ELECTRON BEAM ACCELERATOR ENERGY CONTROL SYSTEM

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Abstract

A control system has been developed for the energy control of the electron beam accelerator using PLC. The accelerating voltage of 3 MV has been obtained by using parallel coupled voltage multiplier circuit. A autotransformer controlled variable 0-10KV DC is fed to a tube based push pull oscillator to generate 120Khz, 10KV AC. Oscillator output voltage is stepped up to 0-300 KV/AC using a transformer. 0-300KVAC is fed to the voltage multiplier column to generate the accelerating voltage at the dome 0-3MV/DC.

The control system has been designed to maintain the accelerator voltage same throughout the operation by adjusting the input voltage in close loop. When-ever there is any change in the output voltage either because of beam loading or arcing in the accelerator. The instantaneous accelerator voltage or energy is a direct proportional to 0-10KVDC obtained from autotransformer. A PLC based control system with user settable energy level has been installed for 3MeV, EB accelerator. The PLC takes the user defined energy value through a touch screen and compares it to the actual accelerating voltage (obtained using resistive divider). Depending upon the error the PLC generates the pulses to adjust the autotransformer to bring the actual voltage to the set value within the window of error (presently set to +/- 0.1%).

INTRODUCTION

The circuit diagram of 3MeV accelerator is given in figure.2. A variable dc input of 0-10kV is inverted to 120 kHz by Colpitts type power oscillator and stepped up to 150kV-0-150kV by RF toroidal transformer. It is multiplied to 3 MV, by a parallel coupled voltage multiplier, with SF_6 gas insulation at 6kg/cm^2. It powers a triode geometry electron gun, employing a LaB_6 cathode. The electron beam is transported in 10^{-6} Torr vacuum, through metal-ceramic diffusion bonded & graded accelerating tubes. This electron beam is scanned, and extracted out, into atmosphere, through a thin titanium window, irradiating up to 1m wide job on the product conveyor. Concrete shields around the accelerator area limits X-ray radiation level to <300μR/hr. The by product like Ozone is evacuated from the process zone by exhaust blowers and their level is kept below 0.1ppm near to the accelerator area.

SYSTEM OPERATION

The electron beam energy can be controlled by controlling the 0-10kV DC voltage which is generated by controlling the three phase auto transformer. The 0-10 kV DC generates a corresponding voltage at dome 0-3MV to accelerate the electron to the dome voltage (Energy). The HVDC control has been done using a PLC model TWDLCAE40DRF, Schneider Electric make. The dome energy control can be done either in Manual or Auto mode, selectable from the control panel. For the user interface a 15" touch screen interface has been provided. The touch screen is communicating to the PLC in Modbus TCPIP mode. On the main page of the touch screen, the user has to select the Auto/Manual type of operation by pressing the mode selection button. User settable HV trip limit feature has been provided in the system. The trip value once set in the PLC gets stored in its flash memory. This trip value does not change even if the power to PLC is switched OFF. The new trip value if required can be over-written on the present value. For our use during commissioning we have set the HV trip limit 100kV above the operating voltage.

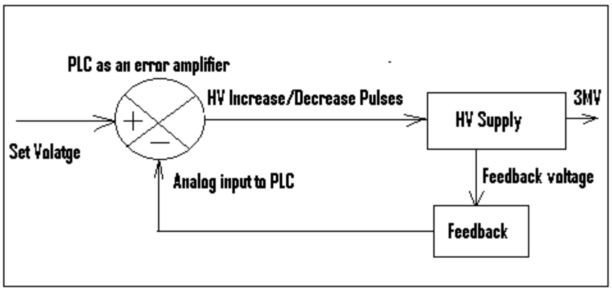

Figure 1: PLC Control loop diagram.

(1)Auto mode

This mode of operation is preferred during commercial operation of the accelerator. The PLC based close loop control diagram is shown in figure-1. Automatic mode of voltage correction helps in regulating the beam energy when there is any change in HVDC because of electron beam loading. This mode of operation ensures uniform energy electron beam dose to the product being irradiated, since this mode maintains the beam energy constant.

In Auto mode, the user has been provided with an edit window on the touch screen to feed the value of beam energy needed. The user when touches the set voltage area, a keyboard pops up, the desired energy level can be entered in kV. The PLC controller monitors the actual HVDC value and compares it to the set voltage. A timer in the PLC generates square wave pulses of 150ms at an interval of 500ms each. If the actual voltage is less than the set voltage, the pulse train is fed to the HVDC increment switch of the variac to get the desired voltage.

If the actual voltage is more than the set voltage, the pulse train is fed to the HVDC decrement switch to get the is within 0.1% range of the set voltage no voltage correction takes place.

(2)Manual mode

Manual mode operation of HVDC is being used during commission of the accelerator. In the initial phase of high voltage system commission there are lot of arcing in the system that trips the system. On each of the HVDC system trip, the fault reason has to be investigated before desired voltage. An error window of correction is set to +/-3kV or 0.1% of full scale voltage. If the actual voltage starting the HV system again. The possible faults for HV trip could be vacuum failure, system insulation failure, dust particles in the system or sharp points in high voltage structure etc.

Pressing the Auto/Manual mode button takes the system into Manual mode. In manual mode operation of the HV control system, the touch screen interface prompts the user to a manual control page, where a separate button

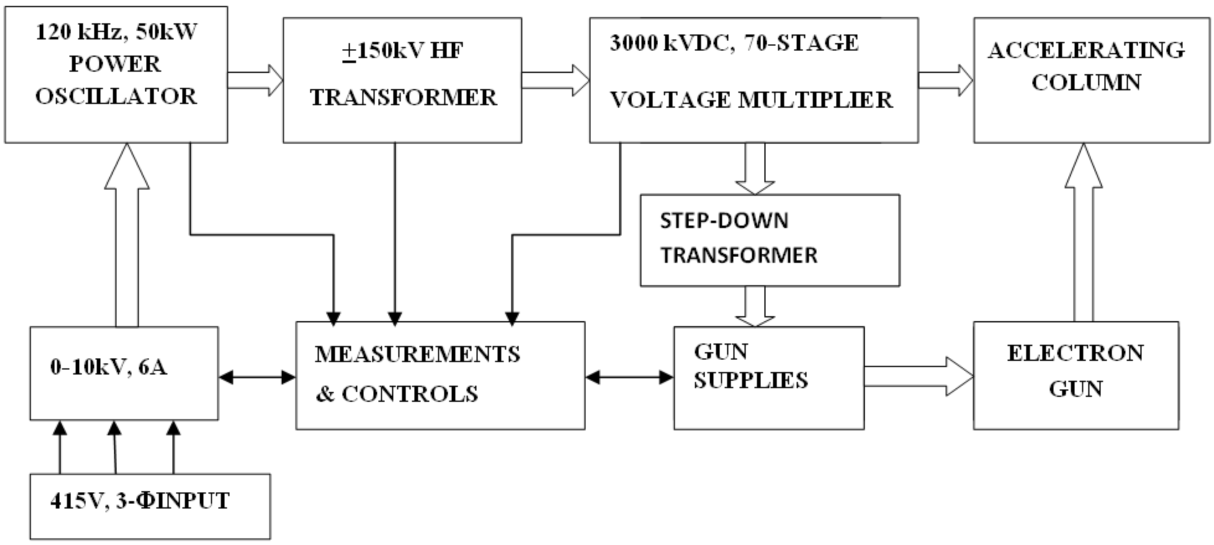

Figure 2: Schematic Diagram of Accelerator Energy control.

has been provided for HV increase or decrease, HV ON/OFF etc.

The operator can press the increase button to increase the high voltage or decrease button to decrease the high voltage. The actual voltage of the system is read by the PLC and displayed to the user on HMI. The magnitude of increase or decrease is directly proportional to the time duration for which the increase or decrease button is pressed. For making fine changes in HVDC, the button can be pressed momentarily or pressed for long time to make a coarse change in the voltage.

Real time charting is displayed on the HMI where the value of HVDC is displayed on the HMI with a sample rate of 1 sample per second on a relative scale of 0-100%. The chart uses 80 points to show the HVDC time characteristics in last 80 seconds. This helps in ascertaining the stability of HVDC during the usage.

CONCLUSION

During commissioning, the HVDC control system has been tested up to 1.6 MV in close loop control. The system gives satisfactory performance.