A control system based on field programmable gate array for papermaking sewage treatment

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Abstract. A sewage treatment control system is designed to improve the efficiency of papermaking wastewater treatment system. The automation control system is based on Field Programmable Gate Array (FPGA), coded with Very-High-Speed Integrate Circuit Hardware Description Language (VHDL), compiled and simulated with Quartus. In order to ensure the stability of the data used in FPGA, the data is collected through temperature sensors, water level sensor and online PH measurement system. The automatic control system is more sensitive, and both the treatment efficiency and processing power are increased. This work provides a new method for sewage treatment control.

1. Introduction
At present, the impact of papermaking wastewater on the environment is more and more serious. In recent years, although sewage treatment has made some achievements, wastewater emission by some enterprise does not satisfy national requirements [1-2]. Wastewater treatment process in paper mills has a very high requirement for analog closed-Loop control system, and the logical relationship of the process is very complex [3-5]. Ensuring the high efficiency is the key of sewage treatment process, so a high level of automation control design is very important.

The principal benefit of the FPGA is unparalleled design flexibility as to where you place the border between hardware and software. The programmability of an FPGA makes it larger (in terms of transistor count) than an equivalent hardwired chip. In this paper, FPGA technology is used to design to improve the efficiency of papermaking wastewater treatment. We have designed a sewage treatment control system based on FPGA. VHDL language is used to design each part of the control program, and Quartus II is used for simulation.

2. The basic process of wastewater treatment
Sewage of paper mill emits from sewer line and flows through the thick grille and fine grille. Large particles in the waste water are filtered effectively by the grille, and the impurities are recycled so as to save raw materials [6]. The process of sewage treatment and reuse is shown in figure 1. Papermaking wastewater treatment process is very complex. In addition to electromechanical equipment, there are also some peripheral equipment, for example digital display devices. The treatment control process designed with FPGA is a very feasible scheme. Since FPGA is used in mechanical equipment control

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system, system operation becomes more convenient, and treatment efficiency and processing power are greatly improved.

![Diagram of Paper Mill Sewage Treatment and Reuse Figure](image)

**Figure 1.** Paper mill sewage treatment and reuse figure.

3. **FPGA digital display system**

Devices in control room and electrical equipment room are used to monitor and control the whole process. In the control room there is a digital indicator that can display temperature, water depth and pH value. All of the data is collected by sensors and processed by FPGA. The display method of the digital indicator is LED dynamic display, and the digital display system is designed with FPGA, MAX7000AE series model for EPM7064AEFC100-7.

Simulation results of Quartus II software are shown in figure 2. When reset='1', screen displays ‘0’; when reset='0', scan starts counting. The input signals are din1, din2, din3 and din4, and the output signals are bus4 and shift. When scan_clk= ‘00’, ‘01’, ‘10’ and ‘11’, bus4 outputs the values of din1, din2, din3 and din4, respectively. This figure shows that the simulation results were consistent with the program, and this program met the demand of the design.

![Simulation Results of FPGA Control LED Displays](image)

**Figure 2.** The result of FPGA control LED displays the simulation.
4. Processing system control of FPGA

This process is designed with FPGA, MAX7000AE series model for EPM7032AEELC44-7 (Altera Company). This chip can completely meet the needs of the design with low cost. We designed the main part of the whole control process. The main control process is shown in figure 3.

![Figure 3. Main control process.](image)

We control start or stop of each step through the switch. Step 1 is waste water pool control process, and step 7 is drain valve control process.

Step 2: This process uses a rake tooth chain rotary grille decontamination machine, which has a strong effect on decontamination. Machine automatically stops after continuing operation one hour and can open again after half an hour.

Step 3: In this design a mechanical brush aerators is used to do aeration work, and an automatic heating device is installed in the pool. Aeration equipment starts heating when the temperature is below 20 °C, and it stops heating automatically when the temperature is beyond 45 °C. A temperature sensor which outputs current (simulator AD590) is used to measure the temperature. The current of sensor outputs from 223 μA (50 °C) to 423 μA (+150 °C), so the sensor can be applied to multi-point temperature measurement and long distance temperature measurement.

Step 4: Considering the difficulty on treating papermaking wastewater, the cycle frequency of mechanical scraping mud can be set to 1 hour. In the settling tank, the inlet valve and the discharge valve can be opened or closed independently. A water level warning device is put in the settling tank. When the level of water in the pool is more than eight meters, the warning device will make an alarm. The water level measurement sensor adopts the model XLH-LHY63 (Beijing), which can work well at the temperature of 40 degrees to +125 degrees.

Step 5: Mechanical scraping mud device can be open and closed at any time, and the work cycle is 1 hour.

Step 6: Equipments of sewage pool work all day. When the pH value of wastewater is from 6.5 to 7.5, the equipments stop running; when the pH value is out of the range, the equipments open the operating mode automatically. The measurement sensor for pH value uses online pH measurement system (Mettler Toledo), which can satisfy the sewage treatment environment and has certain precision.

Partial program is as follows:

```
P1: PROCESS (CLK,E_IN(1)) ----------------------------------------------- ---Waste water pool control
    BEGIN
    IF(CLK'EVENT AND CLK='1')THEN
    E_OUT(1)<=E_IN(1);
    IF(E_IN(1)=1')THEN
    SWITCH1_OUT<=SWITCH1;
    ELSE SWITCH1_OUT<='0';
    END IF;
    END IF;
```
END PROCESS;

P2:PROCESS(CLK,E_IN(2))---------------------------------- Grille decontamination machine control
BEGIN
IF(E_IN(2)='1')THEN
    IF(CLK'EVENT AND CLK='1')THEN
        PR_STATE2<=NX_STATE2;
        IF (TIMER2=1800) THEN TIMER2<=0;
        ELSE  TIMER2<=TIMER2+1;
        END IF;
    END IF;
END IF;
END PROCESS;
PROCESS(CLK)
BEGIN
CASE PR_STATE2 IS
WHEN STATEA2 =>
    IF(TIMER2=1800)THEN
        NX_STATE2<=STATEB2;
        SWITCH2<='1';
        END IF;
    END CASE;
END PROCESS;

P3: PROCESS(CLK,E_IN(3))---------------------------------- Aeration pool control
BEGIN
IF(CLK'EVENT AND CLK='1')THEN
    E_OUT(3)<=E_IN(3);
    IF(E_IN(3)='1')THEN
        IF( TEMPERATURE3>45)THEN SWITCH3<='0';
        ELSIF(TEMPERATURE3<20)THEN SWITCH3<='1';
        END IF;
        ELSE  SWITCH3<='0';
        END IF;
    END IF;
END PROCESS;

P7:PROCESS (CLK,E_IN(7))---------------------------------- Waste water discharge
BEGIN
IF(CLK'EVENT AND CLK='1')THEN
    E_OUT(7)<=E_IN(7);
    IF(E_IN(7)='1')THEN
        SWITCH7_OUT<=SWITCH7; ----------------------------------------------Open shutoff Settings
        ELSE  SWITCH7_OUT<='0';
        END IF;
    END IF;
END PROCESS;
END BEHAV;
Simulation results of Quartus II software are shown in figure 4. The working condition of each step is shown by the level of SWITCH1, SWITCH2, SWITCH3, SWITCH6, SWITCH7_OUT, and SWITCH5-OUT. When the signal is at the high level, the equipments stop working; when signal is at the low level, the equipments start working. Take the third part as an example: when TEMPERATURE3>45, SWITCH3<=’0’, aeration equipment stops heating, but when TEMPERATURE3<20, SWITCH3<=’0’, aeration equipment starts heating. The figure shows the simulation results were consistent with the program, and this program met the demand of the design.

Figure 4. Process simulation results.

5. Conclusions
The principal benefit of the FPGA is unparalleled design flexibility as to where you place the border between hardware and software. In this paper, an automatic control system based on FPGA is designed for sewage treatment. VHDL is used to write the main codes and Quartus II software is used to simulate and compile. Sensors and PH measurement system are used to measure and transfer the current signals to FPGA. The control system operation is convenient, and treatment efficiency and processing power are greatly improved. In a word, this automatic control system based on FPGA for sewage treatment is economical and practical.

Acknowledgments
This paper is supported by the National Science Foundation of China under Grant No.51077035, and the Science Foundation of Hebei province No.A2010000182.

References
[1] Wu S B 2011 Beijing: CIP (in Chinese). p12
[2] Li J and Gao P J 2005 Beijing: CABP (in Chinese). p22
[3] Jiang H and Li Z Y 2007 Microcomputer information (in Chinese) 23 11
[4] Zhang K, Kang Y and Xiong J 1999 Power Electronics (in Chinese) 22 12
[5] Analog Devices 2004 ADSP-TS101 Tiger SHARCR Embedded Processor, Rev. B.
[6] Huan B G, Lei B and Wang P 2011 Environ. Sci. Technol. 9 51