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

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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 energizes 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

Four mode: 1) one rectifier, 2) series, 3) parallel, 4) two rectifiers for two coupling magnet coils. The power supply system consists of a 100 MVA motor-generator set, one vacuum circuit breakers (S1), two combined input disconnect / grounding switches (S2/S3), two 12-pulse rectifiers (RE1, RE2) with the associated transformers (T2, T2), two crowbar switches (CS1, CS2), a reversing switches (RS1, RS2), and the control and protection system. A 100 MVA/185 MVA 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.

The monitored control system

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

III The Design of the Control 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 phase is used in the compensation phase angle $\omega_d$ of dp-RF with filtered $\omega_m$ (or $\omega_m$). This proposed PLL is fast due to its open-loop compensation and can totally get rid of the fluctuation of the amplitude of the three-phase voltages.

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 close-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, so the combined controller has fast responses and good steady accuracy.

IV Experiment Results

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 system is feasible. More than 1000 shots on WHMFC have been carried out on this power supply system safely.