SPECIFICATION

Subject and quantity: Long type modulator power supply design 1 set

GENERAL ITEMS

(1) Delivery address

OIST, Okinawa Institute of Science and Technology Graduate University

1919-1 Tancha, Onna-son, Kunigami-gun Okinawa, Japan 904-0495

(2) Deadline for the delivery

March 31, 2016

(3) Inspection and delivery

Product inspection will be conducted based on the contract by the OIST regulatory officials upon the delivery of the product.

(4) Manufacturing developing of test

It is not contained within this contract.

(5) Materials

Quality of materials used to conclude this contract must meet the standard(s) equal to or better than what is specified in JIS standard unless specified in the specification in advance.

(6) Documents to be submitted

Complete book (data sheet, Dimensions, and circuit diagrams), 3 hard copies (one each)

CAD data of an outline view and a circuit diagram (DXF format), 1 hard copy.

All the data specified above in digital format, one USB memory.

(7) Warranty period

Warranty period shall be for one year after passing OIST inspection.

(8) Details necessary to conclude this contract

Contract office treatment rules apply.

(9) Supervisory staff

Supervisory staff shall be: Masakazu Yoshioka (OIST visiting professor).

(10) Other

This contract shall be performed according to the specifications stated within this contract. In case a doubtful conduct arises, both parties shall follow the instructions given by the supervisory staff, Masakazu Yoshioka, and solve the situation in a cooperative manner.

1. BRIEF OVERVIEW

This contract is intended to carry out the detailed design of the modulator power supply that drives the pulse klystron tube for high power RF source of 8 MeV proton beam linear accelerator (RFQ, DTL). Klystron operating at RF output 500 kW, pulse width 3.5 msec, repetition rate 60 Hz. The variation of acceleration beam energy per pulse is required lower than 8 MeV ± 0.5%. For this reason, voltage fluctuation and pulse top flatness of each pulse of the modulator power supply, 34 kV ± <0.05% (± 500 ppm) are required.

Details of this specification are decided in the technical discussions. In addition, if there is a need to make changes to this specification, contractors will follow the instructions given by the supervisor.

QUOTATION RANGE

Pulse modulator power supply design 1 set

(Breakdown of the contents)

1-1 Electrical circuit design

1) The entire circuit design.
2) Electrical circuit to ensure high maintainability.
3) Flattening of the pulse voltage.
4) Low-noise design.
5) Interlock circuit.
   for modulator power supply.
   for external circuit.
6) Control circuit.
   YOKOGAWA PLC, FA3 series (include EPICS CPU module)

1-2 Mechanical structural design

1) The entire structural design.
2) Structural design to ensure high maintainability.
3) Structural design for low EMI (Electro-Magnetic Interference) .
4) Making a component placement with high maintainability.
5) Making a wire having a high maintainability.

1-3 Control diagram

1) Communication between upper system and local devices.
2) Configuration of control signal for modulator power supply.
3) Interlock signal for slow and fast.

1. SPECIFICATIONS

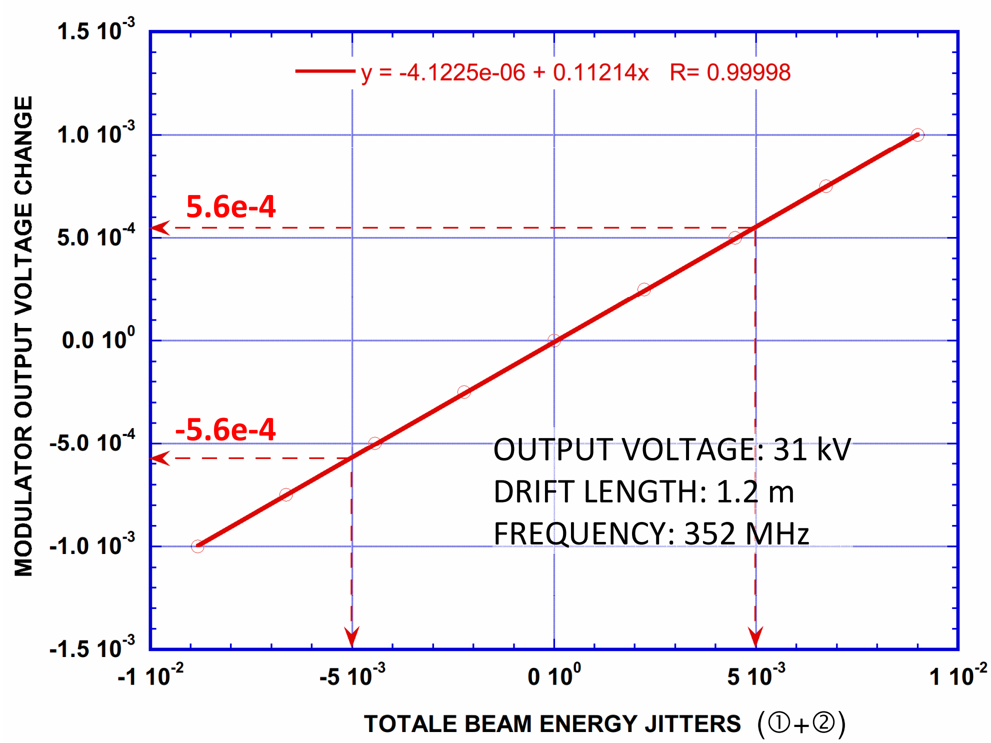
One pulse modulator power supply drive and one klystron tube. 8MeV accelerator system is used for two pulse-modulator power supplies and two klystron tubes. To ensure high maintainability, electrical circuits and mechanical structure of the modulator power supply shall be kept in functional modularity. Also in order to reduce the electromagnetic noise during the operation as much as possible, it is necessary to electromagnetically devised to be equivalent to the Faraday's cage.

2-1 OVER ALL SPECIFICATIONS

1) Peak power: 1.02 MW (rating), 1.3 MW (max.)
2) Average power (@pulse flat top): 227 kW (rating), 280 kW (max.)
3) Output voltage (@pulse flat top): 31 kV (rating), 34 kV (max.)
4) Output current (@pulse flat top): 33 A (rating), 37 A (max.)
5) Output voltage range (@pulse flat top): 1 - 34 kV, 0.1 kV step
6) Output voltage pulse width range (@flat top): 0.1 - 3.7 msec, 0.1 msec step
7) Pulse repetition frequency: single, 1 - 60 Hz, 1 Hz step
8) Load impedance: 920 - 940 Ω (pure resistance)
9) Output voltage stability (pulse)
    Flatness + repeatability: 34 kV <±0.05% (Target: <±0.01%)
10) Output voltage raise time (0→100%): <0.1 msec
11) Output voltage fall time (100→0%): <0.1 msec
12) Output voltage timing jitters: <10 μsec
13) AC line: 3-phase, 420 V±10%, 60 Hz
    3-phase, 200 V±10%, 60 Hz
    1-phase, 200 V±10%, 60 Hz
    1-phase, 100 V±10%, 60 Hz

2-2 TECHNICAL REVIEW CONTENTS

1) Documentation to prove the designing and stable performance of Pulse modulator power (peak 1 MW class, pulse voltage 50 kV class).
2) Documentation to prove techniques and performance for 100 ppm grade flatness and repeatability in a few-millisecond-pulse waveform.
3) Technical proposals to reduce the noise.



ACCELERATOR BEAM ENERGY JITTER	MODULATOR VOLTAGE STABILITY @31 kV, ACCELERATION@60-DEG.	
	REQUIREMENT	MODULATOR SPECIFICATION
$\pm 5 \times 10^{-3}$	$\pm 5.6 \times 10^{-4}$	$\pm{<}5 \times 10^{-4}$ $\pm 1 \times 10^{-4}$ (Target)

COMMENT:
A bean voltage and a drift length of the klystron will be changed after done the detail design by TOSHIBA.

1. KLYSTRON OUTPUT RF PHASE & POWER SENSITIVITIES WITH BEAM VOLTAGE JITTERS.

$$\frac{\Delta\theta}{360} = \frac{e}{mc^2} \times \frac{L}{\lambda_0} \times \frac{V}{(\gamma^2 - 1)^{\frac{3}{2}}} \times \frac{\Delta V}{V_0}$$

$$\gamma = 1 + \frac{V}{0.511 \times 10^6}$$

- $\Delta\theta[°]$: phase change according to HV voltage.
- $e[C]$: 1.6×10^{-19}, electron charge.
- $m\,[kg]$: 9.11×10^{-31}, electron mass.
- $c\,[m/\mathrm{sec}] = 3\times10^8$, light speed.
- $L\,[m]$: 1.2, drift length between input and output cavity.
- $\lambda_0\,[m]$: 0.85, free wave length.
- $V_0\,[V]$: HV pulse voltage. 31kV
- $V\,[V]$: $V_0 \pm \Delta V$, HV pulse voltage change.

$$I_k = \mu k \times V_k^{\frac{3}{2}}$$

$$P_k = I_k \times V_k \propto V_k^{2.5}$$

- I_{KB}: Klystron beam current
- V_{KB}: Klystron beam voltage
- μK: Klystron micro perveance

2. ACC BEAM ENERGY CHANGE ACCORDING TO KLYSTRON RF OUTPUT POWER JITTERS.

① $$E_{z-change-by-\Delta\theta} = \frac{\sin\phi_{60} - \sin(\phi_{60} - \Delta\theta)}{\sin\phi_{60}}$$

$$E_z = \sqrt{P_k \times R_{acc}} \propto \sqrt{P_k}$$

② $$E_{z-change-by-P_k} \propto \sqrt{P_z} = \sqrt{V_k^{2.5}}$$

- E_z: Electric field gradient along axis
- R_{acc}: Shunt impedance [Ω]

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