Design and Analysis of the control system of high voltage (400kV DC) power supply for neutron generator

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Abstract: **The 'Neutron Generator Facility' is operational at PURNIMA, BARC. The Neutron Generator is a 300KeV electrostatic DC accelerator. A 400 kV, 10mA DC power supply is being used for acceleration of deuteron beam. The HV power supply generates 400 kV from 3 phase Mains. The basic logic to generate 400 kV consists of following stages:**

Three phase Mains ⟶ Three phase Converter ⟶ High Frequency Inverter ⟶ Step-Up Transformer ⟶ Balanced CW Multiplier. The converter is controlled by SCR firing card & Converter control card and Inverter Protection Card controls the Inverter. Present project is to design a new PC based control system for SCR Firing, Converter & Inverter circuit to provide local and remote operation.

Keywords: **Accelerator, Converter, Inverter, Step-Up Transformer, CW Multiplier.**

1. INTRODUCTION

Purnima Neutron generator (PNG) is basically a D+ ion beam accelerator. D+ ion beam is produced from the RF or Penning ion source and then accelerated to the tritium target for producing neutrons. The 400kV DC 10mA power supply is used for accelerating the D+ ion beam upto 300 keV as accelerating column is rated for 300 kV. When a 5-6 kV positive potential is applied to anode, the beam is extracted from 1.5 mm diameter canal in cathode which is kicked up by the accelerating supply to bombard on the tritium target which is at ground potential. This supply was designed by RRCAT, INDORE at early 90's. The control system was designed by using basic digital logic and it is operable manually only. So a computer based remotely operable control system is needed for upgradation of Purnima Neutron Generator Facility (PNGF).
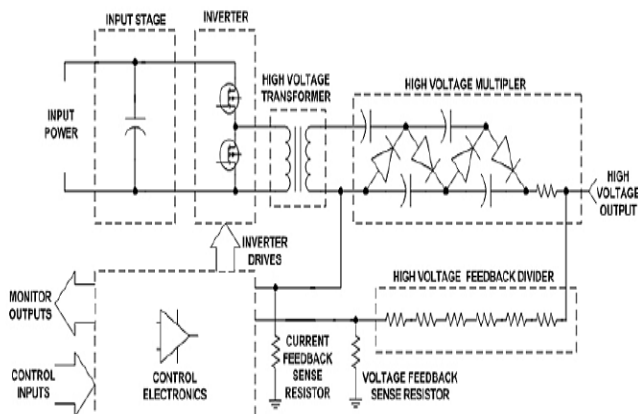
2. BASIC HIGH VOLTAGE POWER SUPPLY

Fig. 1 Basic Schematic of High Voltage Power Supply

Fig. 1 shows the basic building blocks of most high voltage power supplies. The power input stage provides conditioning of the input power source. The power stage can provide rectification and filtering for AC signals, filtering for DC signals and circuit protection. Also auxiliary power sources to power the high voltage power supply control circuits are typically part of the power input stage responsibilities. The output of the power input conditioning stage is typically a DC voltage source. This DC voltage provides the energy source for the inverter stage. The inverter stage converts the DC source to high frequency AC signal.

2.1 Control Circuitry

Control circuits are the glue to keep all of the power stages working together. Circuit complexity can range from one analog I.C. to a large number of I.C.s and even a microprocessor controlling and monitoring all aspects of the high voltage power. However, the basic requirement which every control circuit must meet is to precisely regulate the output voltage and current as load, input power, and command requirements dictate. This is best accomplished by a feedback control loop. Conventional regulation of voltage and current can be achieved by monitoring the output voltage and current respectively. This is compared to a desired (reference) output signal. The difference (error) between the feedback and reference will cause a change in the inverter control device. This will then result in a change of power delivered to the output circuits.

2.2 Inverter Topologies Selection Criteria

The choice of Inverter topologies for a high voltage power supply may be governed by two factors:

- Must isolate reflected parasitic capacitance
- Must be low noise

This is a half bridge parallel resonance inverter

3. BLOCK SCHEMATIC OF COMPUTER CONTROLLED POWER SUPPLY FOR PNG

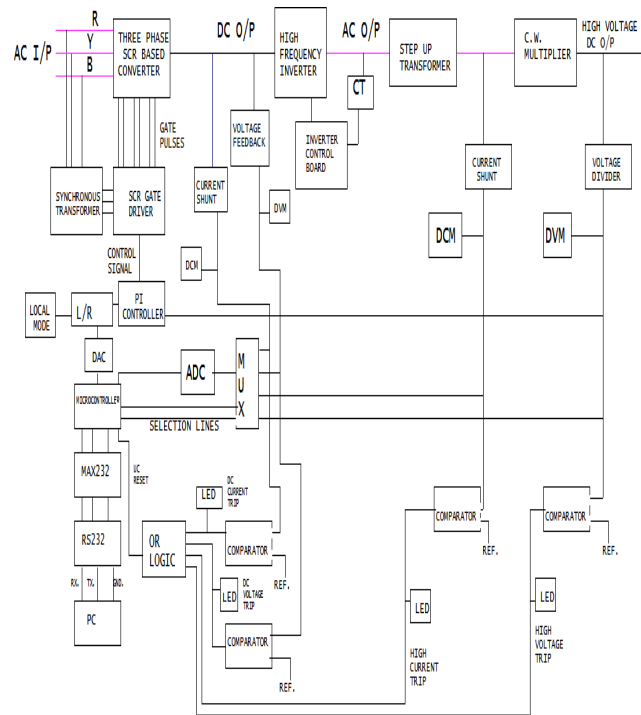Fig. 2: Block schematic of computer controlled power Supply of Purnima neutron Generator

3.1 Description

The Converter is a six pulse fully controlled bridge converter, which controls the output voltage of power supply**.** This delivers 5 KW of DC power (max.) to a variable voltage DC bus that acts as input source for resonant inverter. This has LC filter at output, which reduces the output voltage ripple below 1%. This also incorporates a constant current bleeder circuit, which insures continuous conduction mode of operation from no load to full load.

The high frequency inverter is parallel loaded half bridge resonant inverter. The LC resonant circuit has resonance frequency of 5 KHz. Inverter grade thyristor are used as switches. Output of this is connected to high voltage transformer through DC blocking cap. A series inductor is also placed in series with capacitor to reduce the voltage drop across the capacitor at higher loads. Current Transformer (CT) senses the inverter current and feedback to the inverter control board. The firings of the SCRs are controlled in such a way that at any time the SCRs are not fired simultaneously.

The Step-up transformer consists of two high voltage transformer assemblies, each with a rating of 230V/17.8kV 2.5 kVA, 5 KHz. Each transformer is put in separate oil filled tank. These two combines as a single unit of 230 V/17.8 kV– 0-17.8 kV/5 kVA transformers. Two separate tanks are the two inductors. These are used to compensate the parasitic capacitance of CW assembly. The ferrite cores are used for these inductor & transformer.

The Cockcroft – Walton (C.W.) multiplier is used at the last stage to obtain the high gain. This is an eight stage balanced CW multiplier stack which gives total multiplication of 16 times.

The new control system is designed using microcontroller (P89V51RD2BN). In this design the power supply can be operated both in remote or local mode. Local or Remote (L/R) switch determines which mode to be operated. In both the operating modes the output voltage is determining by the reference voltage for firing gate pulses to converter SCRs.

In local mode the PI controller receives the reference signals from the local potentiometer and output voltage from voltage divider and gives the control signal for SCR firing.

In remote mode the set parameters are sent to microcontroller from the remote PC. The PC is interfaced with the microcontroller through RS232 serial cable. Based on the set parameters by PC the microcontroller generates Reference signal using DAC (16 bit serial DAC).

PC reads 4 outputs and displayed on the screen. The output signals are

  i.   Output Voltage
  ii.   Output Current
  iii. Converter DC Voltage
  iv.   Converter DC Current

The four output signals are connected to the input of the Multiplexer and depending on the selection lines a particular output is selected at a time. The PC reads the signal through microcontroller and an ADC. The output signal is also displayed at the digital meters (DVM & DCM) attached on the panel.

The four output signals compare with the limit value by 4 comparators and if it crosses the limit it generates **Trip** signal. The four Trip signals are

  i.   High voltage Trip
  ii.   High Current Trip
  iii. DC over voltage Trip
  iv.   DC over Current Trip

One LED is attached with each Trip signal and by noticing which LED glows we can identify the trip signal.

If any one of trip signal comes it makes the OR logic output a high value which resets the microcontroller and so reference signal is zero hence no control signal and so the power supply will be OFF.

In SCR gate driver there also has a comparator and if any Trip signal comes it will reset the firing pulses to zero value.
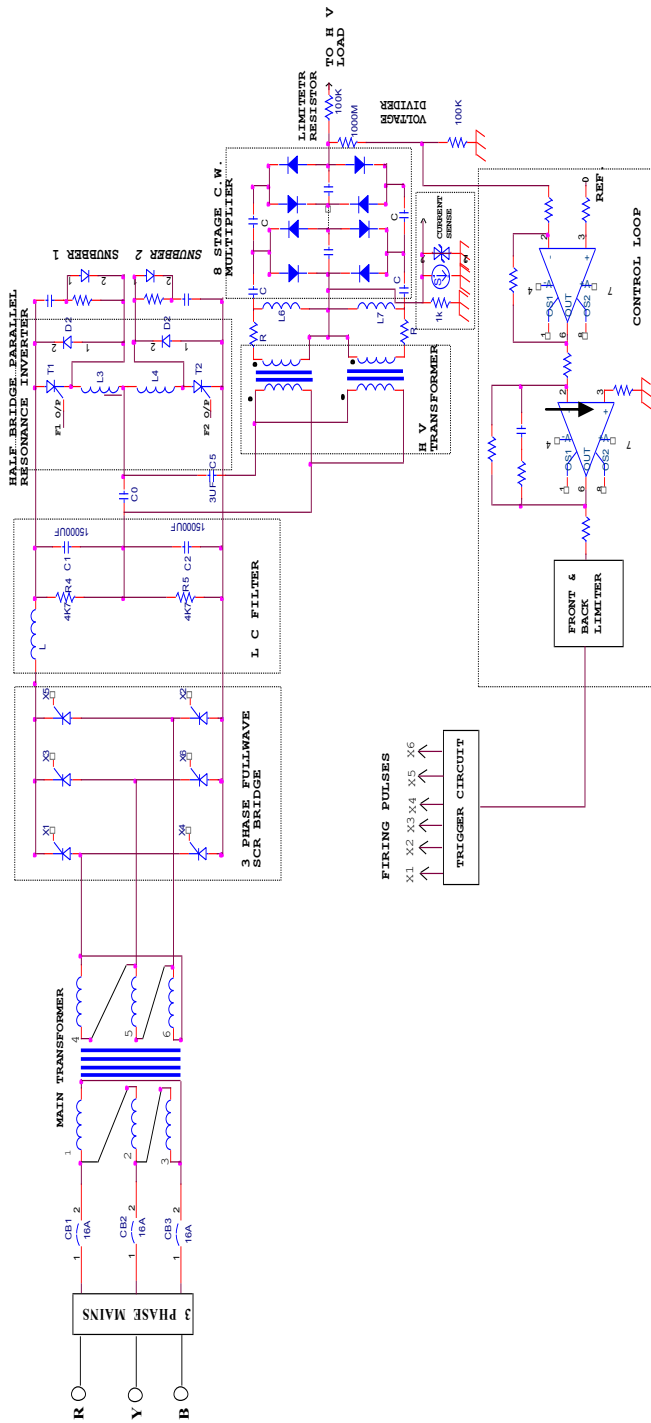
4. CIRCUIT DIAGRAMS

4.1 Main Circuit

4.2 Control Loop Circuit

Fig. 4.1: Main circuit
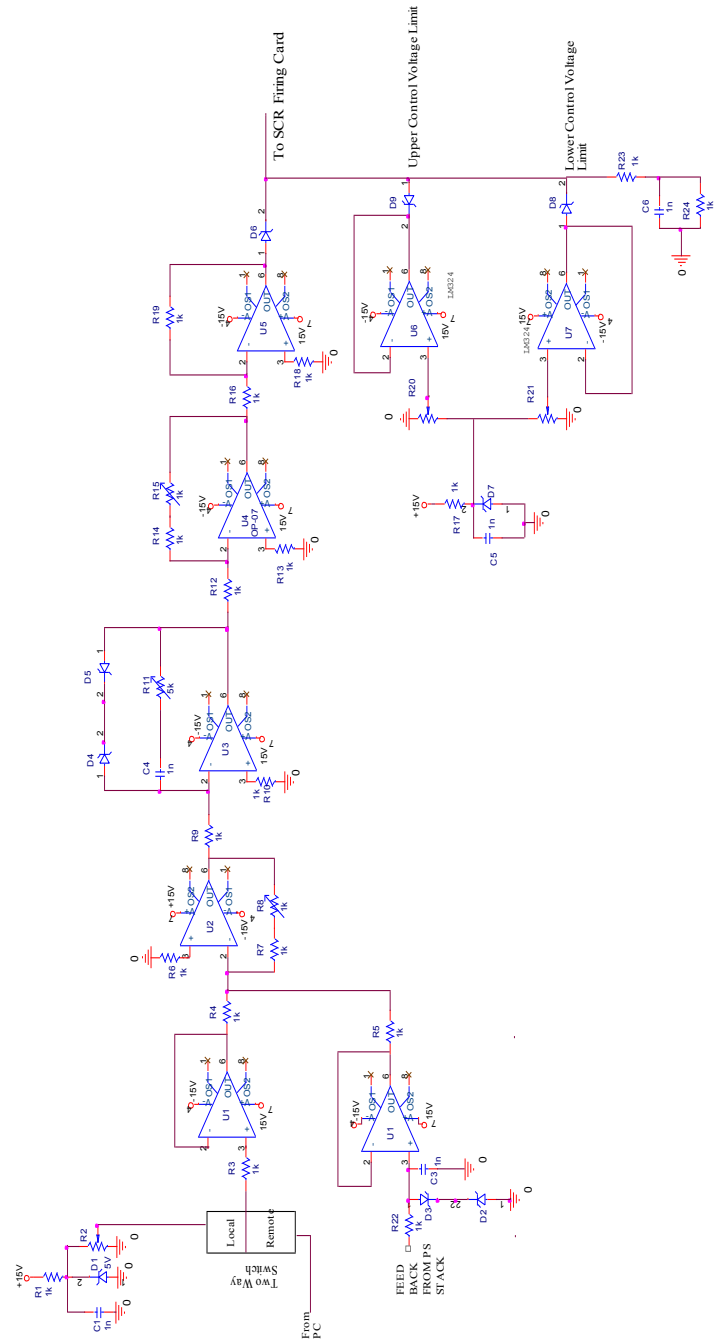
Fig. 4.2: Control loop circuit
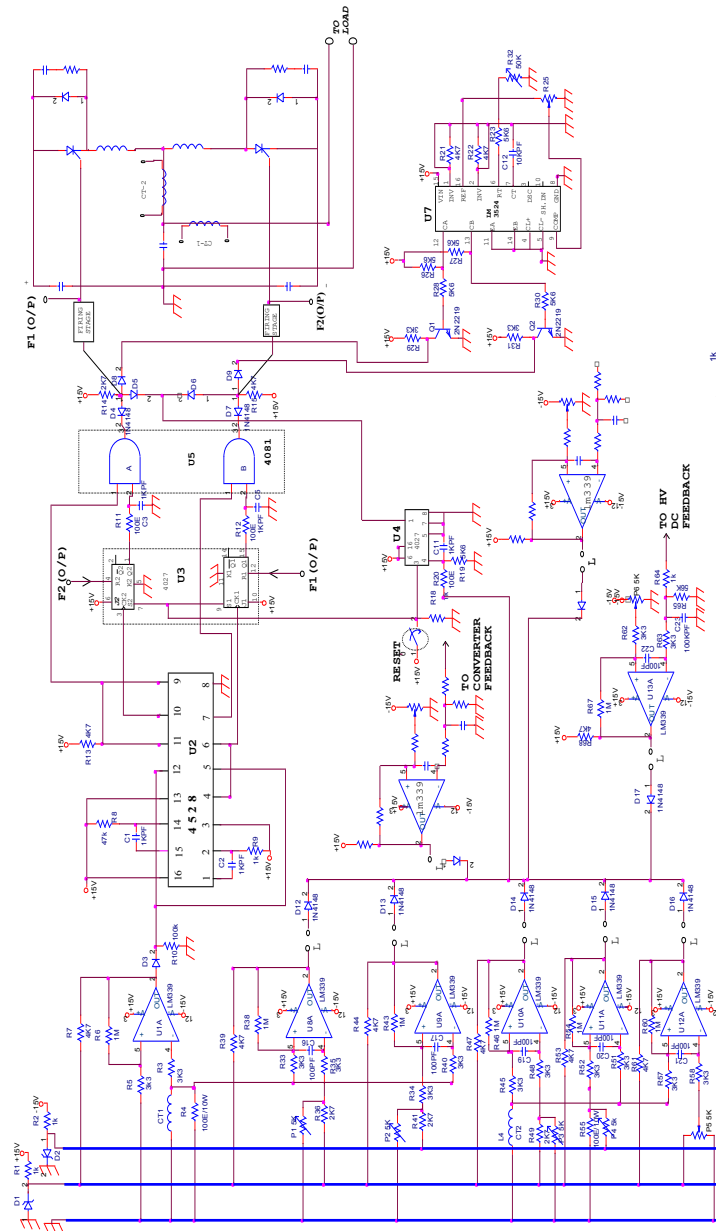
4.3 Inverter Control Circuit

4.4 PC Interfacing Circuit
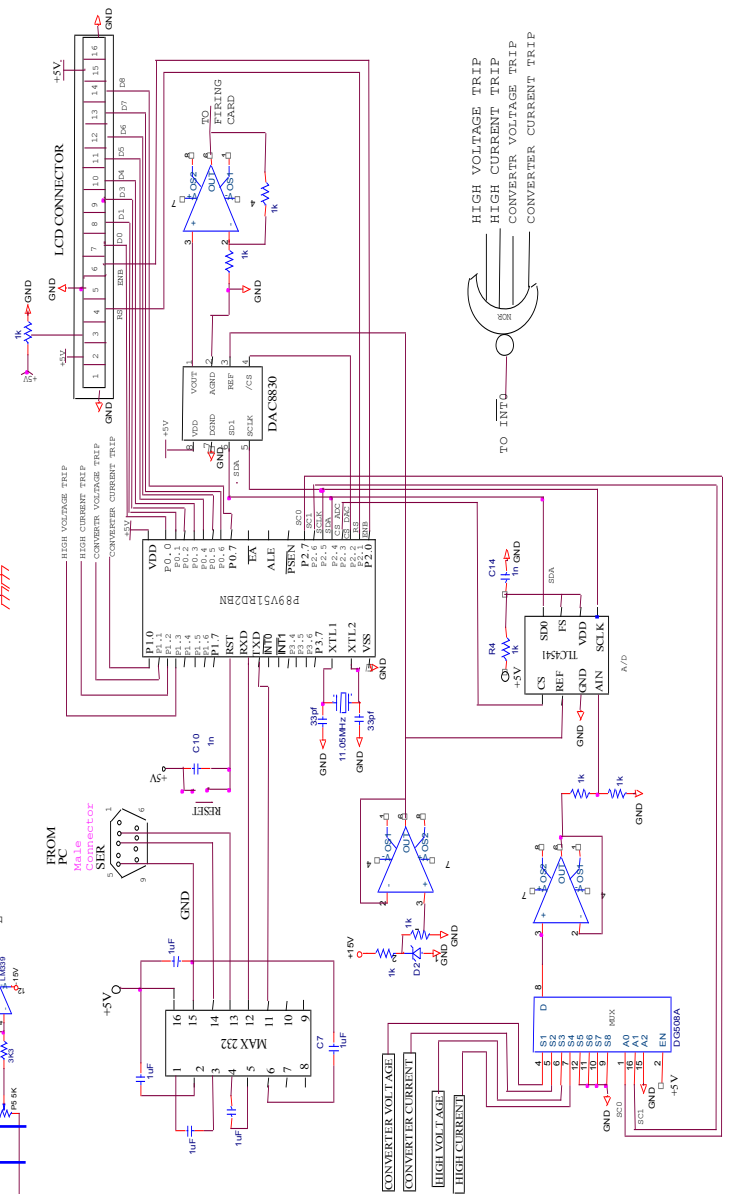
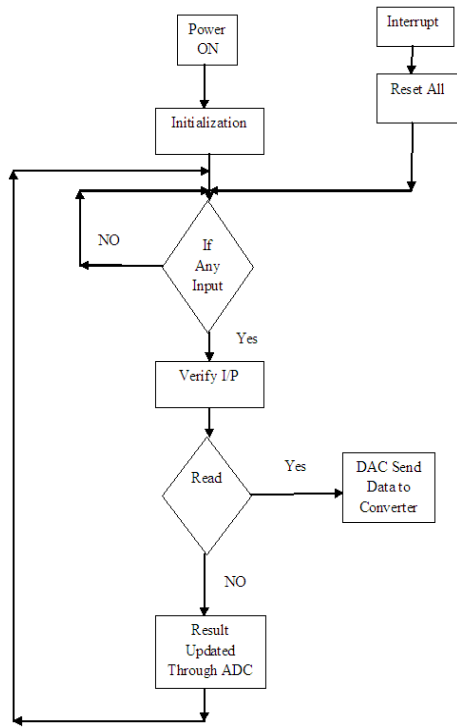Fig. 4.3: Inverter Control Circuit

Fig. 4.4: PC Interfacing Circuit

4.5 Flowchart for Computer Software

7. REFERENCES

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5. RESULT
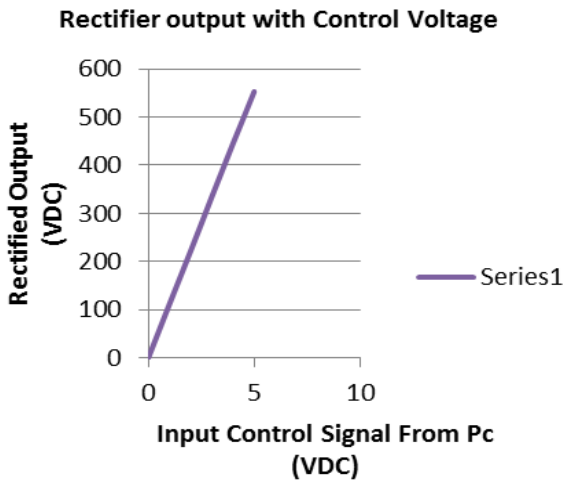
6. CONCLUSION

This control circuits have been tested upto converter stage separately. The result is shown in Fig. 5 where output of converter is linearly varying with control signal. This circuit will be implemented in the existing 400 kV DC power supply.