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DESIGN AN ON-LINE POWER DETECTION SYSTEM USING IMPROVED REDUNDANT MANAGEMENT METHOD

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Abstract. *The article presents a power detection system (PDS) using improved redundant management method to be applied in the on-line power monitoring of the target device. The system contains multiple power detection units, a data integration unit, a target device with multiple power sources, a power source and a PC-based main controller. Each power detection unit measures current and voltage on real-time, and uses four Hall current sensors to measure the current value. Using improved redundant management method is applied in current and voltage detection, and calculates the estimated value. The system calculates the real-time power values according to the estimated values of current and voltage measurement values. The power detection unit can communicate with the data integration unit via I2C interface. The main controller of the power detection system communicates with the data integration unit via series interface.*
Keywords: Power detection system, Improved redundant management method, I2C interface, Series interface

1. **Introduction.** Fast and accurate power prediction plays an important role in power real-time control system. Real-time and accurate prediction is not only the precondition and basis of realizing system, but also the basis of scheduling plan and power supply plan. It is a very important issue to predict electrical power load based on current, voltage and past electricity consumptions. Users can program power loading according to one-day load prediction and one-month prediction values to finish day-schedule plan and month-schedule using auto-regression algorithm, respectively. In addition, it helps dispatchers to adjust the power distribution in the city, and set in moving peak and fill trough. Nowadays, power schedule is a great need to rescue life environment of the earth [1].

We have designed a current detection module applying in the Chung-Cheng security robot using microprocessor (MCS51), and on-line experimental results are very successful [2]. We are implementing the new power detection module applying in the fire fighting robot using HOLTEK microchip, too [3]. The goals of the power detection module extend the interface function, and transmit the measurement data to the controller of the mobile robot using series interface, and extend the function of the current detection module to reduce detection error using the redundant management method [4]. The paper improves the functions of the module to be applied in the other devices, too. In general, the power system of the target device has multiple variety power outputs. We must detect all power status of the target devices.

In the past literature, many researches have proposed power detection and prediction algorithms. Ngaopitakkul et al. proposed a novel distance relay algorithm to detect fault, and companied indicator in order to classify fault type [5]. Sodden and Hawkins reported on numerous experiments where current measurements have forecast reliability problems in devices which had previously passed conventional test procedures [6]. Nguyen et al.

proposed an estimation scheme based on the hierarchical structure of the distributed state estimation to estimate the state of energy management system [7].

2. **System Architecture.** The system architecture of the power detection system is shown in Figure 1. There are multiple power detection units ($\#1, \#2, \ldots, \#n$), a data integration unit and a PC-based main controller. Each detected device has various power sources. These power sources provide each subsystem of the detected device. We want to maintain the power sources of the detected device with normal condition. The PDS is a module to be applied in many fields, and calculates the exact measurement values, and isolates faulty measurement values to improve the measurement values to be exact using the redundant management algorithm and statistical signal prediction algorithm. The controller of the power detection unit is a HOLTEK microchip (HT46R25) to detect the power values of the detected device using four DC type current sensors, and measures voltage values simultaneously.

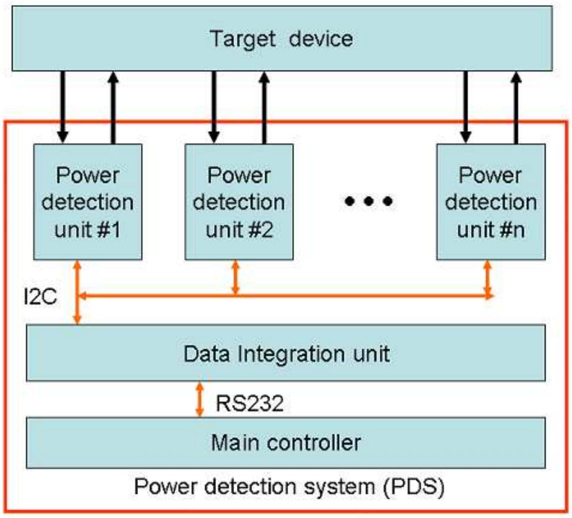

FIGURE 1. The system architecture

The data integration unit connects with each power detection unit via I2C interface, and deals with the received data according to the ID code of each power detection unit, and transmits the measurement signals to the main controller of the PDS via RS232 interface. The prototype of the PDS is shown in Figure 2 to integrate four power detection units. The main controller of the PDS monitors power status of each power source of the detected device, and isolates the faulty measurement values, and predicts the power loading of the target system, and provides the enough power output for the target device to make the maximum working time.

We make a battery device to supply power for the mobile robot as a partner of the detected device (24V input). Then the battery device converts the battery device to three various power sources (24V output, 12V output and 5V output) for the mobile robot. We want to monitor four power sources of the mobile robot using the PDS on real-time. The user interface of the PDS is shown in Figure 3. Uses can select each power detection unit to detect the assigned power, and display four current measurement curves, four voltage measurement curves, power estimated curve. The bottom side of user interface displays communication port, the maximum value and minimum value, detection range and detection result. The user can program the communication port to be COM. 1, and selects any time point of these curves to display the assigned measurement values on the right side of the monitor. The upper of the user interface displays multiple detection power sources for each detected device (24V input, 24V output, 12V output and 5V output).

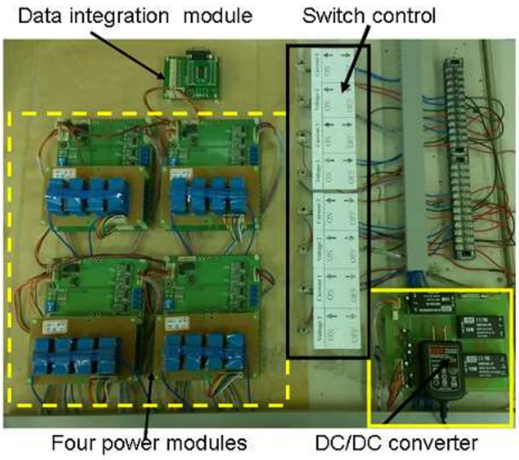

FIGURE 2. The overview of the PDS

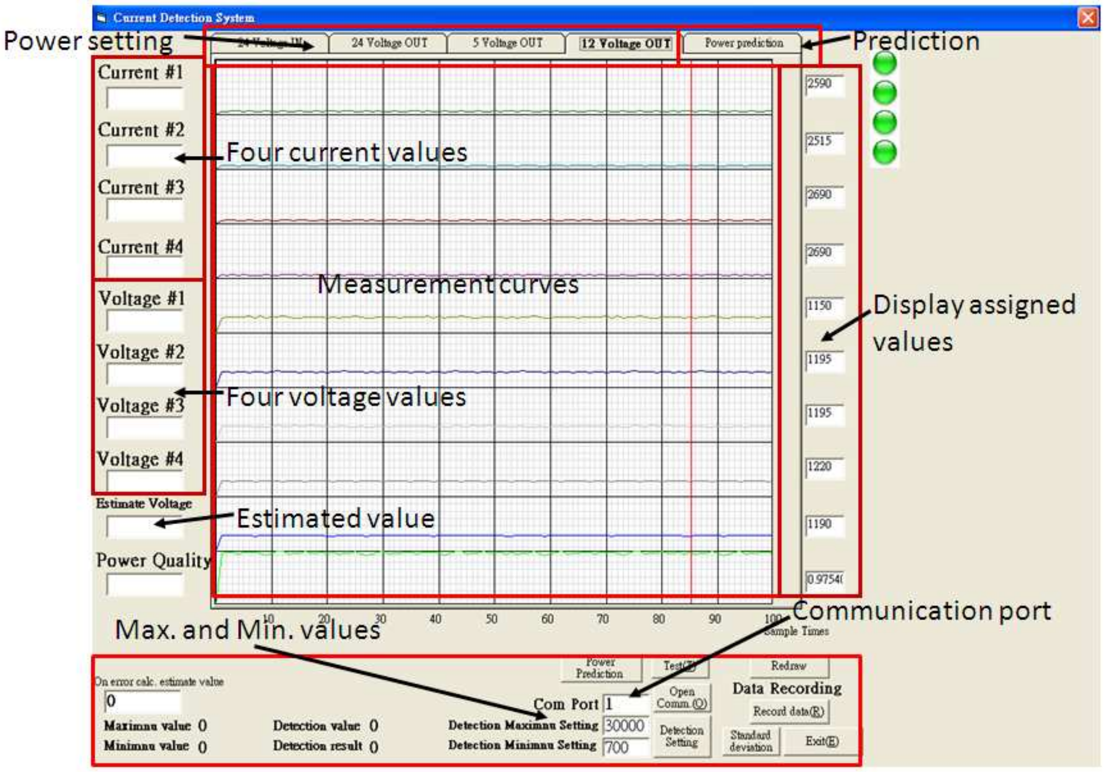

FIGURE 3. The user interface of the PDS

3. Algorithm Analysis.

3.1. **Redundant management algorithm.** In each power detection unit, we use redundant management method to calculate exact power values for the assigned power, and isolate the faulty measurement values. The redundant measurement value of the observed system is l. For the ith measurement value m_i and boundary error b_i, we can compute the indicator function $I_i(k)$, and find the power estimated value $\hat{x}(k)$ of each power detection unit at a given sample time k.

$$\hat{x}(k) = \frac{\sum_{i=1}^{l} m_i(k) I_i(k)}{\sum_{i=1}^{l} I_i(k)} \tag{1}$$

$$I_i(k) = \sum_{\substack{j=1,\\ j\neq i}}^{l} f\left[|m_i(k) - m_j(k)| \leq (b_i(k) + b_j(k))\right], \quad i = 1, 2, \ldots, j-1, j, j+1, \ldots, l \quad (2)$$

$$f[*] = \begin{cases} 1, & \text{if } * \text{ is true} \\ 0, & \text{if } * \text{ is false} \end{cases} \quad (3)$$

In general, we use two performance indicators to compare the simulation results; one is relative error (RE), and the other is mean absolute percentage error (MAPE). RE is used to describe the performance of prediction effect; its computation formula is as follows:

$$RE(t) = \frac{w(t) - \bar{w}(t)}{w(t)} \times 100\% \quad (4)$$

where $w(t)$ is measurement value, and $\bar{w}(t)$ is prediction value. MAPE is aggregative indicator commonly used in power system. It is used to evaluate the performance value of the whole predicting process. The formula is as follows:

$$MAPE = \frac{1}{q} \sum_{i=1}^{q} \left| \frac{w(t) - \bar{w}(t)}{w(t)} \right| \quad (5)$$

The q is sample number. The PDS measures multiple power variances to display on the user interface. Users select the measured value of the power system on the user interface. We make an example to select 12V power output to implement the redundant management algorithm shown in Figure 4, and set the boundary error to be 10%. The power detection unit has one voltage measurement values m_i to be faulty. We can calculate estimated value and each indicator function using Equations (1), (2) and (3). For current measurement value #1 (2590mA) and I_1

$$\left|\frac{2590\text{mA} - 2515\text{mA}}{2590\text{mA}}\right| \leq 0.1 \quad f[*] = 1, \quad \left|\frac{2590\text{mA} - 2690\text{mA}}{2590\text{mA}}\right| \leq 0.1 \quad f[*] = 1 \quad (6)$$

$$\left|\frac{2590\text{mA} - 2690\text{mA}}{2590\text{mA}}\right| \leq 0.1 \quad f[*] = 1, \quad I_1 = 1 + 1 + 1 = 3 \quad (7)$$

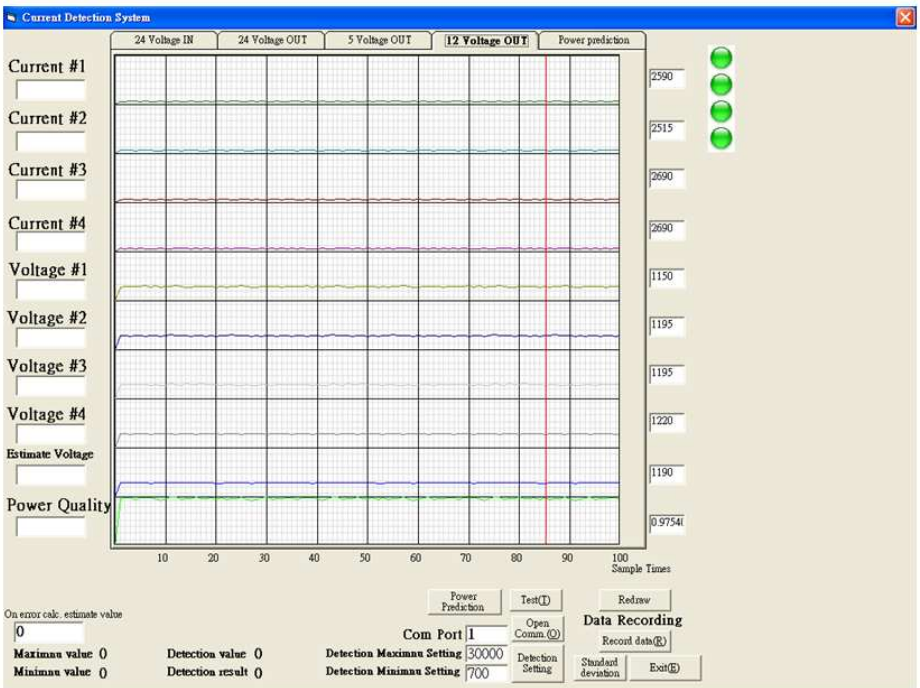

FIGURE 4. The simulatiom result for case I (12V)

The indicator function of the current measurement value #1 (2590mA) is 3. For current measurement value #2 (2515mA) and I_2

$$\left|\frac{2515\text{mA}-2590\text{mA}}{2515\text{mA}}\right| \le 0.1 \quad f[*]=1, \quad \left|\frac{2515\text{mA}-2690\text{mA}}{2515\text{mA}}\right| \le 0.1 \quad f[*]=1 \tag{8}$$

$$\left|\frac{2515\text{mA}-2690\text{mA}}{2515\text{mA}}\right| \le 0.1 \quad f[*]=1, \quad I_2=1+1+1=3 \tag{9}$$

We can calculate the indicator function $I_2 = 3$ for the measurement value (m_2). Then we compute the other values $I_3 = I_4 = 3$ for measurement values m_3 and m_4, and calculate the estimated value as follows:

$$\hat{x} = \frac{2590\times 3 + 2515\times 3 + 2690\times 3 + 2690\times 3}{3+3+3+3} = 2621(\text{mA}) \tag{10}$$

3.2. **Improved redundant management algorithm.** The algorithm is faulty in the two conditions as follows: (1) The measurement values are two consistent pairs that are mutually inconsistent; (2) The total measurement values are mutually inconsistent. In the two cases, we cannot decide which pair or which sensor to be right, and cannot compute the exact estimated value. Then we improve the redundant management algorithm using the statistical signal detection algorithm. If the proposed algorithm is faulty at the sample time $N+1$, we can use P estimation values that are computed to be right by the proposed algorithm, and calculate the mean value as follows:

$$\bar{x} = \frac{\sum\limits_{k=N-P}^{N} \hat{x}(k)}{P} \tag{11}$$

Then we compute the relation error between the measurement value $m_i(N+1)$ and mean value $\bar{x}$, and set the error boundary error to be the same value 0.1. The improved redundant management algorithm calculates the new indicator function $\hat{I}_i(N+1)$, and find out the improved estimated value $\hat{x}(N+1)$ at the sample time $N+1$.

$$\hat{I}_i(N+1) = \begin{cases} 0, & \left|\dfrac{m_i(N+1)-\bar{x}}{\bar{x}}\right| \ge 0.1 \\ 1, & \left|\dfrac{m_i(N+1)-\bar{x}}{\bar{x}}\right| < 0.1 \end{cases} \quad i=1,2,\ldots,l \tag{12}$$

$$\hat{x}(N+1) = \frac{\sum\limits_{i=1}^{l} \hat{I}_i(N+1)m_i(N+1)}{\sum\limits_{i=1}^{l} \hat{I}_i(N+1)} \tag{13}$$

4. **Experimental Results.** The PDS measures multiple power variances to display on the user interface. The user interface implements the experimental results on real-time shown in Figure 5. The user interface of the PDS is shown in Figure 3. Uses can select each power detection unit to detect the assigned power source, and display four current measurement curves, four voltage measurement curves, power estimated curve on the user interface. The bottom side of user interface displays communication port, the maximum value and minimum value, detection range and detection result. The user can program the communication port to be COM. 1, and selects any time point of these curves to display the assigned measurement values on the right side of the user interface. The upper of the user interface displays various detection power sources by the detection unit (24V input, 24V output, 12V output and 5V output). Users can select which detected power source using the mouse to display on the user interface. Users select the measured range value

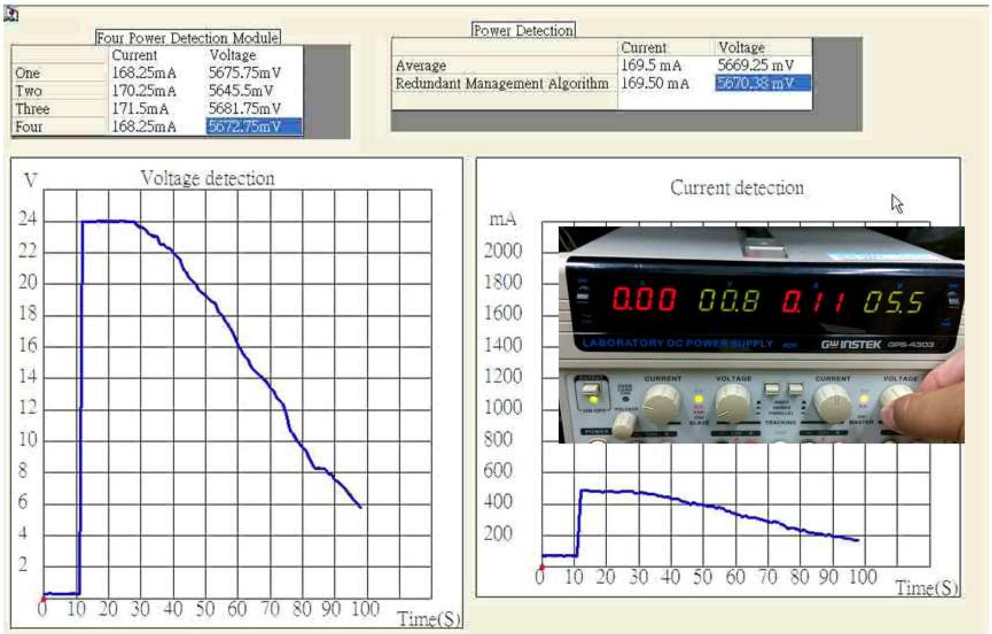

FIGURE 5. The user interface of the experimental result

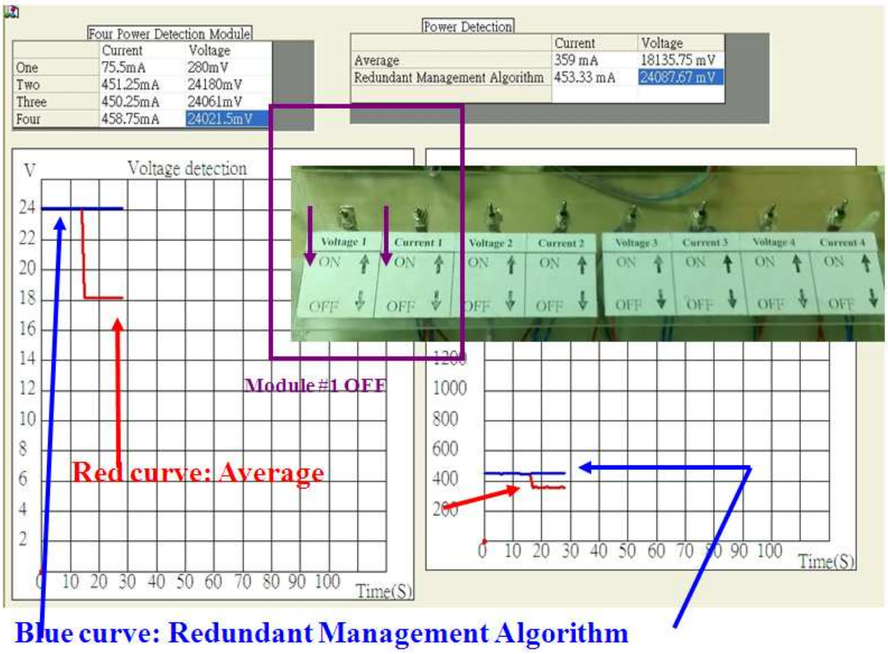

FIGURE 6. The experimental result

of the power system on the user interface. Users can see each power variance curve for each power detection unit.

We select 24V power detection unit to implement the redundant management algorithm, and set the boundary error to be 10%. The power detection unit has no current measurement values to be faulty. The detected device is a power supply device. We increase the voltage output by the user from 6V to 24V shown in Figure 6. We can calculate the indicator function I_i using Equations (1), (2) and (3) as follows.

For current measurement value m_1 (472mA) and I_1

$$\left|\frac{472\text{mA} - 474\text{mA}}{472\text{mA}}\right| \le 0.1 \quad f[*] = 1, \quad \left|\frac{472\text{mA} - 472\text{mA}}{472\text{mA}}\right| \le 0.1 \quad f[*] = 1 \tag{14}$$

$$\left|\frac{472\text{mA} - 478\text{mA}}{472\text{mA}}\right| \leq 0.1 \quad f[*] = 1, \quad I_1 = 1 + 1 + 1 = 3 \tag{15}$$

Then we compute the other values $I_2 = I_3 = I_4 = 3$ for m_2, m_3 and m_4, and calculate the estimated value as follows:

$$\hat{x} = \frac{472 \times 3 + 474 \times 3 + 472 \times 3 + 478 \times 3}{3 + 3 + 3 + 3} = 474(\text{mA}) \tag{16}$$

We can also calculate the estimated value of the voltage detection, and compute the on-line power variety in the power detection unit (24V).

5. **Conclusions.** We designed a power detection system to be applied in the multiple power detection of the target device. The system can calculate the working time of each power source for each settled power value. The controller of the power detection unit is HOLTEK microchip. The system uses multi-sensor fusion algorithms to detect power of the detected device. There is redundant management algorithm and statistical signal detection algorithm. The power detection unit can transmit the measured values to the data integration unit via I2C interface. The data integration unit transmits each power measurement value to the main controller via RS232 interface.

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