MT25

Design and Implementation of a Monitored Control System of the 100 MVA/100 MJ Pulsed Generator Power Supply at WHMFC

Yun Xu, Taiqiang Sun, Lixia Chen, Tieqiang Ren, Hongfa Ding, Liang Li, Yuan Pan

Wuhan National High Magnetic Field Center, Huazhong University of Science and Technology, Wuhan, China

I Introduction

With the characteristics of high energy density and good control performance, A 100 MVA / 100 MJ flywheel pulse generator power supply system has been developed at the Wuhan National High Magnetic Field Center (WHMFC), which energize for the a series of experiments including 100T, 50T flat-top, repetitive 20T, 5 / 10 / 15 / 20 multi-stage pulse magnetic fields. For these experiments, a three-level monitored control system including remote control, process control and real-time control is designed. This paper will analyze the functions and implementation methods of the three-level monitored control system based on the working process and the protection of the pulse generator power supply system. Experiments indicate the monitored control system can realize the remote control of pulse power discharge, energy feedback and dissipating energy in magnet and real-time control of magnetic field waveforms. The experimental results show this system is stable, reliable, and easy to use, and can meet the security, flexibility and visualization requirements.

II The Structure of the Control System

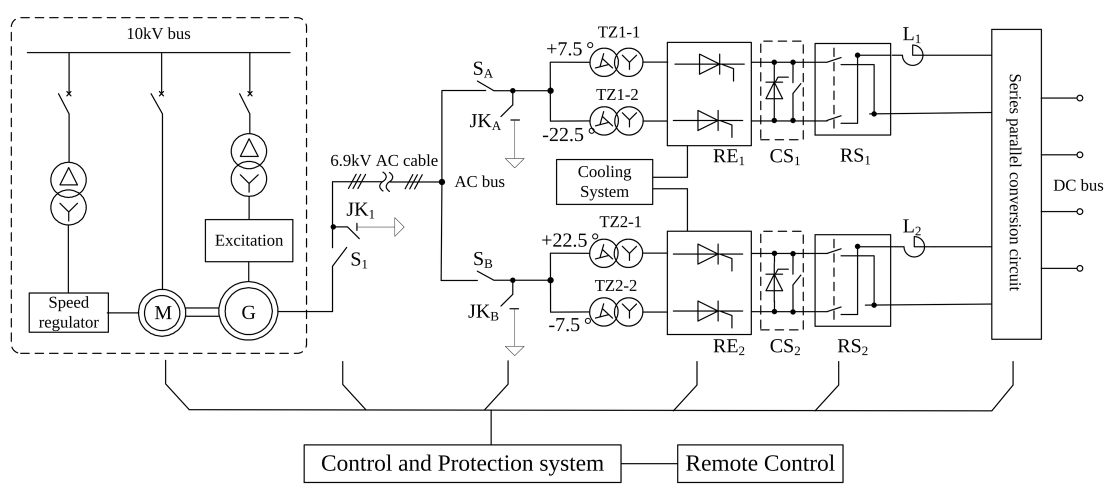


Fig. 1. Power supply layout for the 100 MVA / 100 MJ flywheel pulse generator power supply system

Four supply Mode: 1) one rectifier; 2) series; 3) parallel; 4) two rectifiers for two coupling magnet coils

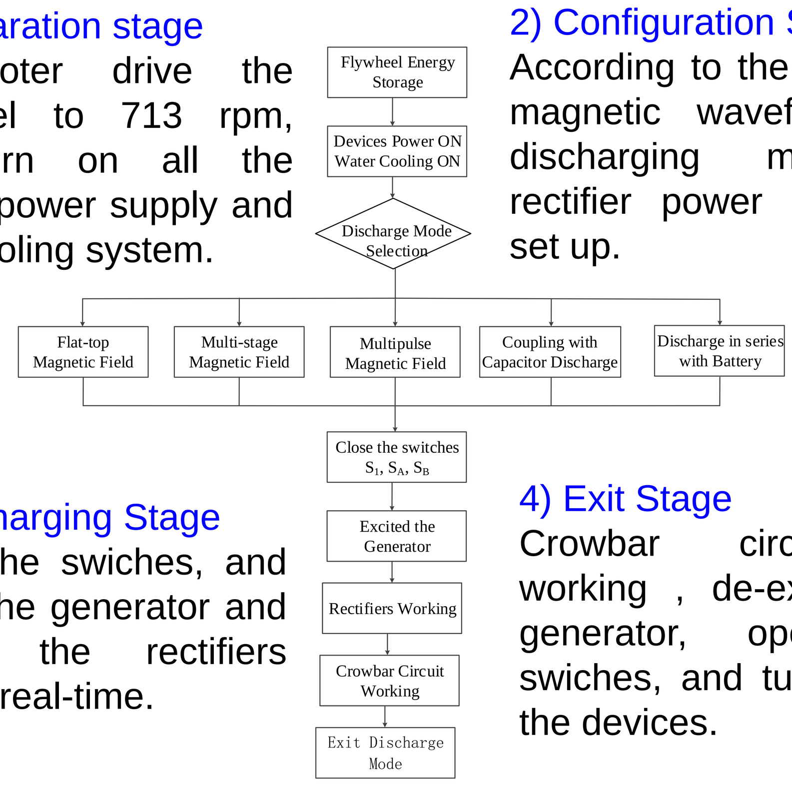
Fig.1 shows the overall layout of the power supply system. The power supply system consists of a 100 MVA motor-generator set, one vacuum circuit breakers (S_1), two combined input disconnect / grounding switches (S_A/JK_A, S_B/JK_B), two 12-pulse rectifiers (RE_1, RE_2) with the associated transformers ($TZ_{1\text{-}1,\ 2}$, $TZ_{2\text{-}1,\ 2}$), two crowbar switches (CS_1, CS_2), a reversing switches (RS_1 , RS_2), and the control and protection system. A 100 MVA/185 MJ inertial energy storage motor-generator (MG) set, which is able to yield 95 MJ energy with the rotor speed reducing from approximately 713 rpm (95 Hz) to 495 rpm (66 Hz), provides energy to the magnet .

1) Preparation stage

The moter drive the freewheel to 713 rpm, then turn on all the devices power supply and water cooling system.

2) Configuration Stage

According to the expected magnetic waveform, the discharging mode of rectifier power supply is set up.



3) Discharging Stage

Close the swiches, and excite the generator and control the rectifiers current real-time.

4) Exit Stage

Crowbar circuit is working , de-excite the generator, open the swiches, and turn off all the devices.

Fig. 2. Discharging flow diagram of the pulse generator power supply system

The monitored control system

The three level structure is the remote control level, the process management control level and real-time control level.

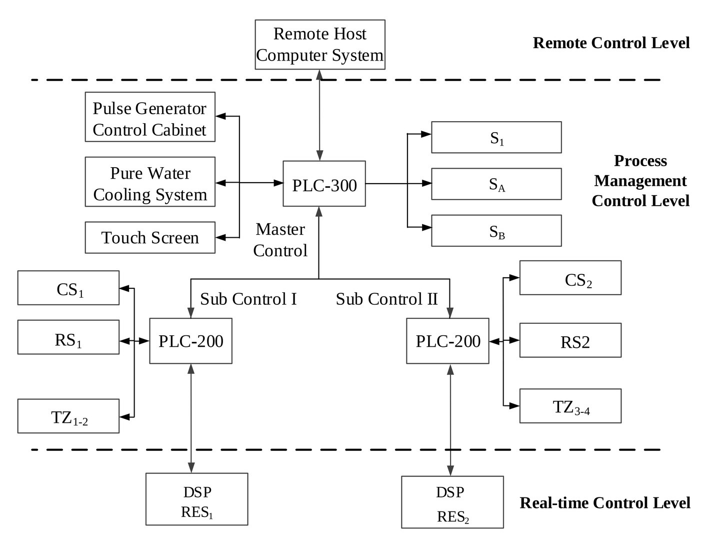


Fig. 3. 3-level Control system Schematic

III The Design of the Control System

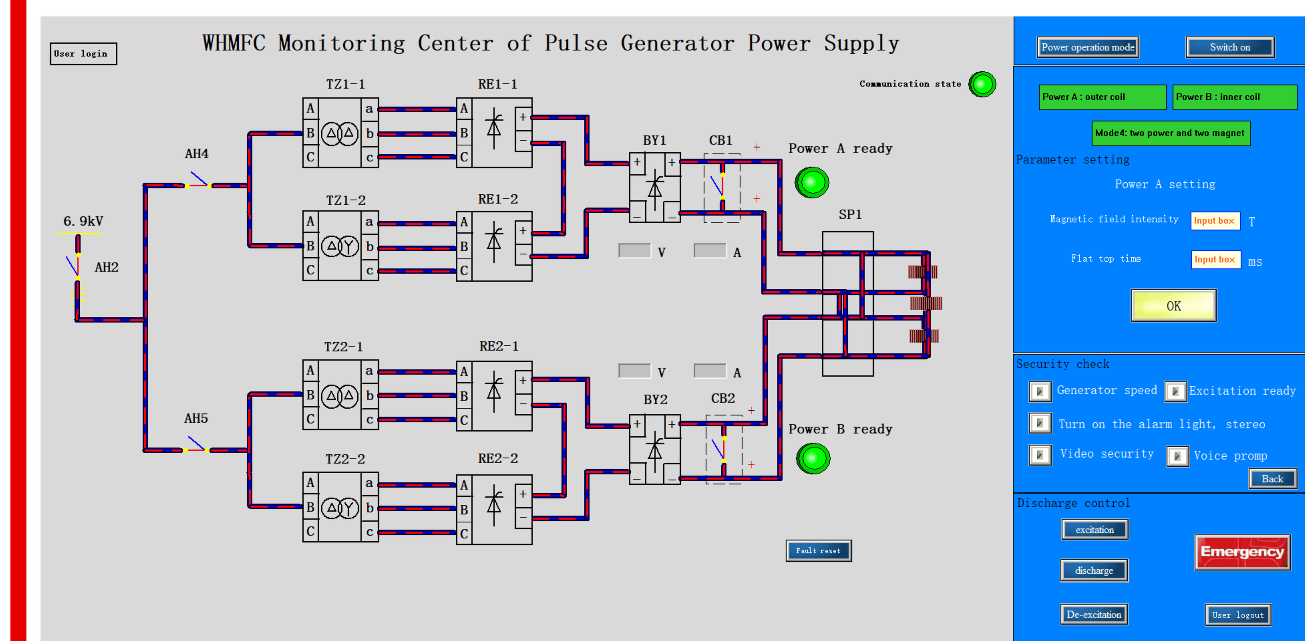


Fig. 4. Human Machine Interface of the Remote Control

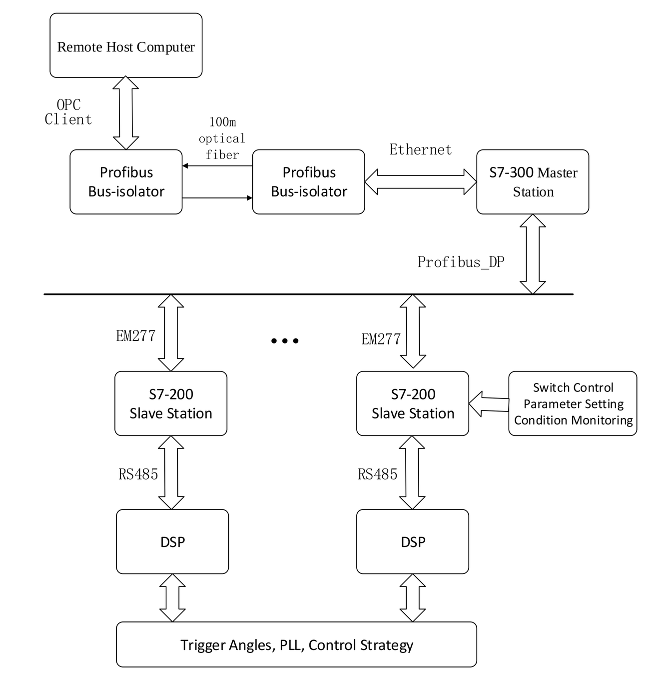


Fig. 5. The Structure Diagram of the Communication

Siemens PLC's communication protocol is not public, so the direct communication between the computer and PLC is limited, fortunately the OPC (OLE (Object Linking and Embedding) for Process Control) can effectively help to relate the third party development tools and Siemens PLC. Profibus-DP is a high speed and low cost communication for field level applications, which is used for communication between device level control systems and distributed I/O. So Profibus-DP is applied to the communication between PLC-300 and computer, between PLC-300 and PLC-200. RS485 serial communication is used between PLC-200 and DSP. Considering that the control system is in the harsh environment of high voltage and strong magnetic field, optical fiber is used as communication medium between remote computer and field equipment. The detailed communication structure is shown as Fig. 5.

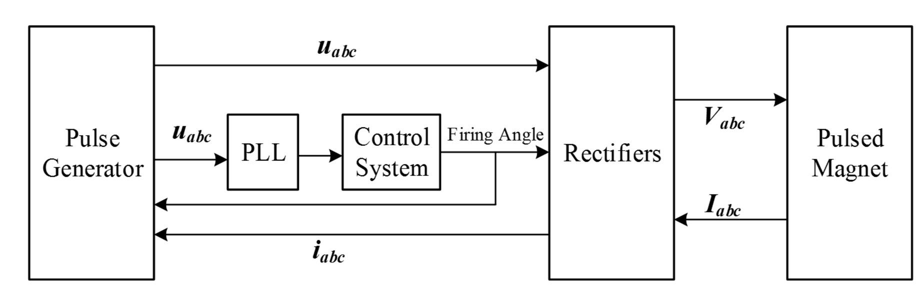


Fig. 6. The schematic of the magnetic field generation system

The proposed PLL directly converts the instantaneous values of voltages to corresponding phase angle deviation. A filters is designed to eliminate the influence of the harmonics. The estimated angle $\hat{\theta}$ is achieved by compensating phase angle $\omega_0 t$ of dq-RF with filtered φ_{dq} (as $\hat{\varphi}_{10}$). This proposed PLL is fast due to its open-loop computation and can totally get rid of the fluctuation of the amplitude of the three-phase voltages.

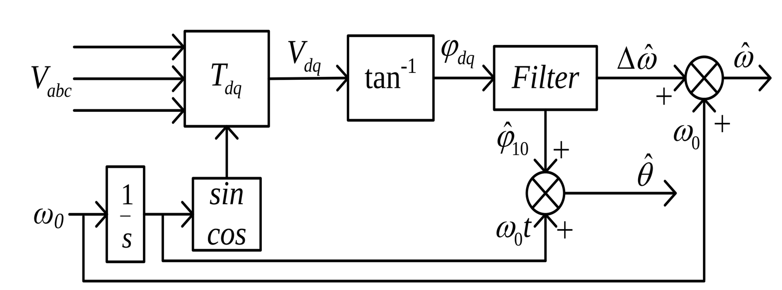


Fig. 7. The schematic of the rectfier power supply

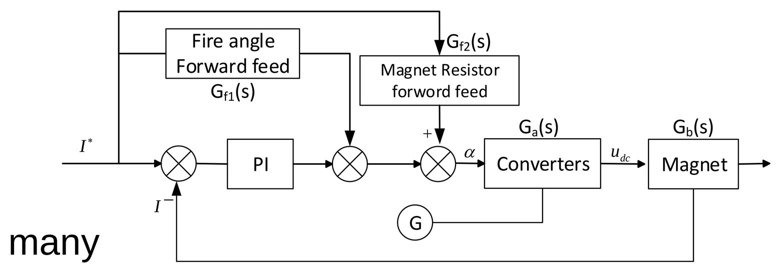


Fig. 8. The schematic of the rectfier power supply

The specialized control method is essential to get the many types of magnetic field waveforms and to overcome the violent change of the magnet resistor and the output voltage of the generator. Considering of the short pulse period, quick response is the primary concern of the controller. In this paper, a closed-loop with feed-forward control system is proposed as shown in Fig. 8. The forward feeding provides the firing angles to roughly compensate the increase of the magnet resistance and the PI close-loop is used for reducing the errors caused by disturbances in the system. The forward feeding is designed to improve the response speed and the close-loop is to ensure the control precision, sothe combined controller has fast response and good steady accuracy.

IV Expetiment Results

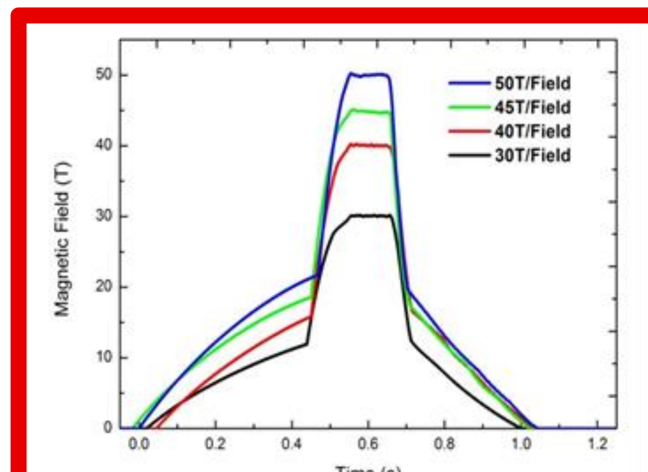


Fig. 9 The waveforms of flat-top magnetic field 30T to 50T

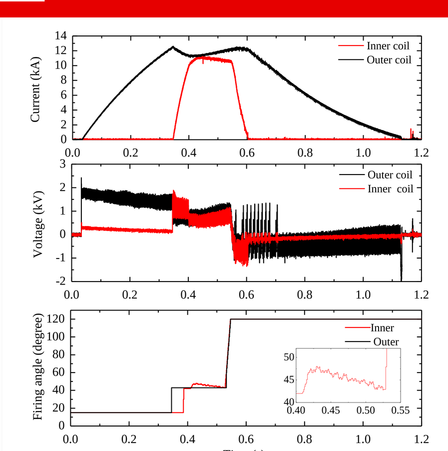


Fig. 10 The current, voltage and trigger angle waveforms of flat-top magnetic field 40T

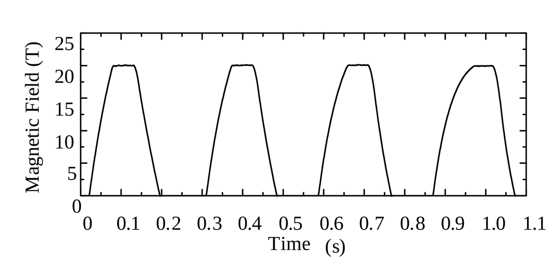


Fig.11 The waveforms of multi-pulse magnetic field 20T/20T/20T/20T

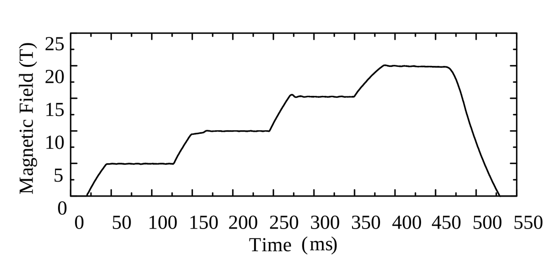


Fig.12 The waveforms of multi-stage magnetic field 5T/10T/15T/20T0

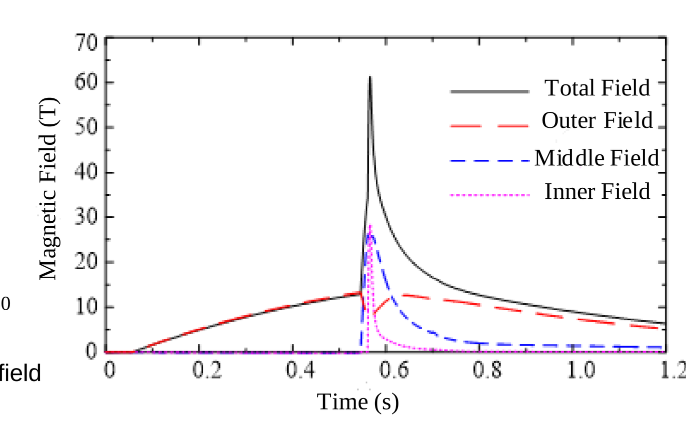


Fig.13 The magnetic field waveforms of 3 coils magnet

V Conclusion

In this paper, a monitored control system for the pulse generator power supply is designed. This control system is composed of 3 subsystems. The remote control subsystem is for the human machine interface, experiment configuration, clock synchronization and data management. The process management control subsystem is to arrange the related non-real time devices. The real time control subsystem is duty on the control strategy and giving trigger signals. The 3-level control system is suitable for this complicated multi-purpose high power system. By this system, the flat-top field from 30T to 50T, the repetitive 20T, multistep field as 5T/10T/15T/20T and background field in the 3 coils magnet are generated as expected.

The results of the experiment indicate the design and implementation of a monitored control system of the 100 MVA/100 MJ pulse generator power supply is feasible. More than 1000 shots on WHMFC have been carried out on this power supply system safely.

WHMFC

WUHAN NATIONAL HIGH MAGNETIC FIELD CENTER

Yun Xu
HuaZhong University of Science and Technology, WuHan, Hubei Province, 430074, China
TEL : +86 18971619300
Email: xuyun@hust.edu.cn

PRESENTATION ID NUMBER

Mon-Af-Po1.12-16