FAULT PROTECTION SYSTEM IN A "REGULATED HIGH VOLTAGE POWER SUPPLY (80 KV, 130A)" FOR NEUTRAL BEAM INJECTOR

Paresh Patel, C. B. Sumod, Dipal Thakkar, L.N Gupta, V. B. Patel, L. K. Bansal, K. Qureshi, V. Vadher, Niranjanpuri Goswami, Kalpvikalp Patel, Kush Mehta, Kapil Oza, Chirag Patel, U.K. Baruah
Institute for Plasma Research, Gandhinagar-382428 India

Abstract

Regulated High Voltage Power Supply (RHVPS) system has been developped at Institute for Plasma Research (IPR) for use with the Neutral Beam and RF applications. The highest ratings manufactured so far is 80 kV, 130 A. The system is developed in house and also being delivered at different research institutes for various applications.

Since it is a multi megawatt output power system, and the loads have very low fault energy tolerant, fault protection system is mandatory. Protections are madatory at each stage of coversion. Output fault protection is done in a variety of ways. Fast turn off at output is achieved and test results are discussed.

Multi secondary transformers (5.6 MVA rating, with 40 outputs) are used in realising the power supply. These special transformers need protection even for over current at one secondary when the output fault current is not reflected to primaries to break the main circuit breaker. It becomes difficult to bifurcate fault in such situations. Special technique is applied to sense it. Electronic means are used for fast detection and tripping the system.

This paper describes the basic RHVPS topology and test results along with presentation on the input and output fault protection systems.

RHVPS TOPOLOGY

RHVPS topology is modular as shown in fig.1. Sources of lower stage voltages (Va) are put in series along with free wheel diodes F_D and switches S_1 to S_N. These fast switches are Insulated Gate Bipolar Transistors (IGBTS).

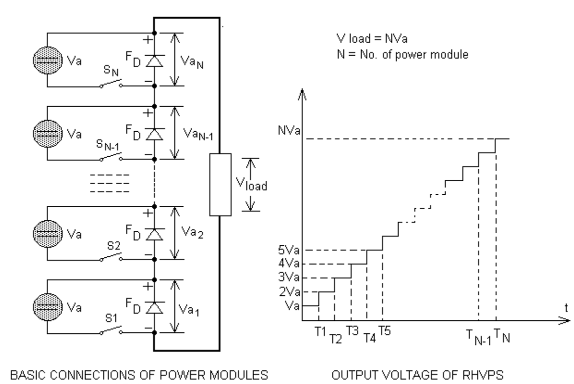

Figure 1: Basic scheme for RHVPS.

Desired regulated high voltage output is available on V_{load} by selecting no. of switches which are made ON. Central controller decides a no. of switches and regulates output.

The output voltage is expressed as:

$$V_{load} = \sum_{i=1}^{N} V_{ai} d_i \qquad (1)$$

where , d_i = 1; if switch S_i is ON, otherwise 0.

Table 1: RHVPS Specifications

Sr. No.	Parameter	Value
1	Output	0-80kV, 130A
2	Regulation	1 %
3	Ripple	< 1 %
4	Duty	Continuous
5	Rise time	~5 µS (Selectable up to 100 m Sec)
6	Turn off time	< 2µS
7	Fault energy	< 10 J

Main RHVPS output parameters are shown in Table 1. Requirement of turn OFF time and fault energy is too low and protection is to be designed in such a way that in case of faults like break down in load (a short circuit), power supply and load must be protected from damages.

FAULT PROTECTION SYSTEM

Protection at stage voltage level

40 secondaries of both multi secondary transformers are connected to 80 rectifiers, which are representative of stage voltages Va as shown in figure 1.

In case of

- short at input of one these rectifiers and
- no current is carried by other secondaries

main primary winding does not carry fault current more than its rating. A main circuit breaker does not trip and particular secondary winding is damaged. To protect from this fault, a technique is applied as shown in figure 2.

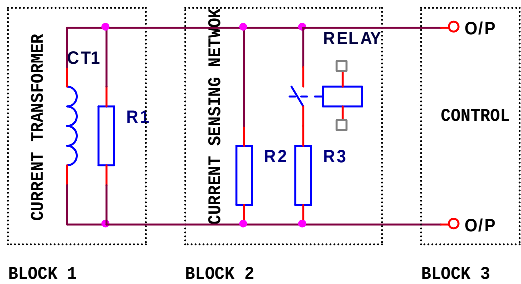

Figure 2: Current sensing at transformer input

A current transformer CT1, senses current signal along with burden resistors R1, R2, R3 and relay. CT1 and R1 are located at transformer primary which is at 11 kV. This CT is properly isolated from mains power. R1 helps CT not to saturate in case of open connection between block 1 and block 2. Block 3 is a control to take action for tripping the mains transformer. Relay is made ON, when output of RHVPS is desired and all secondaries are applying power. Value of parallel combination R2 and R3 is so designed that signal sensed by block 3 becomes suitable to trip the RHVPS only when there is an overload at final output.

Now, in case of short at one of the rectifier and no output is taken from RHVPS (no load condition), relay is not made ON. R2 only, which is much higher in value than R3, is sensing signal in this situation. The signal is, in turn, at higher value and sent to block 3 to trip the main transformer. Thus, a minimal current is sensed and a shorted single secondary winding is saved.

Protection at RHVPS output

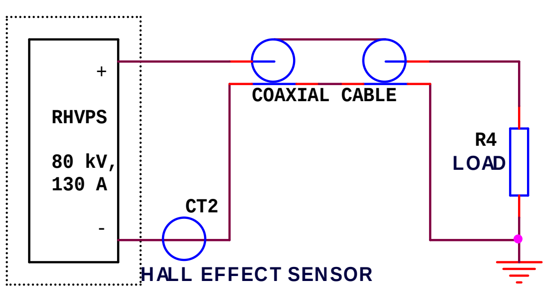

Figure 3: Current sensing at RHVPS output.

RHVPS, connected to a grounded load by a co-axial cable, is shown in figure 3. Electronic current transducer, CT2, inserted in a return path at RHVPS end, senses fault for short in cable or overload by R4.

In conditioning phase, frequent break downs make RHVPS output shorted. CT2 senses them, a fast comparator generates a fault signal and output is made OFF. Turn OFF time, < 2 uSec, is achieved by choosing parts with low propagation delay in a path from sensing fault to switching OFF fast IGBTs.

In figure 4, RHVPS output (CH1) is made OFF in case of breakdown (CH3).

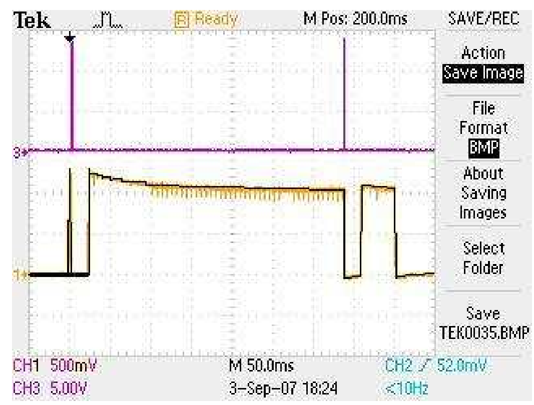

Figure 4: RHVPS output made zero at break down.

Figure 5 is a view of RHVPS and multi secondary transformers.

Figure 5: RHVPS and multi secondary transformers.

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