

PRECISION POWER SUPPLY OF TRAPEZOIDAL CURRENT FOR THE UNDULATOR

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Abstract .

The Circular Polarizing Undulator (CPU) had been built by the joint team of BINP (Novosibirsk, Russia) and ANL (Argonne, USA) for X-rays generation with variable polarization (circular and linear). This Undulator has about 4 m long. It consists of two main windings with maximal currents 1600A (about 30kW power) and 400A (4kW power) and additional correcting low-current windings.

The task of powering CPU requires to design a special power supply. The main requirement to such a power supply is forming the current with polarity switching frequency up to 10 Hz.

The high-current channels are connected to the power line by diode rectifiers with a damped LC-filters and consist of diode bridge rectifier, PWM-controlled IGBT inverters, step-down transformers, diode high-frequency H-type rectifiers with LC-filters and output high-current inverters. The low-current channels are fed from special low-voltage rectifiers. They also performed with PWM control. All the channels are controlled independently and are equipped with precision current monitors. The report describes the principle of operation of the power supplies and the obtained results.

1 TECHNICAL REQUIREMENTS

1.1. Load parameters

There are six windings in the wiggler: one horizontal, one vertical, and 4 correcting windings. Each winding requires a separate power supply.

First of all, note that power supplies of correcting windings are standard and they have low power, therefore, they will not be considered in the report.

Parameters of the undulator main windings.

- Time constant of the horizontal winding is 9 ms;
- Time constant of the vertical winding is 30 ms.
- Active power in the horizontal winding (at maximum current) is 30 kW
- Active power in the vertical winding (at maximum current) is 3 kW;
- Maximum current of the horizontal winding is 1600 A;
- Maximum current of the vertical winding is 400 A;

1.2 The power supply parameters.

- The power supply provides the undulator feeding either with the direct pulsed current or with the current of quasirectangular (trapezoidal) form;
- The switch front duration (for current on/off) does not exceed 12 ms.

2 DESCRIPTION OF THE POWER SUPPLY CIRCUIT

The main feature of the power supply is its ability of forced current switching on/off keeping rather high stability. The power supply has quite small (for its power) overall dimensions. Consider in more detail the power supply channel of horizontal winding since it is the most powerful and complex. Fig.1 shows the functional schematic diagram of the power supply channel of the undulator horizontal winding.

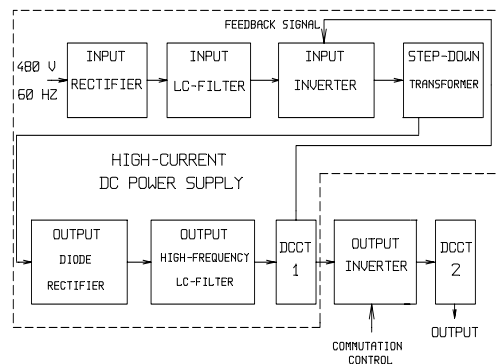


Figure 1: Functional schematic diagram of one channel of the power supply .

Input rectifier, Input LC-filter, Input Inverter, Step-Down Transformer, Output Rectifier and Output High-Frequency LC-filter compose the High Current DC power supply with an intermediate high-frequency section with maximum output voltage at maximum load of 35 V (at the idle run - of 40 V) with output current of 1600 A. Input LC-filter has a low coefficient of ripples suppression of the main harmonics at the output voltage. This LC-filter is mainly designed for suppression of noises induced in the mains by the

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inverter. Input Inverter is the IGBT-module based two bridges each operates for its own transformer. In this case, the transformer secondary windings are connected in series and loaded to one diode bridge rectifier. IGBT-inverter output voltage is controlled with the wide-pulse modulation. The conversion frequency is chosen to be 2.4 kHz. Output high frequency LC-filter has quite low inductance of the smoothing choke but rather high capacity. It was chosen so because the undulator electromagnetic energy is recuperated into the bank of smoothing capacitances when current is either switched off or its direction is changed. Suppression of current ripples at the Output Diode Rectifier is performed with help of the Output High-Frequency LC-filter and also with the undulator inductance. Suppression of the mains ripples 360 Hz (60 Hz x6) is provided by the direct current feedback system, undulator inductance and partially by the Input LC-filter. One of the main parts of the power supply is the Output Inverter that provides the output current commutation.

3 DESCRIPTION OF THE OUTPUT INVERTER OPERATION PRINCIPLE

A simplified schematic diagram of the output current inverter is shown in Fig.2

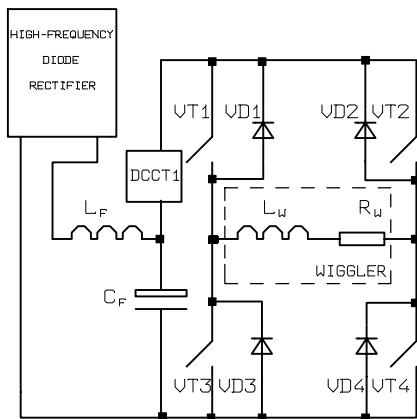


Figure 2: A simplified circuit of the output current inverter

Voltage from the Output Diode Rectifier (see Figs. 1 and 2) is applied to the LC-filter (L_f, C_f) and then through the current monitor DCCT1 to the Output Inverter based on the IGBT switches VT1-VT4 with free-wheeling inverse diodes VD1-VD4. Voltage and current profiles are shown in Fig. 3

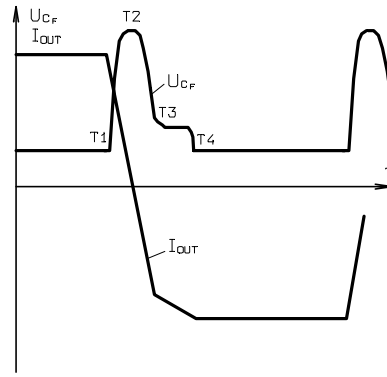


Figure 3: Current and voltage profiles in the circuit

Assume that by the time moment t_1 the switches VT1, VT4 are on and the output current polarity is positive as shown in Fig.3. At the time moment t_1 , the polarity change signal is applied to the Output Inverter control system. VT1 and VT4 are closed and energy stored in the undulator is recuperated into the capacitance bank C_f along the circuit «- C_f - VD3 - Undulator - VD2 - C_f ». As a result of this, voltage at C_f capacitor will increase approximately up to 100 V (at the time moment t_2) and the output current in about 2-2.5ms drops to zero. The interval t_1-t_2 is approximately determined by

$$T = \pi \sqrt{(L_{und} \times C_f)} \quad (1)$$

where L_{und} is the undulator inductance; C_f is the output LC-filter capacity.

After t_2 , the forced raise of current starts into the opposite polarity due to C_f discharge. By this time, control signals are already applied to switches VT2 and VT3 but they do not yet conduct current. After the time moment t_2 , the filter capacitance C_f discharge current starts to go through switches VT2 and VT3, however, High-Current DC Power Supply is in the idle run regime as it is closed by C_f high voltage. In this case, the output voltage of the Input Inverter has its maximum value. As a result of losses in the undulator, the output current cannot be completely recommutated only because of its own energy, therefore by the time moment t_3 (the interval between t_1 and t_3 is approximately $2T$ (see (1)) of 4-5 ms and current does not reach the value that by its module is equal to the current value at the time moment t_1 (its value depends on the commutated current value being within the limit of 90-95% of the static regime current. At the time moment t_3 , the C_f bank voltage becomes to be equal to

the maximum voltage of High Current DC Power Supply. High Current DC Power Supply starts forcefully «push» current value to its required level. By the time moment t_4 (the time between t_3 and t_4 is approximately 6-7 ms), the output current achieves its nominal value and the power supply takes the static state. Further the processes are repeated. Note that the power supply is capable to operate not only in the current sign changing regime but also in the pulse single polarity regime.

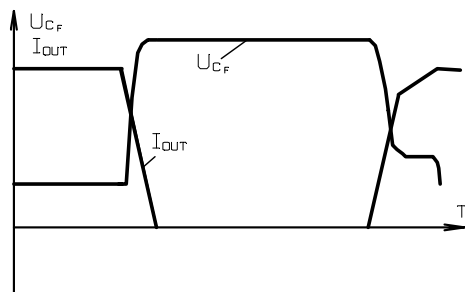


Figure 4: Current and voltage profiles in the circuit in the pulse single-pole regime.

It is worth to add that 8 connected in parallel special low-voltage modules IGBT with especially low voltage drop in a static state, which replace thyristors used in previous versions of such kind of sources, are used as switches VT1-VT4 in the inverter [1]. Note also that the power supply channel of the vertical winding is

structurally the same as the power supply channel of the horizontal winding.

4 MEASUREMENTS AND CONTROL

Control and measurements of currents is performed by two DCCT in each channel. The structural scheme of current measurement is the same for the power supply channel of the vertical and horizontal windings of the undulator. In addition, in both channels of the power supply nearly all the parameters required for monitoring are controlled by VME-crate: voltages of the auxiliary power supply, presence of cooling water, temperature of current carrying parts, the state of input breaker, presence of overcurrent etc. The power supply described here is under operation during about 3 years at the storage ring complex at ANL (Argonne, USA).

5 REFERENCES

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