MW grade CW Klystron system for KOMAC
(KOrea Multi-purpose Accelerator Complex)

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Abstract

In KOMAC(KOrea Multi purpose Accelerator Complex) project the total CW output power of RF system is about 30MW. Therefore high power RF source are necessary for cost saving and reliability improvement. The number of klystrons for 350MHz, 0.5 MW and 700MHz, 1MW is 1 and 31 respectively. Also auxiliary components(power supply, waveguide component, cooling system) for RF source are needed. In this paper the main specifications of klystron system and consideration for system integration is presented. The R&D activity for development of klystron system for KOMAC is also included in the paper. .

1. INTRODUCTION

The KOMAC(KOrea Multi-purpose Accelerator Complex) linac will be used for the development of the transmutaiona technology of nuclear waste. The 20 MW proton beam produces a plenty of neutrons and neutrons transmute the long-lived radioactive isotope to the short–lived radioactive isotope. Therefore the transmutation technology will solve the problem of nuclear waste treatment.

1.1 Design parameters of KOMAC accelerator

The KOMAC linac produces a continuous beam power of 20MW at 1000MeV. The KOMAC linac is comprised of a 350MHz RFQ to 3MeV followed in sequence by a 700MHz coupled-cavity drift tube linac(CCDTL) to 100MeV and superconducting(SC)-linac to 1000MeV. This schematic diagram of linac structure is illustrated in Figure 1. a 50keV injector generates a continuous proton beam above 20mA nominal current. From this input, a 350MHz, 3m radio-frequency quadrupole produces a CW 20Ma at 3MeV. The output beam from RFQ is matched into a 700MHz coupled-cavity drift tube linac(CCDTL), which accelerates it to 100MeV. The CCDTL is composed of two sections that optimized in a different energy range(3~20MeV, 20~100MeV). Acceleration to an energy of 1000MeV takes place in a superconducting(SC)-linac.

The SC-linac is composed of cryomodules that contains 700MHz, 4 accelerating cavities. There are three kinds of cryomodules, each designed for efficient acceleration in a different energy range. Cavities in the low energy section, from 100MeV to 140MeV, are optimized at β=0.45, in the medium energy section, from 40MeV to 260MeV at β=0.54, and in the high energy section, from 260MeV to 1000MeV at β=0.72.

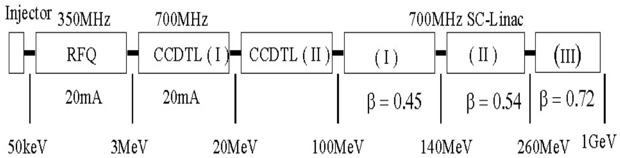

Fig. 1 Accelerator schematic diagram of KOMAC

1.2 RF requirements for KOMAC

The RF system requirements for KOMAC are presented in Table1. The operating frequency selection and power capacity by a different accelerating section is presented in subsequent sections. The table serves to illustrate the scope of the KOMAC RF system. 1 500kW capacity klystron is required and 31 1MW capacity klystrons are required for the desired level of beam power.

2. RF system design

The design of accelerating structure by a different energy range is one of a predominant factors for RF system design. The design parameters of accelerator are presented in table 2. RFQ is operated in 350MHz frequency with about 500 kW input RF power. The 3-20MeV section of CCDTL is composed of 10 CCDTL modules and the 20-100MeV section of CCDTL is composed of 32 CCDTL modules. In CCDTL section the RF input power is 200kW(I) and 210kW(II) in operating frequency 700MHz. The SC-linac is composed of three kinds of beta section. The cavity of section (I) is 6 cell type, the cavity of section (II) is 5 cell type and the cavity of section (III) is 4 cell type.

Accelerator	RFQ	CCDTL		SC Linac			Total
		20MeV	100MeV	140 MeV	260MeV	1GeV	
Frequency (MHz)	350	700	700	700	700	700	
RF Power (MW)	0.47	1.59	5.04	0.8	2.4	14.9	25.1
Number of required RF system (power of rf sys. / number)	0.5MW / 1 ea	1MW / 2 ea	1MW / 6 ea	1MW / 1 ea	1 MW / 3 ea	1 MW / 19 ea	0.5MW /1 ea 1MW /31 ea

Table 1. RF system requirement of KOMAC

There is two ways for SC-linac accelerating option. This option is corresponding to RF input power of accelerating cavity. RF input power is same as 50kW for all different beta sections in option (I). In option (II) the RF input power of β=0.45 section is 40kW, of β=0.54 section is 50kW and of β=0.72 section is 60kW.

Accelerator	RFQ	CCDTL		SC Linac					
		20MeV	100MeV	140 MeV		260MeV		1GeV	
Frequency (MHz)	350	700	700	700		700		700	
No. of Cavity	1	10	32	16(I)	20(II)	48(I)	48(II)	296(I)	248(II)
		(No. of module)		6 cells		5 cells		4 cells	
No. of Cryostat				4(I)	5(II)	12(I)	12(II)	74(I)	62(II)
RF power input (kW/cavity or input coupler)	470	200	210	50	40	50	50	50	60

Table 2. Accelerator design parameters of KOMAC

2. 1 RF Generator (Klystron)

The magnitude of the RF system requirements is one of the predominant cost factors for the KOMAC system. The RF system DC-to-RF conversion efficiency has a primary influence on the operation cost. The RF system must be designed to minimize the number of component failures to insure high availability. An additional requirments for system construction is that the RF system be based on proven technology or low risk extensions of existing technology.

The RF generator in KOMAC system is 700MHz, 1-MW CW klystron, which is required with all but one of klystron. Based experiences at other CW klystron vendors, the operation parameters of 700MHz, 1MW klystron is presented in table 3.

Parameter	Value	Comment
RF output power	**1.0 MW**	
Frequency	**700±20MHz**	**Bandwidth(-1dB) : 1.5 MHz**
DC voltage	**95 kV**	
Cathode current	**17 A**	
Gain saturation	**41 dB**	
Efficiency at satur -ation	**>65%**	
Collector dissipation	**1.6 MW**	**Collector cooling : 1600 l/min (water flow)**
RF window cooling	**100 m^3/hr (air flow)**	

Table 3. Main specifications of 1MW CW Klystron (Reference data : EEV model K3510/KM3510)

The redundancy of KOMAC RF generator is 16-20%. In the KOMAC system these 700MHz klystrons operated at RF power 800-840kW. The KOMAC klystrons collectors are required to dissipate the full klystron beam power for a duration of no RF extraction.

The RF conversion efficiency of klystron is one of a dominant cost factors. The conversion efficiency is 65% in the conventional klystron, but research for increasing the klystron efficiency by advanced multi-stage depressed collector will be achieved in SNU. Also research for the cathode material will be achieved in order to increase the current density and the life time. This factor has an influence on the klystron performance and life time(>10,000hour).

2.2 High voltage DC power supply

The specifications of high voltage DC power supply for klystron system is same below :

- DC power : 2MW
- Output voltage : 100kV (variable)
- Power per module : 200kW
- voltage per module : 10kV
- 10 modules series connection

The baseline design for the KOMAC system is one, switching mode power supply with 10 modules per one klystron . 600V, 3 phase line is injected into rectifier circuit and modules in series connection produce 2MW DC power. The topology of DC power supply for klystron is illustrated in Figure 2.

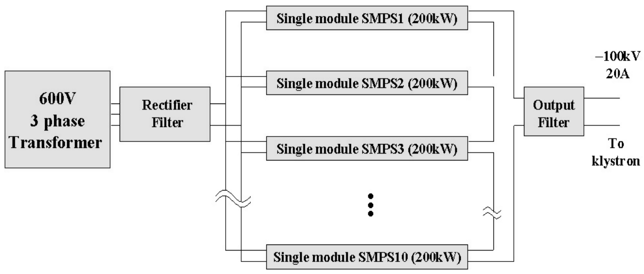

Figure 2. High voltage DC power supply

2.3 RF distribution system

The RF distribution of KOMAC is corresponding to accelerator module design and power capacity of RF input coupler .This system is important for transmission efficiency (>90%), proper power injection and klystron protection.

The 500 kW RF power of RFQ is injected through one RF input coupler. This RF vacuum window can be supplied by commerical vendors. The specifications of 350MHz RF vacuum window is below (EEV MA3512)

- Frequency : 350MHz
- Return loss : better than –30dB at 350MHz
- Flange : 1/2 height WR2300
- Power : >700kW CW
- Construction : Aluminium (air side)
  Copper plated stainless steel (vacuum side)

The CCDTL (I) need two klystrons, CCDTL (II) needs six klystrons. The RF input power is 200,210 kW respectively. The klysrons are protected from high

VSWR with circulators. The extracted RF power is divided by 3dB power splitter and split by directional coupler before being delivered waveguide transmission connected to accelerating cavity to minimize RF window stress. Figure 3 illustrates the RF distribution system of CCDTL.

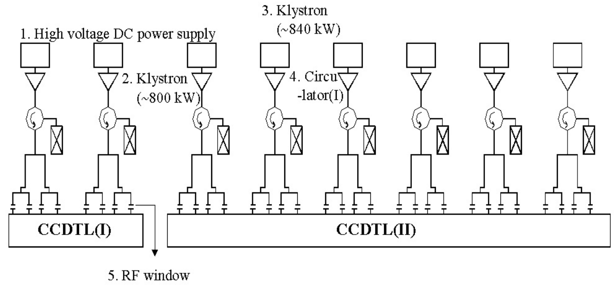

Fig. 3. RF distribution system of CCDTL

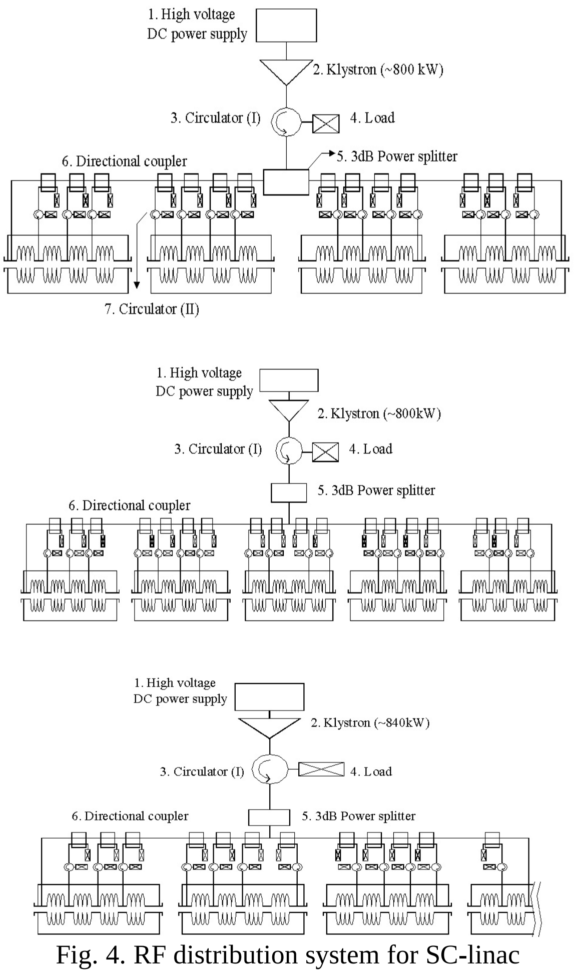

Fig. 4. RF distribution system for SC-linac

In the SC-linac one klystron is connected to low beta section, three klystrons are connected to medium beta section and nineteen klystrons are connected to high beta section. In the option (I) or option (II) beta=0.54 section one klystron is connected to 16 cavities. In the option (II) beta=0.45 section one klystron is connected to 20 cavities. In the option (II) beta=0.72 section one klystron is connected to 14 cavities. These RF distribution systems are illustrated in figure 4 respectively.

The directional coupler for power splitting is 700MHz, 500kW of maximum power capacity, isolation factor 30dB component and the circulator is isolation factor 30dB component. The efficiency of transmission line is 86-90%. The input coupler of SC-linac is achievable by existing technology but 700MHz, 200kW input coupler must be developed for the KOMAC system.

3. RF phase and amplitude control system

When a single cavity or a klystron fails, the beam phase beyond a failure point will be different than reference phase and unless corrected, would result in poor acceleration efficiency and poor longitudinal focusing. Therefor the phase and amplitude control by feedback is important for controlling cavity tuning, phase control. Fig. 5 illustrates the schematic diagram of phase and amp. control system.

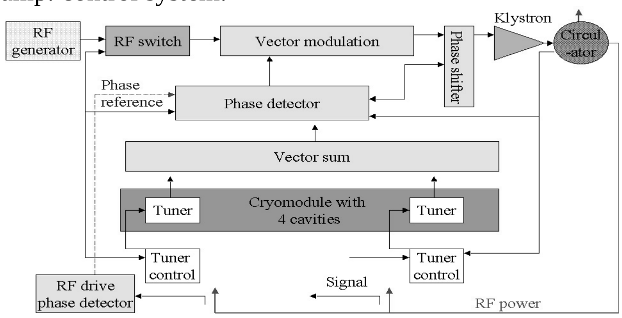

Fig. 5 Schematic diagram of phase and amplitude control

4. Conclusion

The RF system design for the KOMAC accelerator is presented. The specification of all major components is concluded. The conceptual design of RF distribution system is based on 1000MeV, 20 mA proton linac. In future the klystron tube body and electron gun design and construction facility will be achieved and control system design will be proceeded.

5. Reference

[1] "A Study on the Development Plan and preliminary Design of Proton Accelerator for Nuclear Application" , KAERI/RR-1769/96, Nov.1997.

[2] Workshop proceeding on "Accelerator Production of Tritium", LANL, Sept. 1997