8 KV POWER SUPPLY FOR RF-AMPLIFIERS ANODE FEEDING

B.A. Baklakov, A.I. Erokhin, Yu.A. Evtushenko, K.M. Gorchakov, V.V. Kolmogorov,
D.A. Markov, L.E. Medvedev, A.S. Medvedko, S.P. Petrov, V.F. Veremeenko.
Budker Institute of Nuclear Physics, (BINP) 630090, Novosibirsk, Russia.

Abstract

An 8 kV anode power supply with an output power of 2.6 MW for tube-based RF-amplifier feeding is described. It is a 6-pulse thyristor converter with a passive LC-filter for reduction of the output voltage ripples up to 1%. The power supply is equipped with load Fast Protection against the sparks inside the tubes of the amplifier. The 6-10 mcs time of cutting off the output voltage allows one to avoid destruction in the RF-amplifier tubes. Cutting off the output voltage is realized by shorting out the power supply output with the help of a parallel thyristor switch. Operation of the Fast Protection is considered. Serviceability of the thyristors of the converter and Fast Protection Thyristor Switch is checked with the help of the internal monitoring system. This monitoring system is designed with the use of an optical link and computer supervising.

1 INTRODUCTION

The electron-positron colliding storage rings, synchrotron radiation factories and new device, microtron - recuperator as a free electron laser, need high power RF systems. Power scale reaches up to some MW. Some of RF systems use klystron power amplifiers, some are based on tube amplifiers. Works on tube RF amplifiers are carried out at BINP for many years. A tetrode power amplifier modules operating with a 180 MHz beam accelerating frequency have been developed [1]. One amplifying module generates up to 150 kW. The project of a free electron laser [2] requires more than 1.5 MW of RF power. To supply these amplifiers with anode power, it is necessary to have an approximately 8 kV power supply (or a group of power supplies) with the rated output power up to 2.6 MW. The anode voltage is to be variable in the range between 2 kV and 8 kV for safe switching ON, training and operational modes of the RF systems. On the other hand, an RF amplifying tube is a very "delicate" device, which needs to be protected against uncontrolled power dissipation at the anode due to tube internal sparks that inevitably occur during operation. So, a special fast tube-protecting system is to be a part of the power supply. The protection decreases the dissipation energy at the elements under protection to non-destructive values.

2 DESCRIPTION

The power supply contains the following systems:

· power thyristor Converter,
· load Fast Protection System,
· system for control, supervision and measurement of the power supply parameters.

2.1 The power thyristor Converter

The power Converter is the 6-pulse bridge rectifying circuit. Each arm of the rectifier is assembled from 10 in-series thyristors, shunted by snubbers and equalizing resistors. Each arm contains a iron-coil choke, which limits the thyristors current rate of rise. A synchronous phase control circuit with output pulses with duration of about 4 ms was used for control over the Converter. The pulses are filled by a 20 kHz carrier and are passed to the input of each thyristors of the arms with the help of comparatively small-dimension transformers. The one-turn primary winding of each transformer is made of a high-voltage cable for isolation of the Thyristor Driver System against of distribute potential of thyristor firing circuit (Fig.1).

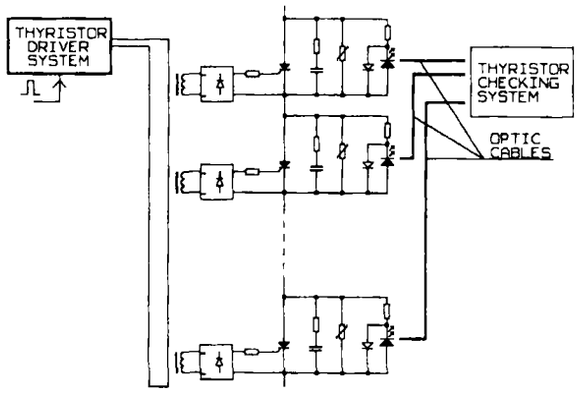

Fig. 1 One rectifying arm of thyristor Converter.

The free-wheeling diode arm and ballast resistors are connected to the output of the rectifier. To protect the thyristor Converter against over-voltages of different origin, its input circuit contains a protective diode bridge, damping RC- circuits and varistor assemblies, designed for voltages of about 17 kV. The Converter is also equipped with a protection against current and voltage excesses in the input and output circuits.
The Converter is loaded for two identical channels that provide current under load up to 160 A each. Such a configuration allows the most optimal connection of several channels of the RF-amplifier to the power supply. Each of the channels contains an LC-filter with a

resonance frequency of 30 Hz (for ripples damping) and a Fast Protection System for the load tubes protection.

2.2 Fast Protection System

The Fast Protection System is developed for the RF amplifier tubes protection against the arc discharge occurring inside them. The Fast Protection System decreases the energy dissipated across the elements being protected to non-destructive values. The functional scheme of the Fast Protection System is presented in Fig.2.

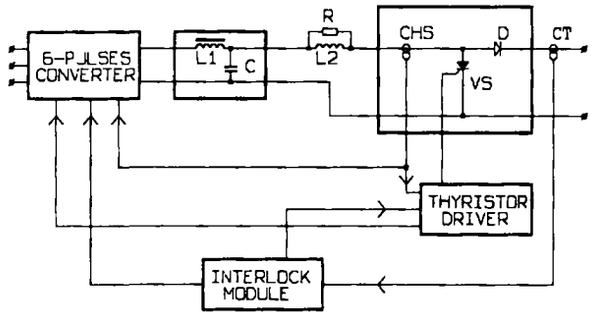

Fig.2 The functional diagram of the Fast Protection System

When a tube spark occurs, it is necessary approximately 6 to 10 mcs to reduce the voltage at the output of the power supply practically to zero, otherwise the tube may be disabled due to the sharp current growth occurring at a arc discharge.
The signal that indicates a current jump is formed by two sensor, which duplicate each other: threshold Hall sensor CHS, which operates when the current reaches an ~1.5 of the nominal value, and Pulse Current Transformer CT with an adjustable operation level. Signals from the detectors come to the input of the thyristor driver circuit and enable Fast Protection Thyristor Switch VS, shorting out the power supply output. From this moment, the tube current is intercepted by the thyristor switch and the transition processes in the power supply don't influence the tube. However, it should be noted that across the Thyristor Switch being switched ON there is a residual voltage of about 20 V (12 thyristors). This voltage is enough to keep arc in the tube. A series circuit of 18 diodes (D) is used to eliminate this effect. In Fig.3 there are presented time diagrams of the currents in the elements of Fast Protection System. During a spark the output current increase up to 400 A only, but the amplitude of the Thyristor Switch current increase up to 2 kA. As a result the Fast Protection action the energy dissipated in the arc will be less than 6 to 8 J under a most unfavorable coincidence. For compare, the energy accumulated in the filter elements is about 3200 J.

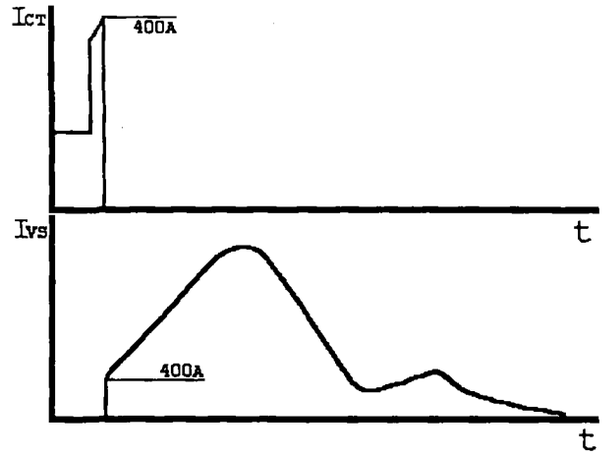

Fig.3. Fast Protection System time diagram. Ict -the output current of the power supply, Ivs - the Fast Protection Thyristors Switch current.

As one can see from Fig.2, a signal indicating the current jump comes also to the control circuit of the Converter thyristors and cuts firing pulses OFF. The three-phase power line breaker is not switched OFF by an operation of the Fast Protection System.

2.3 The system of control, supervision and measurement of the power supply parameters.

In accordance with the operational philosophy for high-voltage devices of such power, all the preliminary operations on switching ON of the power supply are realized manually. Only last procedure of high-voltage switching ON and of output voltage level tuning are remote controlled.
We believe that one of the important points of supervision over high-voltage power supplies made with using of series thyristor assemblies is supervising of serviceability of the thyristors. Here we suppose a variant of the supervision circuit, in which the role of the thyristor serviceability detectors is played by light diodes with optical links. The light diodes are connected through a resistors in parallel with each of the thyristors of arm and check the presence of the reverse voltage across them (Fig.1).

Besides that, the following parameters and states of the power supply are supervised by computer control:
· presence of voltage in the power supply mains,
· presence of auxiliary voltage,
· signals from the Pulse Current Transformers of the Fast Protection System,
· signal input overcurrent,
· signal output overvoltage,
· signal of operation of the Fast Protection System,
· signal of presence of firing pulses of the thyristors,
· signal of the cabinet door interlocks.

Besides that, in the power supply there are measured the values of the input and output currents and voltages.

3 RESULTS AND CONCLUSIONS

For now BINP has manufactured two above-described high-voltage power supplies with thyristor Converters, made for full power, and with single load channels (160 A - for a half load, see *2.1*).
The systems have been tested with a load to 0.6 MW, limited by the input transformer. The Fast Protection System operation was checked with the use of the 0.2 mm wire standard test and under operation with a real RF power amplifier. Later on we assume to increase power of the power supplies to the design values.

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5 REFERENCES

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