THE RF POWER DELIVERY SYSTEM DESIGN AND ITS COMPONENT CHARACTERIZATION FOR PEFP DTL

H. J. Kwon[#], Y. S. Cho, K. K. Jeong, J. M. Han, B. H. Choi, PEFP, KAERI, Daejeon, Korea

Abstract

The PEFP (Proton Engineering Frontier Project) was started at September 2002 whose main goals are to construct 100MeV proton accelerator and develop beam utilization areas. In this project, 20MeV DTL is scheduled to be constructed and tested within three fiscal years. The RF power delivery system for 20MeV DTL was designed and its components were characterized at PEFP, KAERI. The RF power from a 350MHz, 1MW klystron is split into four legs to drive four tanks of the 20MeV DTL. Each leg has a phase shifter to adjust the phase of the RF field in each tank. The design of the RF power delivery system of the 100MeV accelerator will be based on experiences of the 20MeV DTL RF system development.

1 INTRODUCTION

The 100MeV, 20mA proton accelerator is being developed in Korea as a part of the "21C Frontier R&D program" launched by government [1][2]. As a low energy part of the accelerator, 20MeV DTL was designed and being constructed at PEFP [3]. The DTL consists of 4 tanks to accelerator proton beams from 3MeV to 20MeV. As described earlier, the DTL should be constructed within next 2 years and deliver the beam to the users. With this time table, the RF system for 20MeV DTL is preferred to be separated from the other accelerators up to 100MeV. The most suitable RF system for the 20MeV DTL is the similar one to the RFQ RF system [4]. From the viewpoint of construction cost, one RF system for 20MeV DTL is preferred. Therefore, one of the major design issues of DTL was to restrict the required RF power well below 1MW in order to drive the DTL with one klystron. In addition, the number of cells in each tank was determined from the consideration of the nearly equal distribution of the RF power in each tank.

2 DTL RF SYSTEM OVERVIEW

The required RF power for the 20MeV DTL is described in Table 1, which is an output results of the PARMILA code considering 25% power margin from the SUPERFISH code input data. The total required power is about 900kW which can be covered with one 1MW klystron. The power distribution in each tank is within ±1%. The schematic of RF power delivery system is shown in Figure 1. The RF power from one 1MW klystron is split into four legs by magic tee to drive four DTL tanks respectively. Each leg has a phase shifter to adjust the phase of the RF field in each tank. With this type of power distribution, the amplitude of the RF field in each tank can be maintained within ±1% of the design value in spite of feeding equal power into each tank.

Table 1: Required RF power for 20MeV DTL

Tank #	Cu power (kW)	Beam power (kW)	Total power (kW)
1	141.6	83.4	225.0
2	138.8	86.2	225.0
3	138.3	85.7	224.0
4	137.1	83.9	221.0
Total (kW)	555.8	339.2	895.0

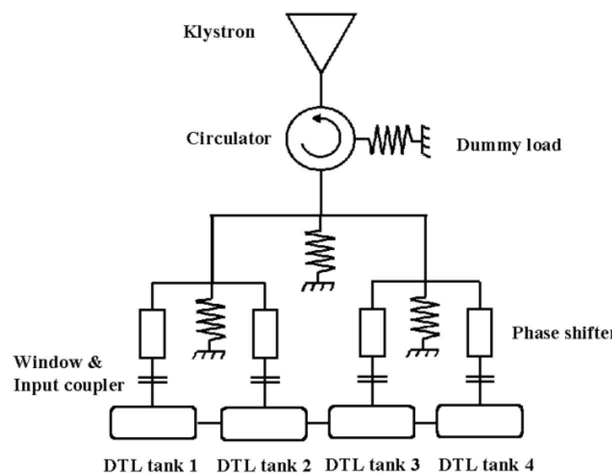

Figure 1: Schematic of RF power delivery system for 20MeV DTL

3 SYSTEM COMPONENTS

Klystron

A TED (THALES Electron Devices) TH2089F klystron which was used as a RF source for 3MeV RFQ will be also used for 20MeV DTL. It is a slightly modified model of the 352MHz, 1.1MW klystron used at CERN. The klystron has a modulating anode to control the beam current and is capable of dissipating the full beam power up to 1,800kW. The klystron is scheduled to be delivered to PEFP site at Jan. 2004.

[#]hjkwon@kaeri.re.kr

High voltage power supply

The requirements of the high voltage power supply are 100 kV, 20 A with the conditions that both the voltage ripple and regulation are less than 1 %, and energy deposition in the klystron at the tube arc is less than 20 J. A three phase AC voltage controller type using thyristor is used. The thyristor controller is located at low voltage side and control the output voltage by adjusting the conducting angle of the 12 pulse AC power. A device which limits the load arc energy is important component because it should limit the deposition energy into the klystron below 20J at klystron arc condition otherwise the klystron has permanent damage. An opening switch which consists of IGBTs is used for that purpose. The switch is now developed by POSCON. The modulating anode power supply comprised of voltage dividing resistors and tetrode will be used. That type was successfully operated as a modulating anode power supply of the 3MeV RFQ klystron. The voltage can be adjusted by controlling the grid voltage of the tetrode. The schematics of the high voltage power supply and modulating anode power supply are shown in Figure 2 and Figure 3 respectively.

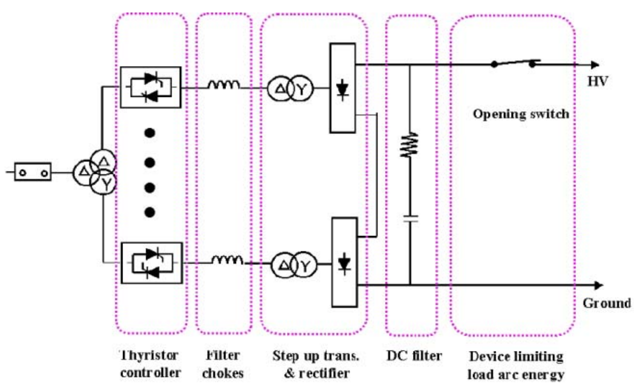

Figure 2 : Schematic of high voltage power supply

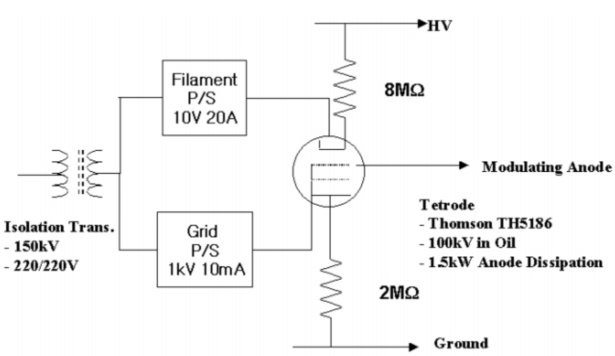

Figure 3 : Schematic of mod. anode power supply

Circulator

An AFT (Advanced Ferrite Technology) circulator which was also used for RFQ RF system will be used for 20MeV DTL RF system. It is a Y-junction type circulator which can deliver 1.3MW RF power for forward direction and permit 1.3MW reverse power at any phase. It uses temperature compensating system to compensate the temperature dependent ferrite saturation magnetization. The circulator is scheduled to be delivered to PEFP site at the end of this year.

RF dummy load

In addition to the role of RF station to the accelerator, the high power RF system for 20MeV DTL has also the role of a high power test stand of various RF components including klystron, circulator, window and so on. Because there is no additional space for high power test in the present site. Under this situation, to test a klystron, a shorting plate is installed between circulator and DTL tank, then all the RF power reflected from the shorting plate is directed to the dummy load located at one side arm of the circulator and dissipated. For this reason, the dummy load at the one side arm of the circulator can dissipate the full power from klystron. A dummy load which is cooled by the water and MEG (Mono - ethyleneglycol) mixture will be used.

Waveguide system

The components of the waveguide system include power divider, phase shifter, harmonic filter, E & H bends, full height to half height transition and so on. The full and half height WR2300 waveguide components will be used. The power balance of the divider should be less than ±1% in order not to use an amplitude adjuster in each waveguide leg. But the power balance of the general divider is less than ±0.25dB. Therefore, precisely balanced power divider or general power divider plus amplitude adjuster structures are required in our case. The phase shifter should have the full range of phase shift above 45° because the phase difference between the waveguide arms for low energy side tanks and for high energy side tanks are nearly 45°. The phase shifter which has three stub tuners and ±45° tuning range is considered for that purpose.

Input coupler

The RF input coupler is one of crucial components in accelerator development. Generally, two types of couplers are used, one is loop type and the other waveguide type. In spite of the cooling difficulty. the loop type coaxial coupler is considered for DTL input coupler because of its easy matching. Among several types of coaxial loop coupler, the one with cylindrical window and half height waveguide to λ/4 coaxial transition is selected primarily, because of the relatively easy fabrication method. This type of coupler is very similar to the input coupler of the spoke cavity in Accelerator Driven Test Facility at LANL [5]. In addition to the development of reliable window, the potential difficulty of this coupler in our case is the multipacting in the coaxial line. The single point multipacting level follows the scaling law : $P_{one\text{-}point} \sim (fd)^4 Z$, where f is the RF frequency, d is the diameter of the outer conductor and Z is the impedance of the coaxial line [6]. According to the data from the paper [5], the single point multipacting level for several geometries can be estimated from the scaling law and is shown in Figure

4. The operating power level is also shown in the Figure. With these data, several geometries are currently investigated (inner diameter of the outer conductor of the coaxial line : 100mm, 103mm, line impedance : 50ohm, 75ohm). As a start up for the development of the input coupler, a cylindrical window was fabricated to verify the fabrication processes including material, machining, brazing, coating as shown in Figure 5. The inner diameter of alumina ceramic (purity : 95%) is 130.1mm and thickness 4.8 mm. The ceramic was brazed into 1.5mm thick copper sheet, which was e-beam welded into the copper-stainless steel flange. The window will be TiN coated and installed in the coupler section to check vacuum tight and low level RF properties.

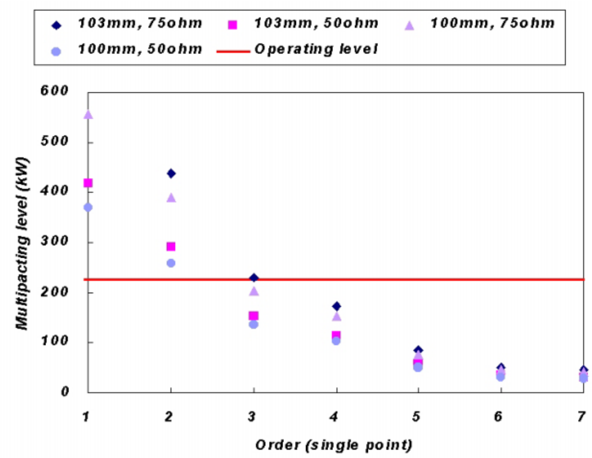

Figure 4 : Single point multipacting level for various coaxial geometry

Figure 5 : Cylindrical window for vacuum and low level RF test

4 CONCLUSIONS

The high power RF system for PEFP 20MeV DTL was described. Some components such as klystron, circulator, high voltage power supply are now in purchase or development stage, and others require more detailed information about the specification before setting up the purchase order. The development of the input coupler is the first trial in our group. The estimated potential difficulties are loop cooling, window failure at high power condition and multipacting in the coaxial line at operating condition. Some modifications and improvements of the 20MeV DTL RF system which are based on the experiences on the operation of the 3MeV RFQ RF system will be carried out. The R&D on the high power RF system of 3MeV RFQ and 20MeV DTL will be a valuable experience for developing RF system for 100MeV accelerator.

ACKNOWLEDGEMENT

This work was supported by the Korea Ministry of Science and Technology.

REFERENCES

[1] B. H. Choi, et al., “High Power Proton Linac Program in Korea”, Proc. of XXI International LINAC Conference, Gyeongju, Korea, 2002.
[2] Y. S. Cho, et al., “Development of 100MeV Proton Accelerator”, Proc. of XXI International LINAC Conference, Gyeongju, Korea, 2002.
[3] Y. S. Cho, et al., “PEFP DTL (3MeV~20MeV) Preliminary Design Report”,PE-30000DD-P001, 2002.
[4] H. J. Kwon, et al., “RF System for RFQ”, Proc. of XXI International LINAC Conference, Gyeongju, Korea, 2002.
[5] E. N. Schmierer, et al., “Design of the Spoke Cavity ED&D Input Coupler”, Proc. Of 10th Workshop on RF Superconductivity, Tsukuba, Japan, 2001.
[6] E. Somersalo, et al., “Analysis of Multipacting in Coaxial Lines”, Proc. Of 1995 Particle Accelerator Conference, Dallas, Texas,1995.