**Design of Graphic User Interface for Smart Hybrid Powerpack System with IoT Technology**

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**Abstract**—This paper is an analysis of the Graphical User Interface (GUI) system to design, build, and test the Smart Hybrid Powerpack (SHP) system. The SHP is an electro-hydraulic system combined with advanced technologies, such as a remote control, a fault tolerance, and an intelligent control. A GUI system that can perform monitoring and control function is vital for a remote control of SHP. CAN-USB converting and socket enables each GUI can control and monitor SHP system. End users can take appropriate actions by monitoring data that shows state of SHP system, so the users can manage and change a control mode or an emergency stop in a manual mode. A remote control through using Mobile GUI builds an Internet of Things (IoT) structure for the SHP system. This GUI program can be verified by testing for the prototype machine.

**Index Terms**—Smart Hybrid Powerpack (SHP), Graphic User Interface (GUI), CAN communication, socket communication

I. INTRODUCTION

Conventional Hydraulic Actuator systems (CHA) have been widely used in many fields of industry. However, they have some weakness of low energy efficiency, fluid leakage, maintenance load, heavy weight, and limited installation spaces. Electro Hydraulic Actuator (EHA) systems have been developed to overcome CHA systems’ weakness [1]. EHA uses two ways of servo valves and unite other machines so that increase energy efficiency over 40% than the conventional hydraulic actuator. EHA systems could benefit from smaller size, higher energy efficiency, and faster response due to high stiffness than CHA systems. Nowadays, EHA is raising system to apply many fields of defense industry like missiles [2], rolling machines [3]. However, a GUI testing is vital for quality assurance because the GUI testing is performed from the view of the end users of the application. It’s possible to reload all the functionality of the application from the GUI [4]. SHP combined with Electro Hydraulic Platform is combined with smart control and IoT technology contains suitable GUI for system.

In this paper, we will suggest 3 types of the SHP GUIs in terms of Machine GUI, Office GUI, and Mobile GUI. The SHP system can be done by a remote control and a remote sensing through these GUI. In order to test our SHP GUIs, the actual product was used, and the product was set up by PID controller.

The rest of this paper is organized as follows: In the Section 2, this paper will introduce a composition of the SHP user interface system. In the Section 3, it will explain each GUI design, and in the Section 4, it will show the results of our test as applied real SHP system. In the conclusions, this paper will be represented in the last section.

II. COMPOSITION OF SMART HYBRID POWERPACK

The SHP is an EHA system with advanced techniques that sensor fault tolerance, network fault tolerance, intelligent control, and remote control and monitoring using office and mobile GUI. The sensor fault tolerance technique is a noise filter using Kalman filter and sensor observer using the sliding mode observer. The network fault tolerance technique is an error control code for a wire and a wireless communications between components. These fault tolerance and control techniques recover from faults like noises, disturbances, and permanent fault. With the remote control and monitoring using office and mobile GUI technique, all of these advanced techniques make it as the SHP system. The structure of SHP system is shown in Fig. 1.

![The SHP system structure](image1)

Figure 1. The SHP system structure

![Structure of smart hybrid powerpack GUI](image2)

Figure 2. Structure of smart hybrid powerpack GUI
III. COMPOSITION OF POWERPACK PROGRAM

As mentioned before, the SHP system has developed through the electrical control system. The components are operated by signal of Electronic Control Unit (ECU). ECU contains control algorithms, an adaptive-fuzzy control and Kalman-filter of a fault-tolerance logic. ECU needs super control signal from human command like GUI. GUI testing is vital for quality assurance because the GUI tests are performed from the view of the end users of the application. It’s possible to reload all the functionality of the application from the GUI. This means that GUI testing can cover the entire application [5]. Also, the GUI is useful to manage and control the whole SHP system. Therefore, own GUI program is necessary for the SHP system.

Because of the advantages of efficiency, light weight, and small volume, EHA system will be applied to an excavator and a coil tilter system in industry. The primary advantages of SHP program are a remote control and a remote management. Office GUI and Mobile GUI support the management of every multi powerpack as shown in Fig. 2.

A. Design of Machine GUI

Machine GUI directly connected with ECU of SHP in order to control and monitor a system. Controller Area Network (CAN) is used to connect program and ECU. PCAN USB Pro is used as CAN communication equipment. Machine GUI program is based on JAVA and JAVA library PCAN Basic.

As shown in the Fig. 3, it shows the main tab of Machine GUI. The Machine GUI supports both monitoring and controlling widely.

A user can select an auto mode, a distance control mode, or a speed mode in the manual mode. The auto mode supports an automatic running mode that the position of the cylinder is moved to forward and backward repeatedly between 500mm~800mm.

The distance and speed mode are a control mode that selects the distance of piston control and the motor RPM control signal reference to ECU. The distance mode supports the distance control, and LVDT sensor detects state of the piston distance. The speed mode manages the rpm control of servo motor in SHP system and encoder. The hall sensor detects state of motor and sends to Machine GUI through ECU. ECU controls the machine with transferred reference signal data and login in the ECU. Data host byte order is big endian hex data with 8 byte length standard form and 500kBit/s bit rate. CAN data table is shown as below Table I and Table II.

<table>
<thead>
<tr>
<th>CAN ID</th>
<th>Byte</th>
<th>Name</th>
<th>Signal</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x700</td>
<td>0</td>
<td>Data</td>
<td>Control mode, Position Reference, Motor Speed, Max RPM</td>
</tr>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>Pressure1</td>
<td>Hi</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>Pressure2</td>
<td>Hi</td>
</tr>
<tr>
<td>4</td>
<td></td>
<td>LVDT sensor</td>
<td>Hi</td>
</tr>
<tr>
<td>5</td>
<td></td>
<td>Low</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
<td>control mode</td>
<td>Hi</td>
</tr>
<tr>
<td>7</td>
<td></td>
<td>Low</td>
<td></td>
</tr>
<tr>
<td>0x720</td>
<td>0</td>
<td>Motor speed</td>
<td>Hi</td>
</tr>
<tr>
<td>1</td>
<td></td>
<td>Low</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>Pressure1</td>
<td>Hi</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>Pressure2</td>
<td>Hi</td>
</tr>
<tr>
<td>4</td>
<td></td>
<td>LVDT sensor</td>
<td>Hi</td>
</tr>
<tr>
<td>5</td>
<td></td>
<td>Low</td>
<td></td>
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<tr>
<td>6</td>
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<td>7</td>
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<td>Low</td>
<td></td>
</tr>
<tr>
<td>0x721</td>
<td>0</td>
<td>Position reference</td>
<td>Hi</td>
</tr>
<tr>
<td>1</td>
<td></td>
<td>Low</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>Position feedback</td>
<td>Hi</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>Low</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td>Position integral/1000</td>
<td>Hi</td>
</tr>
<tr>
<td>5</td>
<td></td>
<td>Low</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
<td>quad counter</td>
<td>Hi</td>
</tr>
<tr>
<td>7</td>
<td></td>
<td>Low</td>
<td></td>
</tr>
</tbody>
</table>

Figure 3. Main view of machine GUI

Figure 4. CAN mode view of machine GUI
The control mode uses same CAN ID to send control data and distinguishes each data through packet ID like mode change and reference signal. The receiving data is distinguished by CAN ID and byte of signal. Table II is a part of receiving data for monitoring and feedback. Fig. 4 shows CAN connection tab of Machine GUI program.

B. Design of Office GUI

Office GUI program supports an integrated management of each single powerpack and operates communication with Machine GUI and Mobile GUI as a server. Office GUI program can manage multi powerpack controls and monitor with the sensor error state of each machine. As shown in the Fig. 5, it shows the main management view of Office GUI that monitor sensor state of each machine.

Office GUI is the server of SHP system. As the server of SHP system, Office GUI authorizes users to multiple. End user assigns a permission rate depending on the authorization level. As shown in the Fig. 6, it shows the log in window of the program. After authorizing as a user, the user can approach to GUI program. By selecting the picture button of a single powerpack on the computer screen, we can connect to the single Machine GUI window as shown in the Fig. 7. In the following Fig. 8 and Fig. 9, it shows the other monitoring tabs of Office GUI.

C. Design of Mobile GUI

Generally, a GUI is represented as pictures or icons on the computer screen or Mobile screen, and it provides information through them by selecting. In other words, a GUI is a combination of technologies and devices to allow a user the visualization on the screen. When the GUI meets with a smartphone, it is called, “Mobile GUI”. The goal of Mobile GUI is to increase the convenience and efficiency. The EHA by using the Mobile GUI can control and monitor a system in the real time. The configuration of Mobile GUI in the EHA consists of a coil tilter system and an excavator hydraulic system.

In the coil tilter system as shown in Fig. 10, there are two functions in terms of an auto mode and the manual mode. When the auto mode button is selected, a message or signal is sent to the Office GUI by a socket networking. The office GUI received the signal from the Mobile GUI is sent to ECU. In other words, in the auto mode selected,
the cylinder speed stays in the safety speed which is between 100 revolutions per minute and 200 revolutions per minute, and the cylinder moves the forward and backward repeatedly in the range of 400 millimeters and 450 millimeters. Simultaneously, it can be monitored in rear-time by using the other smartphones.

The front pressure, rear pressure, and cylinder stoke position as shown in Fig. 11 are displayed in the monitoring of the coil tilter system. Through this screen display, a user can find out the pressure value in the real-time. Also, he or she can find out the cylinder location in the real-time, too. This monitoring function is the mode for the observers, and it receives only signal only the pressure signal and the cylinder location signal from the office GUI. When the controller as shown in Fig. 12 in the manual mode is selected, the cylinder’s position goes to the initial location of 400 millimeters and then gets ready to the controller mode. In the controller mode, a reference input, a horizontal slide bar, the front and rear pressures, a reset button, and the four different types of the speed limits are represented on Mobile screen. A user can directly put an input value to the reference signal box or drag the bar where he or she wants to move the cylinder’s position. The cylinder’s position can be operated within 100 millimeters to 400 millimeters.

In the Excavator system as shows in Fig. 13, this display is designed in the same format as the coil tilter system, such as the auto mode button and manual mode buttons. However, the difference is the top picture in the display. The function of the auto mode is the same as the auto mode of coil tilter system, but the moving range of the cylinder’s position is between a negative 450 millimeter and a positive 450 millimeter like the up and down.

In the monitoring mode, a motor speed, cylinder stokes force, a desire vale, and arm angle are displayed in the monitoring of the excavator. An observer can monitor these terms in his or her smartphone in the real time.

In other words, the minimum is 100 millimeters, and the maximum is 400 millimeters. Therefore, a user can only put an input value between 100 millimeters and 400 millimeters. By using the send button in the controller mode, the desired value is sent to the office GUI. The speed buttons are divided into three speed limits in terms of a safety, a normal, and a fast speed. Respectively, the speed buttons have its own speed limits and signal ID values. The maximum speed of safety is between 100 revolutions per minute and 200 revolutions per minute, the normal speed is between 500 revolutions per minute and 700 revolutions per minute, and the fast speed is between 900 revolutions per minute and 1000 revolution per minute. As one of buttons in the speed section is selected, immediately the signal ID value is sent to the office GUI.

In the controller in the manual mode as shown in Fig. 14, a user can control the cylinder speed and position through this controller screen. The three buttons, which are boom, ram, and bucket play the role of the speed control. The boom is 150 revolutions per minute, the arm is 450 revolutions per minute, and bucket is 750 revolutions per minute. The vertical slide bar is located between the excavator picture and the speed section as shown in the Fig. 14. The bar is dragged by the up and down direction between a negative 750 millimeter and a positive 750 millimeter.
D. GUI Communication Structure

The SHP powerpack program is constructed of Java JDK 1.8 platform. The virtual Machine and the compiler of Machine GUI and Office GUI are used through Eclipse and NetBeans. ECU of the SHP and Machine GUI communicate to each other with CAN communication. Machine GUI, Office GUI, Mobile GUI communication implements with socket networking. The structure of the SHP GUI is shown in Fig. 15. The five types of sensor signals (LVDT, Pressure 1, Pressure 2, Encoder, Hall, and Temperature) transfer from the EHA to machine GUI through CAN to USB converter. Machine GUI allocate sensor signals to variable by CAN ID classification and hex data to decimal data transform. Machine GUI performs based on allocated sensor variable. At the same time, the sensor variable of Office GUI is allocated by TCP socket. Office GUI reflects the changes in the variables in real time. Mobile GUI variables are also allocated from socket in real time for monitoring. In the case of controlling, the thread in the Office GUI catches change of variables and generates events to allocate. Finally, the multi Powerpack system is configured with several powerpack Machines and ECU, one Office GUI and several Mobile GUI structure shown in Fig. 16.

IV. GUI PROGRAM TEST ON THE SHP SYSTEM

After develop GUI programs, it was applied to real EHA system for a test. The real EHA system which uses consists of hydraulic HWs, ECU, electric power source, CAN communication equipment, laptop for Office GUI, and smartphone for Mobile GUI shown in Fig. 17 and Fig. 18. In this test, GUI was tested in Single powerpack to Single GUI structure.

First, we operated EHA system by using Office GUI and observed the state of the system in Office GUI and Mobile GUI. Next, we sent control signal from Mobile GUI and similarly observed the state of the system in Office GUI and Mobile GUI. In each step, the system ran well and values of its sensors were represented in each GUI without problem. 3 types of control modes and emergency stop mode also worked properly.

From these steps, we composed real EHA system and applied developed GUIs to the system, and then confirmed that developed GUIs operate well in real system.
V. CONCLUSIONS

In this paper, JAVA based Office GUI and Android based Mobile GUI was developed for EHA system. The 1st function of the GUIs monitors the state of the system, such as cylinder’s pressure, temperature, and distance. The 2nd function is to control values such as the motor speed and cylinder distance for EHA system. Mainly, EHA system is operated by Office GUI which uses CAN to communicate with ECU of the system and monitored also. Meanwhile, if it is needed, the system also can be operated by Mobile GUI. In that case, user can send control signal from Mobile GUI, and then the signal will be transmitted to Office GUI and ECU.

These GUIs provide user with means not only to recognize the state of the EHA system intuitively, but also to control the system. Especially, by using Mobile GUI, users who are far away from the office or the system can monitor and control.

In the near future, these GUIs will be improved and completed. After that, they can be used in real industry.

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REFERENCES


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