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DESIGN AND IMPLEMENTATION OF INTERNET-BASED REMOTE MONITORING FOR CONTINUOUS VACUUM PANS IN SUGAR FACTORY

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Abstract. *This paper presents a practical technique to design and implement the Internet-based system for remotely monitoring key performance indicators (KPIs) in operation of vacuum pans for sugar crystallization by using supervisory control and data acquisition (SCADA) software, which provides web-enabled human machine interface (HMI). The remote monitoring system for the DECHAROEN^{TM} continuous vacuum pans is described as an illustrative case study to verify the proposed technique performance. At the remote site, the programs (or script functions) based on web services were developed for detecting and collecting the KPIs in the text file format from the operator workstation of the host system in the raw sugar plant. The created text files are transferred to the data center through the Internet. At the data center, the database was created using XAMPP software, and the website and web pages were built using HTML and CSS. The proposed system can be useful in performance analysis for continuous quality improvement. Experimental results demonstrating the proposed monitoring system are also included.*
Keywords: Sugar crystallization, Continuous vacuum pan, Key performance indicator, Remote monitoring, SCADA software, Internet, Web service, Database

1. **Introduction.** The design, implementation, and operation of vacuum pans used for crystallization process in cane sugar factories have a significant effect on raw sugar production [1-3]. The crystallization process comprising several complicated steps is the most complex stage of the raw sugar production; therefore, it is required to have an effective control strategy for providing optimal crystalline conditions to achieve high quantity and good quality of raw sugar crystals produced [4-7]. In general, a controller will have a good control effect, if it is configured by a set of suitable parameters. These suitable controller parameters are normally set by a process expert during commissioning and start-up phase. However, the fine adjustment of the controller tuning parameters is still needed to improve the control loop responses due to effects of variation in raw material quality while the process is running. Especially, the commercial cane sugar (CCS) of raw material can vary due to the cultivars of sugarcane at different crop ages. In current practice in Thailand, some sugar factories face a problem of poor crystallization process control, since plant operators lack skills and knowledge on how to maintain the optimal crystalline conditions and the crystal growth rates. While these factories need to produce the high quality raw sugar at low production costs for increasing their competition ability. The aim of this paper is to propose a remote monitoring system to fulfill the requirement for experts to analyze the sugar crystallization stage for continuous quality improvement. For multi-plant company, a single data center to monitor the key performance indicators (KPIs) of the crystallization process conditions at multi-plants or multi-sites, so many experts at each plant are not required. The private Internet process information from various

plants can be accessed across the Internet by company employees only. The design and implementation of Internet-based remote condition monitoring by using the supervisory control and data acquisition (SCADA) software called 'WW InTouch' or 'Wonderware InTouch' are presented. The DECHAROEN™ continuous vacuum pans (CVPs) are used as the examples for demonstrating the proposed technique performance.

The rest of this paper is structured as follows. The sugar crystallization using DECHAROEN™ CVPs is introduced in Section 2. The proposed remote monitoring based on Internet and web services is described in Section 3. The experimental results and discussions are provided in Section 4. The conclusions and the future work are discussed in Section 5.

2. Sugar Crystallization Using DECHAROEN™ CVPs.

To produce the raw cane sugar, the crystallization in vacuum pans requires to be carried out in various steps defined by sugar boiling schemes such as three-boiling scheme or double Einwurf scheme, which can be chosen to suit the purification of syrup and the quality of sugar to be produced [1]. The crystallization steps and their separated products are generally identified by letters. For example, the highest purity state is the A stage to produce the A sugar and A molasses, and the other stages are labeled B and C in case of three-boiling scheme. The DECHAROEN™ CVP as shown in Figure 1 is a horizontal multiple compartment pan providing a number of mixed cells in series, and it is suitable for all A, B, and C massecuite production duties [8]. The number of mixed cells as well as the diameter of the pan can be varied by specified process conditions and pan duty [3]. The CVP is usually designed with a flow path that gives an approximately equal residence time for all the seed crystals. The residence time must be long enough for growing the seed crystals until the crystals reach the required size. There are three major issues to achieve the effective pan operation for sugar crystallization process: good massecuite circulation, high heat transfer rates, and uniform conditions.

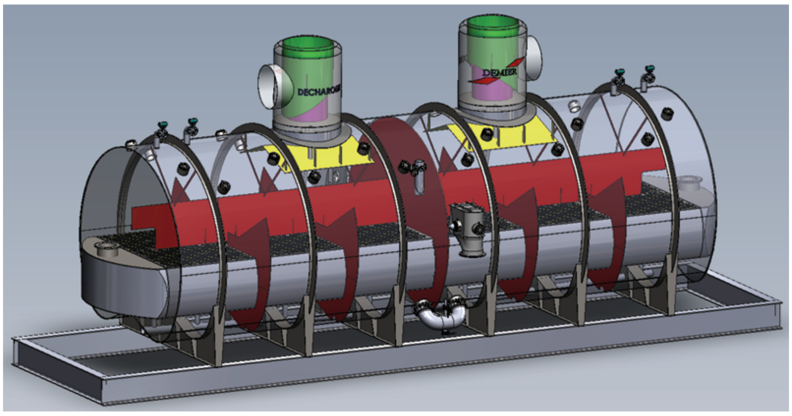

FIGURE 1. DECHAROEN™ CVP with twelve compartments [8]

Figure 2 displays an automatic control system to operate the DECHAROEN™ CVPs by connecting these pans to the host system located in a central control room [8]. The control loops for each CPV consist of absolute pressure control, vacuum pressure control, stream pressure control, conductivity (brix) control, massecuite flow control, syrup/molasses flow control, and seed flow control. The crystallization KPIs to be monitored are absolute pressures, vacuum pressures, temperatures, and conductivity values. Figure 3 illustrates an example of human machine interface (HMI) screens on the operator workstation for monitoring and control of the crystallization process in the DECHAROEN™ CVP with fourteen compartments.

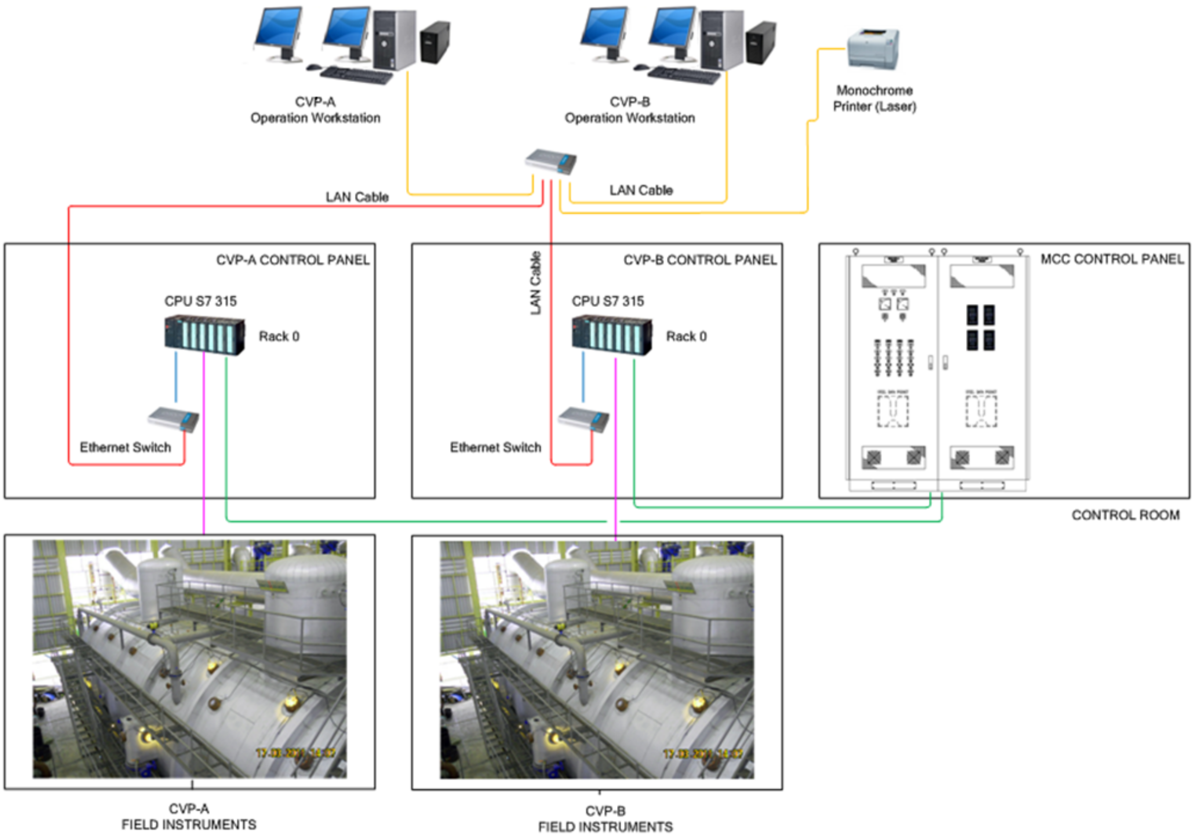

FIGURE 2. Automatic control system to operate the DECHAROEN^{TM} CVPs [8]

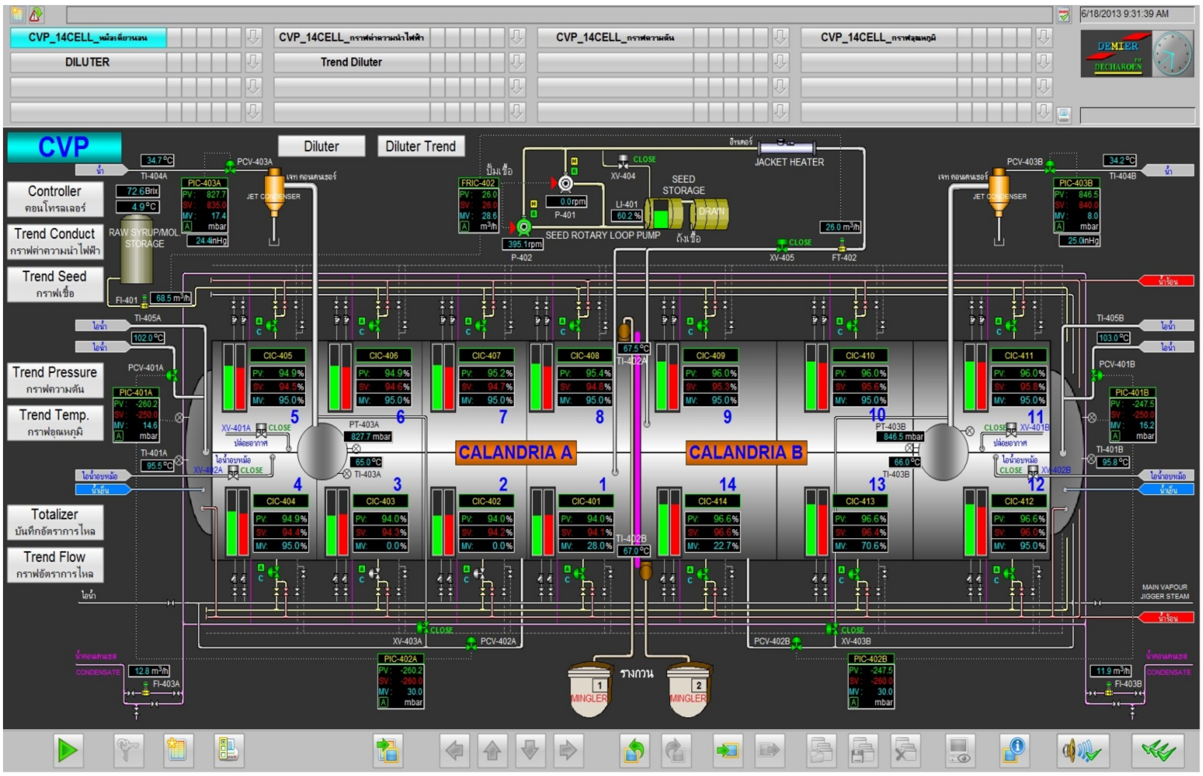

FIGURE 3. HMI screen on the operator workstation for monitoring and control

3. **Proposed Remote Monitoring.** Figure 4 shows the system architecture of the proposed remote monitoring for the crystallization in the vacuum pans from the multi-sites of the sugar production company for minimizing the requirement for experts to analyze the processes. Figure 5 shows the software architecture for detecting and collecting specified data from the sugar crystallization. At each remote factory site, the WW InTouch software is installed on the operator workstation for creating the HMI screens to monitor and control the crystallization in the vacuum pans as well as for building the script functions to detect the assigned tag names of the process KPIs (see Figure 6). The application based on visual basic (VB) software was developed to collect the KPI data obtained from the created script functions in the text file format, called comma separated value (CSV) file. This VB-based application can be installed in the operator workstation or in the separated data server, dependent on the factory's requirement. At the data center site, the VB-based application called 'Data Sync' was developed by using time synchronization method to import the text files from the remote factory site to the management/application server via the Internet. The imported text files are then stored in the database by the operations of the database management system (DBMS). The hypertext preprocessor (PHP) scripts were created to execute on the server for web development. The data transfer from one remote factory site to the data center is summarized by the flowchart in Figure 7. A technique to manage the data transfer from multi-sites to the data center as well as a method to store the KPI data imported from multi-sites in the database is our future work.

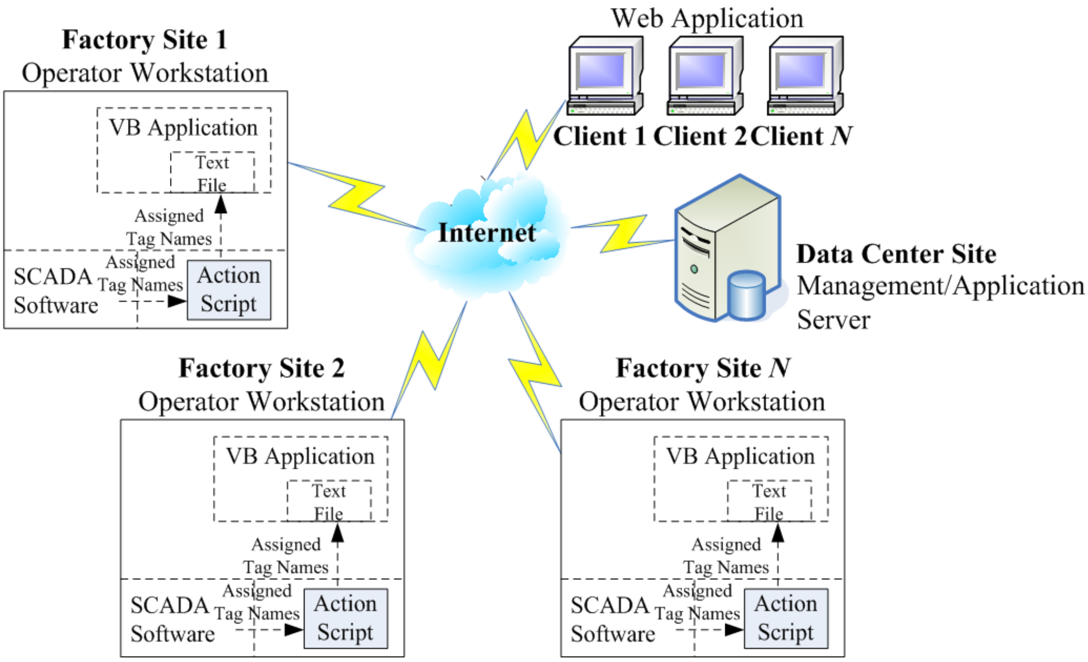

FIGURE 4. System architecture of the proposed remote monitoring

In order to demonstrate the workability of the proposed system for data transfer from the factory site to the data center in experiments, the script function divided into 4 sub-scripts was created by the WW InTouch software running on the operator workstation for detecting and collecting some KPI data from two CVPs (A pan and B pan); csvexport11 (for assigned tag names from ID101 to ID150), csvexport12 (for assigned tag names from ID151 to ID190), csvexport21 (for assigned tag names from ID201 to ID250), and csvexport22 (for assigned tag names from ID251 to ID284), where two sub-scripts were built for one vacuum pan. Each script function is required to be divided into 4 sub-scripts because of a limitation of the assigned execution time of the WW InTouch software. The CSV file can be exported from the WW InTouch by the developed script function, and

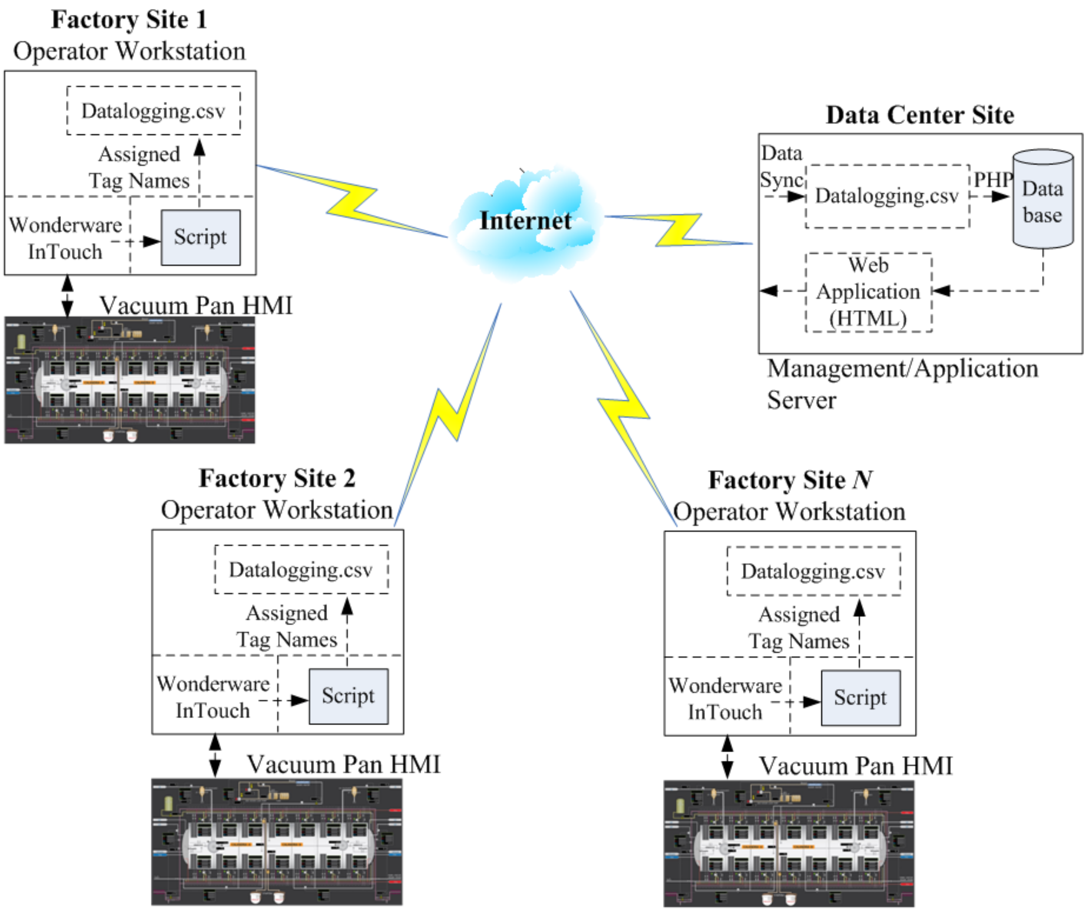

FIGURE 5. Software architecture for detecting and collecting specified data

```
TIMESTAMP = StringFromIntg($Year,10) + "-" + month + "-" + day + " " + hour + ":" + minute + ":"
+ second ;
path_1 = "E:\CSV_File\";
path_2 = ".csv";
path_date = StringFromIntg($Year,10) + month + day + hour + minute + second ;
path_save = path_1 + "datalogging" + path_2;
```

FIGURE 6. Example of script functions created for detecting the assigned tag names

the exported file is named as 'datalogging.csv'. This exported CSV file is then stored in the specified directory root on the operator workstation. To receive the text files from the operator workstation through the Internet, some parameters of the created 'Data Sync' application running on the data center are required to configure during start-up as shown in Figure 8, which include the source file path, the destination server path, and the Sync time (the requested time interval for obtaining data). The obtained CSV files are then stored in the database created using XAMPP software by the PHP command-line tool (see Figure 9), where the database table named 'dic' is composed of 'NAME', 'VALUE', and 'TIMESTAMP' columns that hold KPI data from the CVPs. The HTML was employed to design the elements within the web page such as the menu bar, log in, log out, and front-end framework template. The CSS was also utilized for specifying display properties on the web page. The PHP script function was created to access the database and to query data for web page display as shown in Figures 10 and 11, respectively.

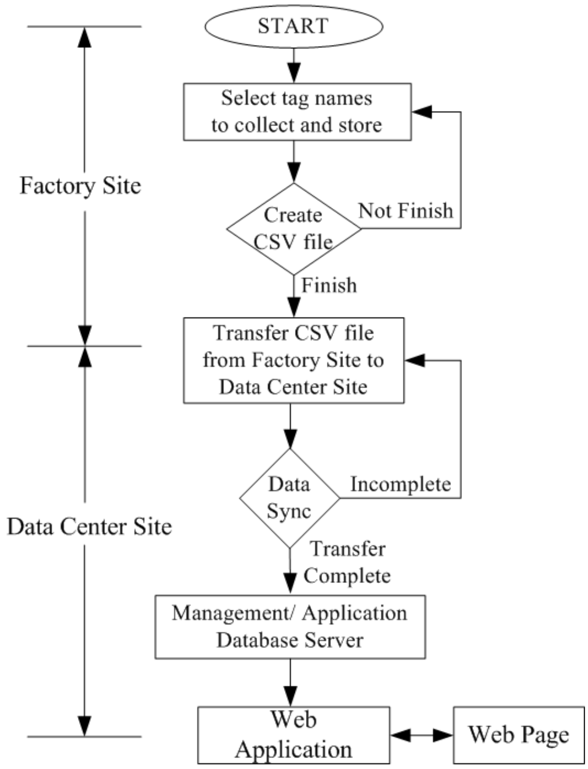

FIGURE 7. Flowchart of data transfer from the factory site to the data center

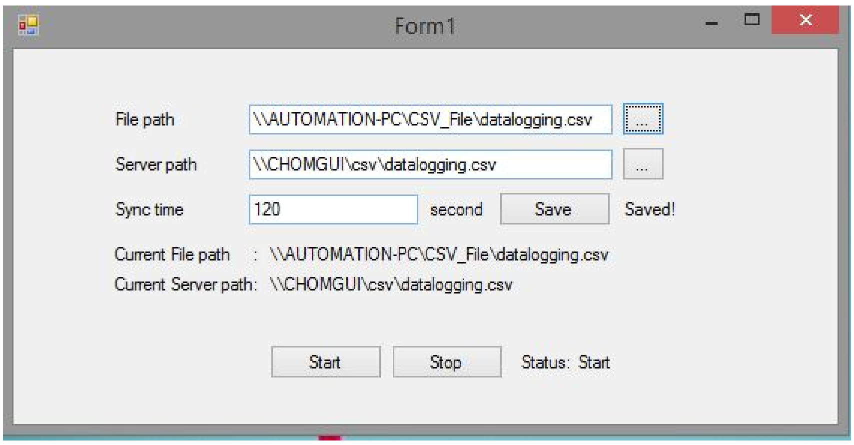

FIGURE 8. Configured parameters of the 'Data Sync' application

```php
testcsv.php
<?php
include('query.php');
if (($handle = fopen("csv/Book1.csv", "r")) !== FALSE) {
    while (($data = fgetcsv($handle, 1000, ",")) !== FALSE) {
        $strSQL = "INSERT INTO dic (NAME, VALUE,TIMESTAMP) VALUES ('".$data[1]."','".$data[2]."','".$data[3]."')";
        echo $strSQL ;
        queryall($strSQL);
    }
    fclose($handle);

}
?>
```

FIGURE 9. PHP command-line tool to import the obtained CSV files into the database

```
MyConnect.php
<?php
$hostname_MyConnect = "localhost";
$database_MyConnect = "dw_db";
$username_MyConnect = "root";
$password_MyConnect = "12152249";
$MyConnect = mysql_pconnect($hostname_MyConnect, $username_MyConnect, $password_MyConnect) or trigger_error(mysql_error(),E_USER_ERROR);
?>
```

Figure 10. PHP command-line tool to access database

```
 <?php
 $objQuery = queryall('SELECT * FROM dic where NAME ="TI104A" ORDER BY TIMESTAMP DESC LIMIT  1');
 while($result = mysql_fetch_assoc($objQuery)){
   echo '<input disabled class="showdata" style="position: absolute;left: 135px;top:36px;" type="text" value="'.$result['VALUE'].'">'; /*
   TI-104A */
 }
?>
 <?php
 $objQuery = queryall('SELECT * FROM dic where NAME ="BX101" ORDER BY TIMESTAMP DESC LIMIT  1');
 while($result = mysql_fetch_assoc($objQuery)){
   echo '<input disabled class="showdata" style="position: absolute;left: 98px;top: 79px;" type="text" value="'.$result['VALUE'].'">'; /*
   BX-101*/
 }
?>
 <?php
 $objQuery = queryall('SELECT * FROM dic where NAME ="BT101" ORDER BY TIMESTAMP DESC LIMIT  1');
 while($result = mysql_fetch_assoc($objQuery)){
   echo '<input disabled class="showdata" style="position: absolute;left:98px;top: 100px;" type="text" value="'.$result['VALUE'].'">'; /*
   BT-101*/
 }
?>
 <?php
 $objQuery = queryall('SELECT * FROM dic where NAME ="FI101" ORDER BY TIMESTAMP DESC LIMIT  1');
 while($result = mysql_fetch_assoc($objQuery)){
   echo '<input disabled class="showdata" style="position: absolute;left:153px;top: 229px;" type="text" value="'.$result['VALUE'].'">'; /*
   FI-101*/
 }
?>
```

Figure 11. PHP command-line tool to query data for web page display

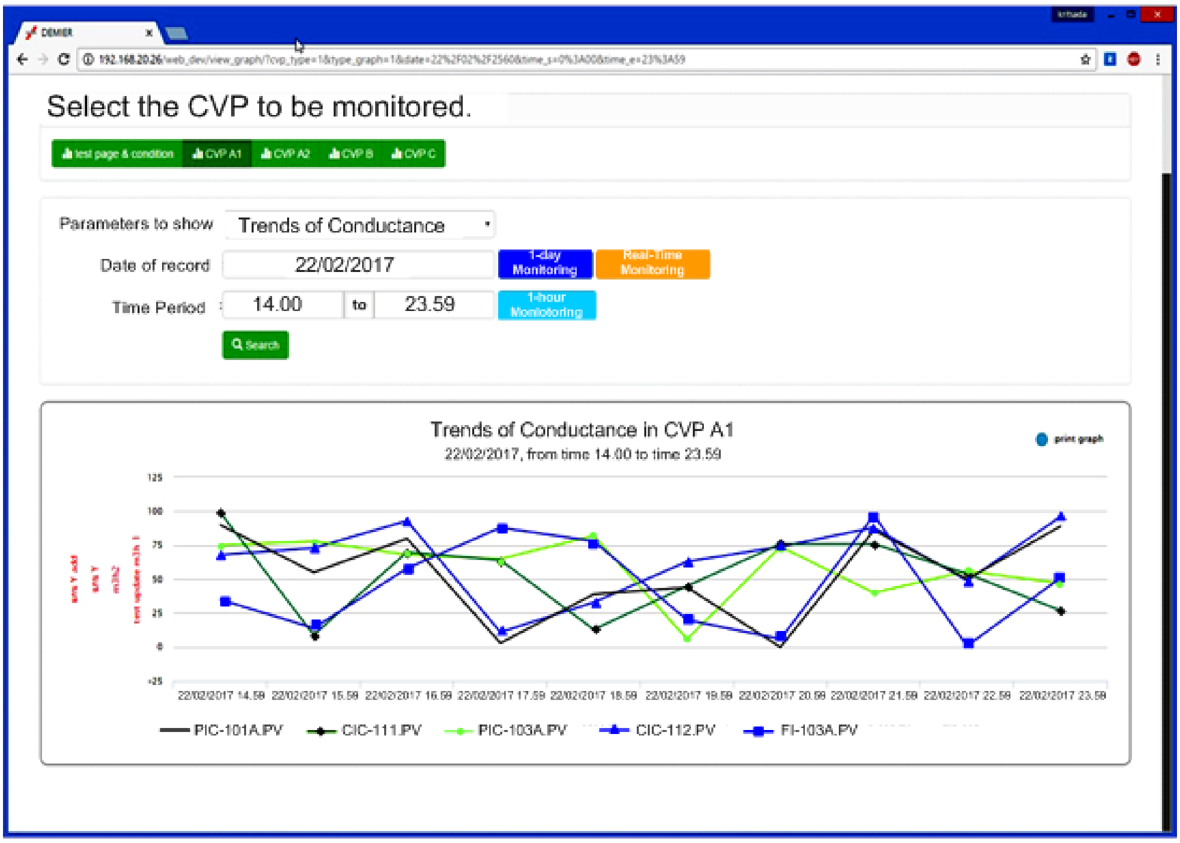

Figure 12. Trends of the interested KPI data shown on the web page

4. Experimental Results. The authenticated users only can access the web application to monitor the interested KPI data obtained from the crystallization in the CVPs. The phpMyAdmin authentication process is provided for login name and password. The authenticated users can select the query and parameters (custom time range, vacuum pan, tag) that they need to monitor. In addition, the authenticated users can also edit, add, and delete the graph for data display. Figure 12 shows the interested KPI trends shown on the web page at the client to remotely monitor the conductivity values of the studied CVPs.

5. Conclusions. The Internet-based remote monitoring for major data of crystallization process in vacuum pans to analyze the process performance has been proposed. The proposed system based on the utilization of the vacuum pans of the DECHAROEN^{TM} technology for verifying the system functionalities has been described. The technique for data transfer between the operator workstation of the remote site and the server of the data center has been introduced. The workability of the proposed remote monitoring system has been confirmed by experimental results. Furthermore, the future work should aim not only a technique to manage the data transfer from multi-sites to the data center but also a method to store the KPI data imported from multi-sites in the database.

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