that the power falls, with the falling time of $T_{off}(i)$, the active power falling value of ΔP_d and the reactive power falling value of ΔQ_d , and go to Step 6); otherwise go to Step 2);

6). traversing the started electric appliance list: when $|\Delta P_d|/|\Delta P_u| > 3$ and $|\Delta Q_u|/|\Delta Q_d| > 2$, go to Step 7); otherwise go to Step 2);

25 7). calculating the time interval between two power changes $\Delta T_i = T_{off}(i) - T_{on}(i)$: if $10s < \Delta T_i < 30s$, determine that the microwave oven operates; otherwise return to Step 2).

2. The non-intrusive microwave oven operating identification method based on hybrid criteria according to Claim 1, characterized in that the range of the sampling frequency f in Step 1) is 0.5kHz~
30 2kHz.

3. The non-intrusive microwave oven operating identification method based on hybrid criteria according to Claim 1, characterized in that the real-time average active power sequence $P(k)$ and the real-time average reactive power sequence $Q(k)$ described in Step 2) are calculated by the following formula:

$$P(k) = \frac{1}{mn} \sum_i^{i+mn} u(i) * i(i)$$

$$Q(k) = \frac{1}{mn} \sqrt{\sum_i^{i+mn} u(i)^2 * \sum_i^{i+mn} i(i)^2 - (\sum_i^{i+mn} u(i) * i(i))^2}$$

wherein, m is the number of power frequency cycles contained in the first time window, i is the sampling point number, and n is the number of sampling points contained in a power frequency cycle.

4. The non-intrusive microwave oven operating identification method based on hybrid criteria according to Claim 1, characterized in that the duration of the second time window described in Step 3) is $n \times T$, wherein, n is the number of sampling points contained in a power frequency cycle, and T is the power frequency cycle.

5. The non-intrusive microwave oven operating identification method based on hybrid criteria according to Claim 3 or 4, characterized in that $n=1000 \times (f/50)$.

6. The non-intrusive microwave oven operating identification method based on hybrid criteria according to Claim 1, characterized in that the voltage and current signals of the main power inlet line are sampled with a voltage sensor and a current sensor in Step 1).

7. The non-intrusive microwave oven operating identification method based on hybrid criteria according to Claim 1, characterized in that the active power variation $\Delta P(k)$ and the reactive power variation $\Delta Q(k)$ are calculated by the following formula in Step 3): $\Delta P(k)=P(k+1)-P(k)$, $\Delta Q(k)=Q(k+1)-Q(k)$.