ENERGY STABILIZATION OF 2.5 GeV LINAC USING DEQING

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Abstract

The 2.5 GeV electron linac of Pohang Accelerator Laboratory (PAL) employs 80 MW klystrons with matching 200 MW modulators as RF sources. Beam voltage stability of the klystron is directly related to a PFN (pulse forming network) charging voltage of the modulator. Therefore, a good regulation of a PFN charging voltage is essential in the modulator. The regulation of the klystron pulse voltage amplitude is made by controlling the PFN charging voltage. In a conventional resonant charging pulse modulator, the regulation is usually achieved by using a deQing circuit. The required beam voltage regulation of less than +/- 0.5 %, without deQing circuit, has been achieved by using a SCR phase controller with a voltage regulator. For further improvement of the beam voltage stability for the PAL XFEL (x-ray free electron laser) linac, PAL is studying a deQing circuit aiming at the stabilization of less than 0.02%. A prototype deQing controller has been developed with a compensation function which can reduce a charge voltage fluctuation by about several times. The design concept and performance of the deQing circuit will be discussed.

INTRODUCTION

Without a deQing circuit, the beam voltage regulation of about 0.5% has been achieved by using a SCR phase controller with a DC feedback circuit. However, we have to study a deQing circuit aiming at the stabilization of about 0.02% due to getting further improvement of the beam voltage stability for the PAL XFEL linac.

A deQing system is a conventional method of regulating the PFN charging voltage [1]. The klystron beam voltage stability depends on the PFN charging voltage of the modulator. To keep a good regulation of PFN charging voltage in the modulator a deQing circuit is employed, and it can accomplish the required regulation. Finally the deQing unit controls the stability of PFN voltage. When the PFN charging voltage reaches desired level, the deQing SCR is triggered to remove energy remained in a charging inductor. The deQing unit consists of a deQing controller and deQing SCR switch assembly. The deQing should satisfy the following two most important conditions: (1) the peak voltage across primary of charging inductor during a period of deQing should be smaller than the PFN charging voltage. (2) The energy in the charging inductor should be removed by the deQing action before starting next charging cycle.

The prototype deQing controller has been tested in a test linac modulator that has a 150 MW peak power, and a HV divider is installed near the PFN inside of the modulator to use it for PFN charged voltage measurement. A signal coming from the divider will be compared with a DC reference voltage in the deQing controller, and according to the compared result, when the desired level of PFN voltage exceeds the DC reference voltage the comparator in the deQing controller generates an output pulse to trigger the SCR. The prototype deQing controller has a compensation function which can reduce E_{PFN} jitter and a charge voltage fluctuation of dV/dt.

POWER CONTROL SECTION

There are some voltage fluctuations in the input AC line. Since the AC line stability is not good and its amplitude is unstable, that makes fluctuated dV/dt. The dc power supply of the modulator is a conventional, three-phase full-wave bridge dc supply with choke input filter. In stead of using an induction voltage regulator (IVR), a phase-control system with six SCRs is used because the phase controller is more effective than IVR in terms of cost, space, and controllability. A SCR AC-AC voltage regulator controls primary 3-phase 480V AC power. The voltage regulator receives feedback signals from the primary AC voltage and the high voltage DC (HVDC) detector. The closed loop control of the AC-AC voltage regulator ensures stable HVDC output. Therefore, the phase control charging scheme has been used for control of full three phase primary power. Using a SCR phase controller with active feedbacks in a high voltage dc power supply can help us to get a stabilization of PFN charging voltage. We stabilized a high voltage charging power supply within 1% by a phase controlled SCR voltage regulator with AC feedback. We get about 0.5% variation of the PFN charging voltage by employing dc feedback circuit in the phase controller.

DEQING CRICUIT DESCRIPTION

The deQing SCR switch assembly is shown in Fig. 1. The amplitude of the PFN voltage is controlled by the deQing unit connected in parallel to a charging choke. The charging choke has a secondary winding to match the relatively low voltage components of the deQing unit to a high voltage charging circuit in the primary winding. When the desired PFN voltage exceeds the dc reference voltage coming from the prototype deQing controller, the comparator in the deQing controller generates an output pulse to trigger the SCR. The energy left in the charging chock at that time is dissipated in the secondary load resistors. The deQing circuit is normally adjusted to dissipate a few percent (about 3 ~ 5%) of the charge in each cycle. It can regulate the PFN voltage to 0.1% or more low levels.

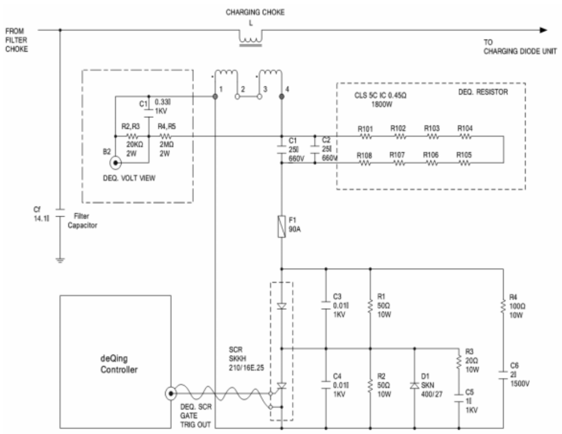

Figure1: Block diagram of SCR for deQing.

As shown in the figure 1, it consists of the secondary of the charging choke, a SCR switch with a diode in a series connection of RC parallel network for power dissipating resistors and energy storage capacitors in which R and C are 3.6Ω and 50μF, respectively. The values of R and C are determined by a simulation result. Various values of R and C in the deQing SCR switch assembly are tried to find optimum value. The function of these components is to regulate the charge placed on the PFN capacitors.

FUNCTION OF A DEQING CONTROLLER

Figure 2 and 3 show the picture of the controller and a simplified schematic of the deQing controller, respectively. It consists of a circuit of differentiating PFN charging voltage, sample and hold, a difference amplifier, ADC, digital delay, comparators, CPU for trigger control, LCD display, and a 0.01% high accuracy divider. The HV divider with an excellent performance is necessary to get a fine regulation of the PFN charging voltage. The HV divider, made by ROSS VD60-6.2Y-BD-KC-UJGA-F, placed on the modulator has acquisition bandwidth of 5Mhz, 0.01% DC, isolation voltage of 60KV dc, and a ratio of 10,000:1.

Figure 2: Picture of the deQing controller.

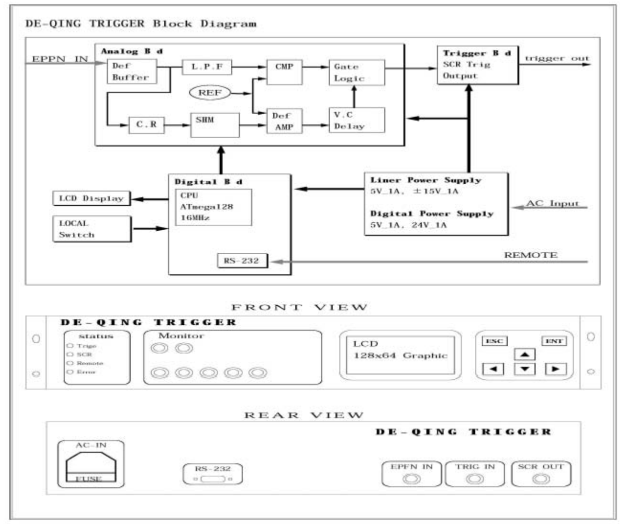

Figure 3: Block diagram of the prototype deQing controller.

As shown in the Fig. 3, the function of the circuit of differentiating PFN charging voltage is that it detects PFN charging voltage electrically from a difference buffer in the deQing controller. The sample and hold circuit picks up the peak value of the slope voltage coming from the differentiated charging waveform. The voltage selected from the sample and hold circuit and a dc reference voltage are compared with a difference amplifier. The difference amplifier outputs an error signal voltage compared with the reference which is coming from the deQing reference voltage which is calculated from the deQing controller. The role of the voltage control delay is that the error signal level obtained from the comparator is adjusted by the following amplifier and converted into a digital signal used for a deQing trigger delay. Its value makes the adjustment of the timing of a deQing trigger by the digital-delay circuit. The role of CPU is that displays a reference voltage and current high voltage, and condition of deQing on or off.

TEST RESULTS

The deQing controller has been tested in a test linac modulator that has a 150 MW peak power. The charged PFN voltage was 34KV with pulse duration of 6μs, and the pulse repetition rate is 30Hz. The HV divider which has 10,000:1 ratio is installed near the PFN inside of the modulator to measure PFN charging voltage. The charging voltage measured has been done using the digital oscilloscope (Tektronics DPO 7104).

Fig. 4 shows charging inductor secondary voltage waveforms that are measured by a 100:1 divider. The left trace is a waveform with 4.3% deQing, and the right trace is a waveform of over 5% deQing. At the measurement of a grade of deQing by using the deQing controller, the grade of 4.3% deQing is the best working. At the test of the grade below 3% deQing and over 4.5%, the stability of PFN charging voltage is more deteriorating. Thus, the grade of the deQing is set about 4.3% of the full PFN charging voltage.

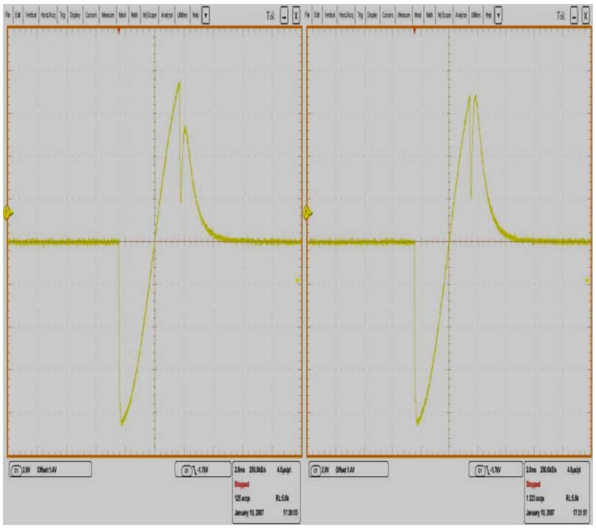

Figure 4: Waveforms of a charging chock secondary voltage. X: 2ms/div, and Y: 200V/div.

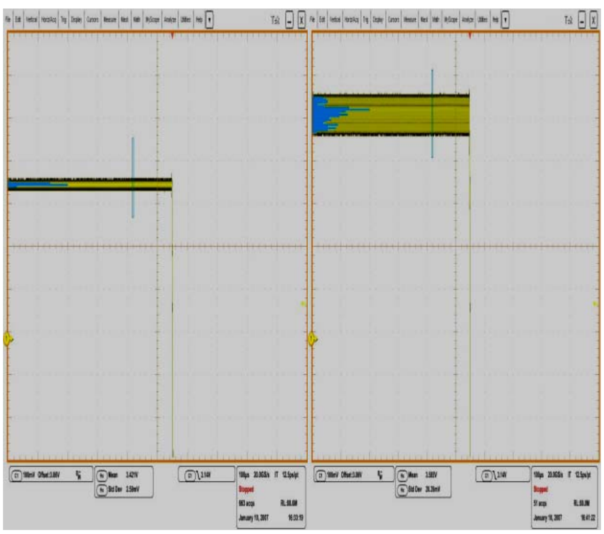

Figure 5: Accumulated waveforms of a PFN charging voltage. X: 100μs/div, and Y: 1kV/div.

PFN voltage waveforms that are measured by a 10,000:1 divider are shown in Figure 5 and 6. In the right Fig. 5 when the deQing controller is not activated, the stability accumulated for 10 minutes is about 0.57% (value of mean: 3.585(V) and value of standard deviation: 20.39(mV)). With the aid of deQing, as shown in the left Fig. 5, the variation measured for 1 hour is reduced to 0.076% (value of mean: 3.421(V) and value of standard deviation: 2.59(mV)) which is reduction of about 7.5 times from the previous value that is measured without the deQing.

As shown in the left Fig. 6, there are many noises remaining at the deQing controller PCB if the ground of the deQing controller PCB could not connect with a modulator ground. The left waveform shows occurring of noise by no connection with the modulator ground, and the right one does not remain noise at the waveform by connection with the modulator ground.

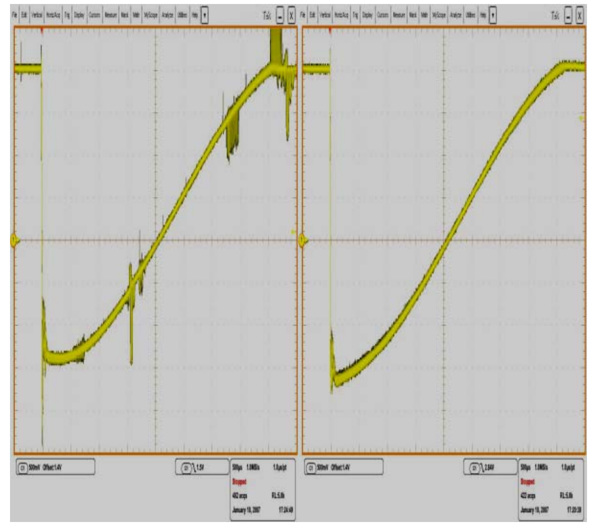

Figure 6: Waveforms of electrical noise and killing noise. X: 500μs/div, and Y: 5kV/div.

CONCLUSION

For improvement of the beam voltage stability for the PAL XFEL (x-ray free electron laser) linac, PAL has been studying a deQing unit aiming at the stabilization of less than 0.02%. The prototype deQing controller has been tested in the test linac modulator that has a 150 MW peak power. To get the required beam voltage stabilization of the modulator with a 65 MW SLAC 5045 klystron tube for PAL test linac, SCR AC-AC voltage reg ulators and the deQing controller are employed.

With the aid of deQing, the variation of PFN charging voltage is reduced to 0.076% which is about 7.5 times reduction from the value measured without the deQing. In the feature, the deQing controller will apply to the linac m ain modulator, and functions that adjust automatically a reference voltage of the deQing compared with a PFN voltage of the modulator may be added to the deQing controller at next upgraded one. Upgrades of the deQing controller will be continued to achieve performance characteristics of the modulator for the PAL XFEL linac.

ACKNOWLEDGEMENT

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REFERENCE

[1] R.B. Neal, ed., “The Stanford Two-Mile Accelerator,” W.A. Benjamin, New York, 1968.