CONTROL AND PROTECTIVE SYSTEM FOR A PLASMA FOCUS INSTALLATION

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Abstract

The paper presents a control and protective system for the plasma focus installation IPF-4/5A of 1 MA plasma current. All the fusion installation sequences are governed by strict hard and soft interlocking using in parallel two control and protective systems: one based on PC-control methods and other based on classical control techniques.

1 INTRODUCTION

A Control and Protective System, designated CPS-4/5A, was designed for the plasma focus installation IPF-4/5A, the fifth installation of this type designed and built in Romania. IPF-4/5A main parameters are: capacitor bank charging voltage 14-20 kV, maximum stored energy 45 kJ, peak plasma current 1 MA, working gas (deuterium) pressure 1-5 torr.

2 DESCRIPTION OF THE IPF-4/5A PLASMA FOCUS INSTALLATION

An overall view of the IPF-4/5A plasma focus installation is presented in Fig. 1, showing the main components of the high power circuit (capacitor bank, switches, and high voltage pulse generators). IPF-4/5A main sub-systems are described below.

The discharge chamber consists of the coaxial plasma accelerator connected to the plasma focus driver (pulsed power supply) by means of a disk shaped current collector. The coaxial accelerator uses stainless steel electrodes, with the central electrode having a heavy alloy insert.

The high voltage capacitor bank (modular structure) uses high current spark gap switches of the CIT-10/20 type [1]. Energy transfer from the HV capacitors to the discharge chamber collector is done by means of 150 low inductance coaxial HV cables.

The measurement and acquisition system consists of 12 devices for the detection of the electromagnetic, optical and nuclear phenomena. Signals generated by various transducers are simultaneously transmitted over 30 acquisition channels (bandwidth ~200 MHz).

The control and protective system CPS-4/5A ensures the control and automatic operation of the whole experimental facility [2].

IPF-4/5A has been used mainly for fusion studies (investigation of the plasma focus neutron generation): produces neutron yields up to $5x10^9$ neutrons/pulse [3].

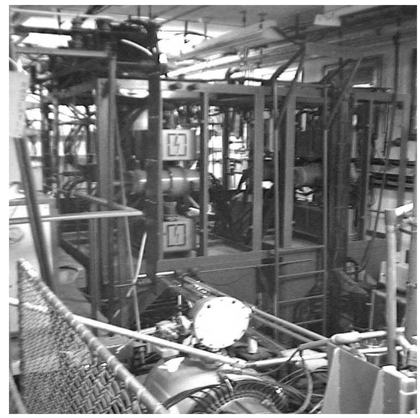

Figure 1: Overall view of the IPF-4/5A plasma focus installation

3 DESCRIPTION OF CPS-4/5A

CPS-4/5A was designed to operate in a very harsh environment due to high voltage (tens of kV, d.c. and pulsed), high currents (around 1 MA) with very high derivatives (10^{12}A/s), intense nuclear radiation (neutron and hard X-rays) pulses. Due to IPF-4/5A complexity and the specific conditions under which it operates, CPS-4/5A has been designed to allow simultaneous or alternate use of both classical automation techniques and modern on-line computer control. Main CPS-4/5A functions are:

- Personnel and sensitive apparata protection against dangerous events by centralized control of all protection devices (programmed interlocking and warning signals during experimental runs);
- Prevention of IPF-4/5A malfunction and reduction of device misfire, as well as control of fusion device operation in a preselected time sequence;
- Protection against electromagnetic interference.

3.1 System configuration and working principles of CPS-4/5A

CPS-4/5A block diagram and IPF-4/5A main sub-assemblies are shown in Fig. 2. The control and protective system allows main IPF-4/5A subassemblies (condenser bank charging and discharging system CDS, spark gap switch triggering system SGS-TS, vacuum and gas filling system VGFS) to be operated both individually, at the same control level, and centralized, in a hierarchy-like structure.

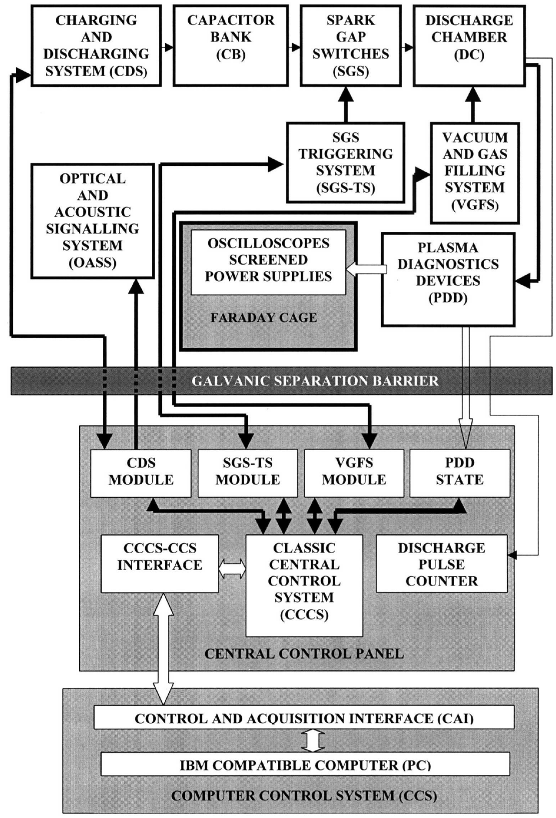

Figure 2: CPS-4/5A block diagram and IPF-4/5A main subassemblies

Moreover, main IPF-4/5A subassemblies may be controlled from their local control panels as well as from the corresponding modules in the central control panel (CCP). Fig. 3 shows the IPF 4/5A central control panel, illustrating the location of the operating modules: SGS-TS, CDS, VGFS, discharge pulse counter (DPC), plasma diagnostic devices (PDD) status signaling, classic central control system (CCCS) and CCCS to computer control system (CCS) interface. In order to prevent any electromagnetic coupling between high power components of the fusion installation and the control system, the latter is separated by a galvanic separation barrier consisting of optic fiber cable assemblies (for analogue signals) and of low stray-capacitance transformers (for logical commands and states).

The slow time-varying signals (working gas pressure in the discharge chamber, switch triggering system charging voltage and condenser bank charging voltage) are transmitted to CPS-4/5A via the measurement chains (transducer, voltage to frequency converter, infrared emitter, optic fiber cable, optical pulse detector and frequency to voltage converter). The measurement chains deliver voltages proportional to the input value (within a precision of 2%). The evolution of the slow time-varying signals is surveyed by the operator both by means of classical instruments (on control panel) and by means of the computer control system. Digital commands and statuses are transmitted via high voltage and low stray capacitance separation transformers (24 Vac/24 Vac). CPS-4/5A units and the HV components of IPF-4/5A are coupled to the main a.c. supply via separation transformers of various powers from 500 VA to 6 kVA.

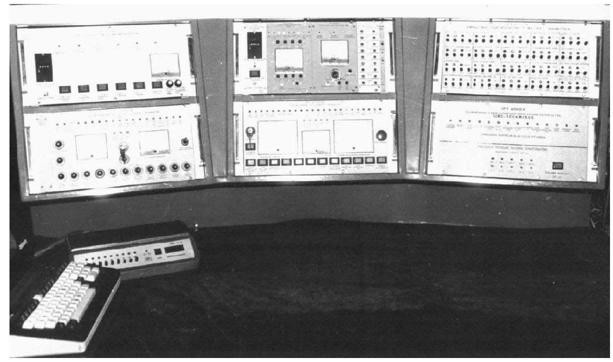

Figure 3**:** IPF-4/5A central control panel

Fig. 4 shows some parts of the galvanic barrier. The high voltage on CB modules is detected by five HV dividers and transmitted to the operator via five optical chains, each ending up with a LED on the central control panel

(a) (b) (c)

Figure 4: Some parts of the galvanic separation barrier; (a) Optical system which transmits the analogue signals through fiber optic cable assemblies; (b) high voltage–low stray capacitance separation transformers of 24 VA for the logical commands and states (24 Va.c. /24 V a.c. and 0.022pF measured stray capacitance); (c) high voltage –low stray capacitance separation transformers of 500 VA for the feeding to the main a.c. supply (0.025 pF measured stray capacitance);

The spark gap switches operation is detected by five Rogowsky coils and transformed into five optical signals of 30 seconds duration. The information provided by these two systems is used to locate certain post-discharge failure effects within the experimental installation. The current through the discharge chamber is detected by a magnetic probe, giving a fast rising, short signal that is transmitted via a high voltage-high frequency separation transformer, processed in order to increase its duration to a few seconds and then supplied to the discharge pulse counter (DPC). This delivers a delayed command to actuate both the high current switch gas purging device and the neutron activation counter.

The computer-controlled system (CCS) is used both as operator interface and as input-output controller. The latter function is based on a general-purpose control and acquisition interface (CAI) mounted in the IBMcompatible PC, as shown in Fig. 2. CCCS is interfaced to CCS by a dedicated module, which transfers logical commands/states between the digital I/O bus of CAI and CCCS as well as analogic signals between CAI and CCCS.

CCS provides mainly the following functions:

- Applies 23 interlocked logical commands to the IPF-4/5A subassemblies;
- Acquires and processes 28 logical states from the installation subassemblies;
- Acquires, processes and displays three slow time-varying signals (condenser bank high voltage, switch triggering system high voltage and pressure in the discharge chamber).

Certain precautions have been taken in order to protect the personnel working on the installation, taking into account the presence of tens of kV (d.c. and impulse), of intense nuclear radiation and of high voltage interferences during the experiment. In this respect certain technical solutions were implemented, using both classical and computer (soft) interlocking:

- Condenser bank charging system is interlocked with safety devices that control the access of any person to the experimental area;
- Condenser bank charging is continuously announced around the experimental area by optical and acoustical devices;
- The actual condenser bank discharge pulse is delayed by a few seconds introduced after the operator "START PULSE" command
- IPF –4/5A operation sequences are governed by strict hard and soft interlocking in order to reduce the risk of, or entirely prevent, any operation error.

3. 2 Computer-controlled operating mode

Before the start of the experiment the operator has to introduce by means of the keyboard, in a conversational way, the experimental parameters and the operating mode (completely automated or sequential):

In the completely automated operating mode, the operator commands only the start of the experiment, the system operation being software and hardware-controlled afterwards. The evolution of the experiment is continuously presented on the PC display, every experimental phase providing the operator with a set of commands, which he could use in case of system malfunction.

In the sequential mode, the operator from the system keyboard commands both the start of the experiment and also the evolution from one phase to the other. The system displays continuously each phase of the experiment, the measured values of the main device parameters, as well as a set of commands for operator intervention in case of malfunction.

Both operating modes provide the operator with the possibility of interrupting the experiment at a certain phase ("decision phase"), in order to change the experimental parameters that have been previously introduced. At the end of experiment, the operator has the possibility of adding his observations regarding the evolution of the experiment. He also decides whether the experiment data are to be stored on PC as experimental data files.

Software development occurred under MS-WINDOWS. It is therefore in close proximity to the analysis, modeling and office tools running on the PC. Application programs were developed with the Borland C/C++. The software package has a modular structure allowing the implementation of new functionalities as the demands for changes/additions appear.

The operator interface software is simple, menu driven and has been optimized for minimum operator interaction (completely automated operating mode). The software guarantees:

- The possibility of a dialogue between the operator and the system:

-The selection of the operating mode (completely automated or sequential) by the operator;

-The interruption of the experiment by the operator using dedicated commands;

-The remote control of the whole experimental run (recommended start-up and shut-down sequences for IPF-4/5A are provided);

-Delivery of alarm messages and guidance for troubleshooting in case of operational problems;

- Sequence interlocks to prevent unsafe (to system and personnel) conditions;
- The software-controlled interruption of the experiment in case of different kinds of damages;

The acquisition and pre-processing of relevant parameters;

- Presentation of data as tables and charts;
- The transfer of the experimental data to the PC, archiving.

The software consists of a set of applications for execution of control algorithms, data acquisition, initial pre-processing of data for protection of equipment and interlocks, transfer of information to the PC.

4 REFERENCES

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