DRFS Development

KEK S. Fukuda

- Introduction : DRFS R&D Plan
- Talks concerning with DRFS in LCWS10 in Beijing
- Concept of DRFS
- R&D Plan for DRFS in KEK
- Summary

Introduction : DRFS R&D Plan in KEK

- DRFS Plan is supported in ASIAN ILC project, especially it is matched with Japan site condition.
- For S1 global in end of 2010, budget of 2-klystron DRFS system are approved or will be approved).
- For STF phase-II project in 2013, DRFS system for 1 full cryomodule, i.e., 4-5 klystron DRFS system, is strongly supported.
- For these periods, study of DRFS basic configuration are performed.
- Critical issues such as the reliability of the over-current protection HV relay or switch and crowbar protection are intensively studied.
- Cost related study of klystron are now under consideration.

Talks concerning with DRFS in LCWS10 in Beijing

- S. Fukuda DRFS Equipment Joint CFS March 27 am

  CFS matter: Layout, Cooling etc.

- S. Fukuda DRFS Development HLRF March 27 pm

  This presentation

  M. Akemoto(Webex) Power supply for DRFS March 27 pm

  Power Supply System R&D of DRFS

  S. Michizono DRFS LLRF system configuration March 27 pm

- S. Fukuda S1-Global RF Preparation March 29 am

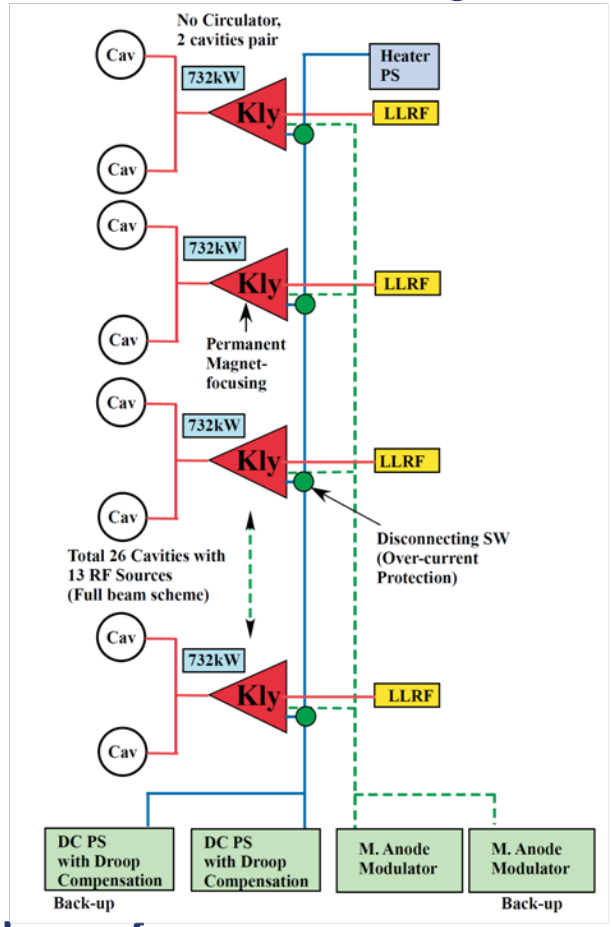
  S. Michizono S1-Global study plan March 29 pm

Concept of DRFS

Concept of DRFS

- The Distributed RF System (DRFS) is another possibility for a cost-effective solution in support of a single Main Linac tunnel design.

- Base line of proposed DRFS
  - **one unit of 750kW Modulating Anode (MA) klystron would drive two cavities (in basic configuration scheme –BCS/HCS).**
  - **totally about 8000 MA klystrons would be used.**
  - **It is based on much simpler and more compact HLRF and LLRF units than the RDR baseline or KCS.**
  - **It offers a good operational flexibility in coupling with performance variations of individual cavities.**
  - **By employing suitable back-up modules for key component, high availability would be expected.**
  - **Complete single tunnel model, no facility in the surface**



Parameters in DRFS

In the RDR scheme, three units of ILC cryomodules, containing 26 cavities in total, are driven by the RF power from one unit of 10MW L-band klystron.

In the proposed new scheme of DRFS, 2 cavities are driven by one unit of 750kW L-band MA klystron. Therefore, one would see that three cryomodules with 26 cavities will be driven by thirteen units of MA klystrons.

Klystron	Frequency	1.3	GHz
	Peak Power	750	kW
	Average Power Output	7.50	kW
	RF pulse width	1.5	ms
	Repitition Rate	5	Hz
	Efficiency	60	%
	Saturated Gain		
	Cathode voltage	64.1	kV
	Cathode current	19.5	A
	Perveance(Beam@64.1kV	1.2	mPerv
	(Gun@53kV)	1.56	mPerv
	Life Time	120,000	hours
	# in 3 cryomodule	13	
	Focusing	Permanent magnet	
	Type of Klystron	Modulated Anode Type	
DC Power supply per 3 cryomodules			
	# of klystron (3 cryomodul	13	
	Max Voltage	71.5	kV
	Peak Pulse Current	244	A
	Average Current	2.47	A
	Output Power	177	kW
	Pulse width	2.2	ms
	Repitition Rate	5	Hz
	Voltage Sag	<1	%
	Capacitor	26	mF
Bouncer Circuit			
	Capacitance	260	mF
	Inductance	4.9	mH
M. Anode Modulator			
	Anode Voltage	53	kV
	Anode Bias Voltage	-2	kV

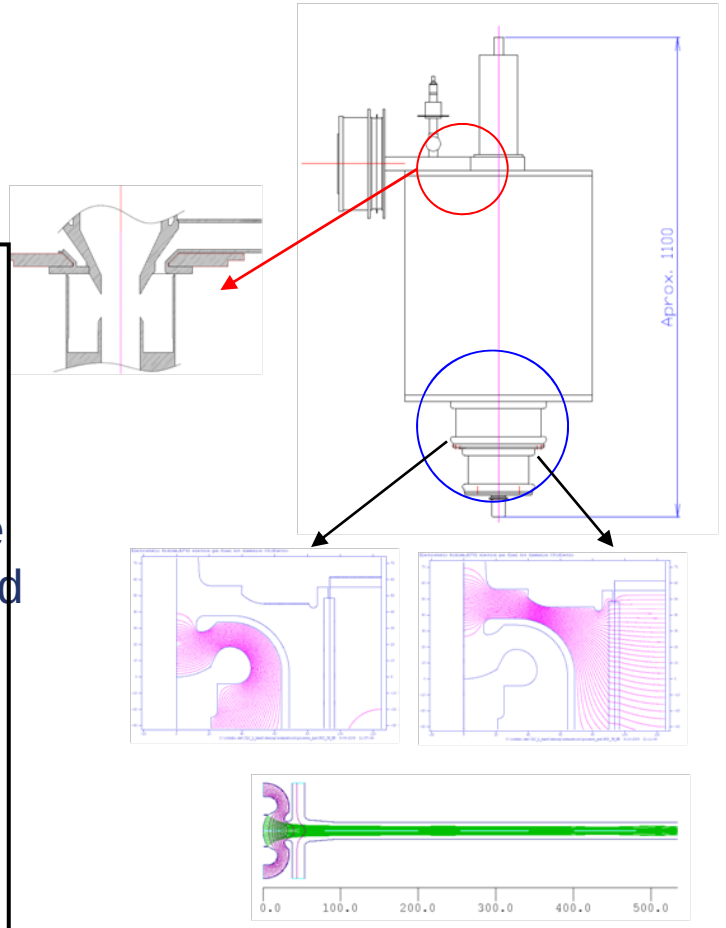
Klystron for DRFS

Parameters of MA klystron is summarized
In the previous table.

Features of DRFS klystron

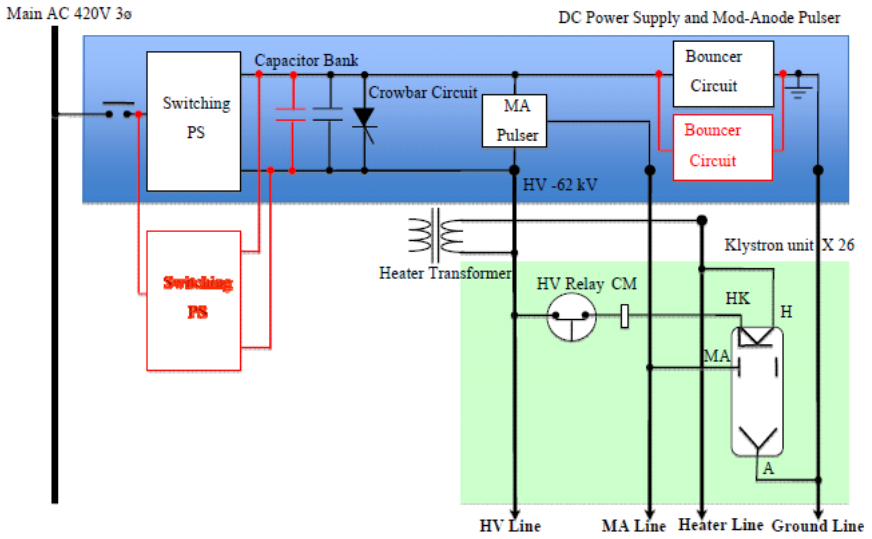
Applied voltage of less than 65kV
60% efficiency with 1.2 microperveance
Low field gradient in klystron gun —few arcing
Low cathode loading--- long cathode life
Low output power--- free from output window failure
⇒ Long life of klystron would be expected

Permanent magnet focusing--- free from magnet and power supply failure
Common heater power supply with back-up --- contribute to high availability



Modulator Scheme/Base Line DRFS

- The DC power and anode modulation for a group of 13 units of klystrons are provided by **one common DC power supply and one common anode modulator** (MA modulator).
- In order to realize high reliability, each of the DC power supplies and MA modulators is associated with **one backup** units, which will be designed and implemented to be "hot-swappable".
- Each of the power and voltage distribution circuits will have **a high-voltage SW or relay**, which switches off the line when over current failures are detected.

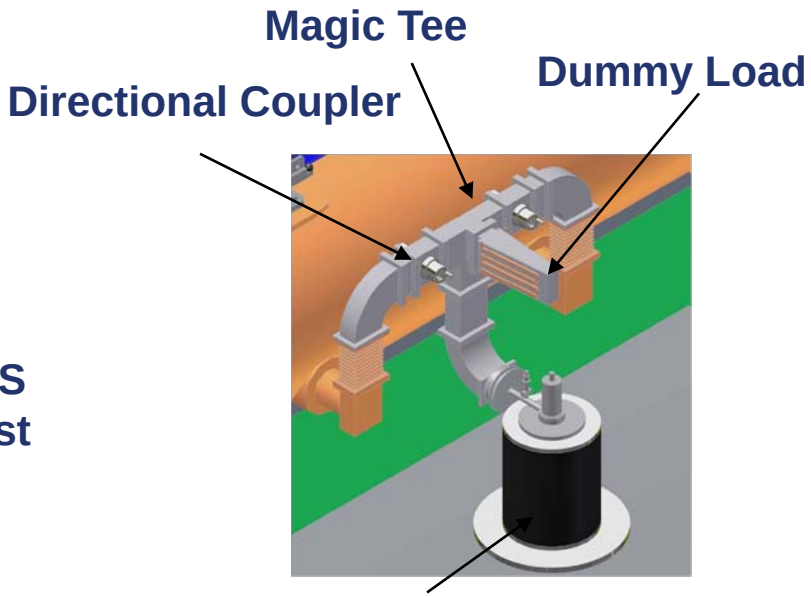


- A DC power supplies has a **bouncer circuit for compensation of the pulse flat droop**. (This leads to a relatively small condenser bank)
- The charger of a DC power supply comprises of a bundle of several units of identical switching PS. This allows us to increase its electrical power with ease, simply by adding more switching PS.
- Common heater power supply and permanent magnet focusing to eliminating magnet power supply.

Power Distribution System (PDS) in Base line DRFS

Very simple power distribution system

- **No circulator**
- **Power divider employs magic tee with high isolation for space saving.**
- **One Phase-shifter with symmetric PDS between couplers or asymmetric PDS with a phase-fixed waveguide for cost saving**
- **Modification of cavity interval helps greatly for the PDS of DRFS.**
- **Design of eliminating flange as possible leads to the cost reduction.**
- **750kW RF is propagated in the dry air without any extra ceramic window**



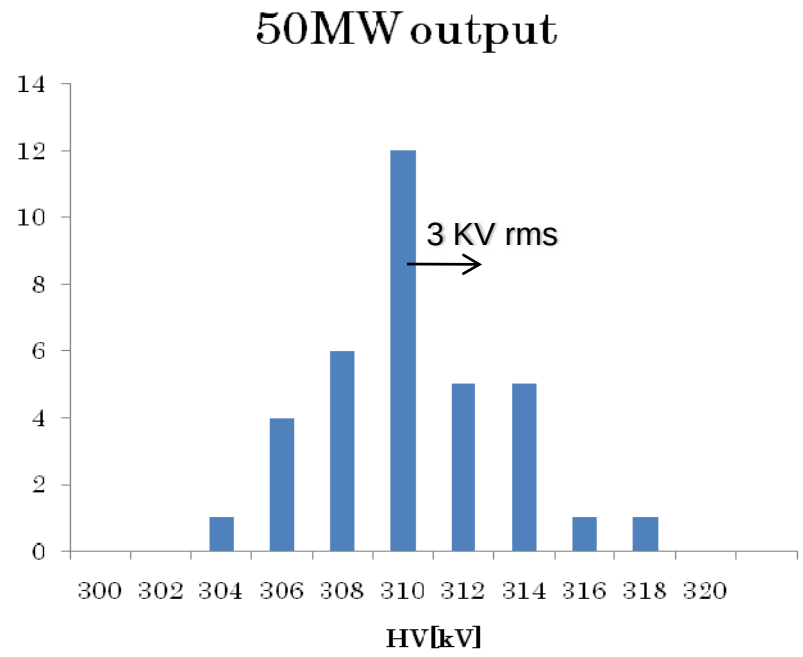
DRFS Basic PDS (HCS)

Cavity Pairing Scheme in DRFS

- We permit that SCRF Cavity Property varies 31.5 MV/m+-20%. This means from 25MV/m to 38MV/m.
- In DRFS, baseline doesn't use circulator and in order to accept above variety, cavity pairing scheme of having almost the same gradient is required.

  (25MV/m&25MV/m …….38MV/m&38MV/m)
- From the HLRF viewpoint, most severe condition is come from the pair of 38MV/m cavities, while 770kW output from the DRFS klystron can drive the pair of 38MV/m cavities if 15% overhead of rf is allowed.
- Considering the klystron yield rate, proper combination of klystron variation and cavity variation result in efficient application of resources.

HLRF requirements



- KEKB injector klystrons (40 MW and 50 MW) are statistically analysed.
- Klystrons have 1.2% (40 MW) and 1% (50 MW) rms HV distribution to reach 40 or 50 MW.
- These correspond to ~3% power distribution with same HV. (P~V^2.5)

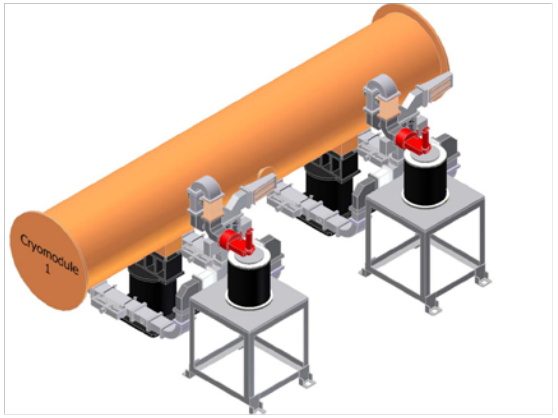
- Suppose the cavity distribution is 3 MV/m rms (~10%), 770kW klystrons can drive 38 MV/m cavities with 15% rf overhead.

					10%sigma cavities		
				31.5	0.5		4000
35				32	0.563059	0.063059	504.4741
	3%sigma Klystron			33	0.683031	0.119971	959.7712
34	0.158655254			34	0.786301	0.10327	826.1597
35	0.5		4000	35	0.86674	0.080439	643.5129
36	0.841344746	0.341345	2730.758	36	0.923436	0.056697	453.5723
37	0.977249868	0.135905	1087.241	37	0.959597	0.036161	289.2881
38	0.998650102	0.0214	171.2019	38	0.980467	0.02087	166.9581

R&D Plan for DRFS in KEK

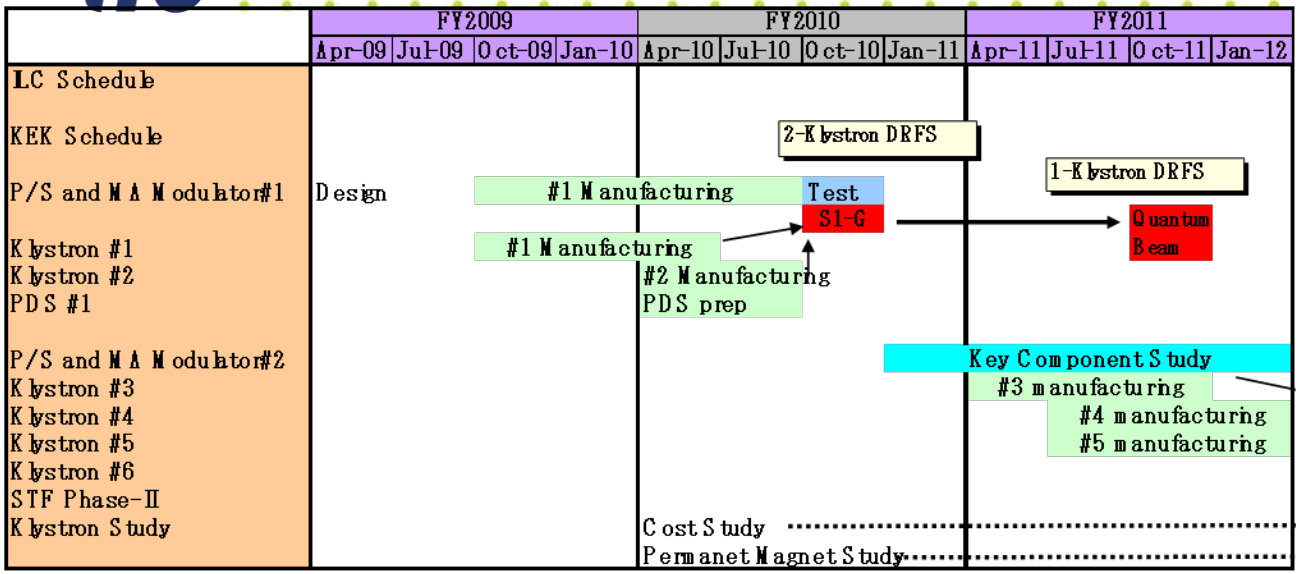
Task and R & D schedule of DRFS in KEK

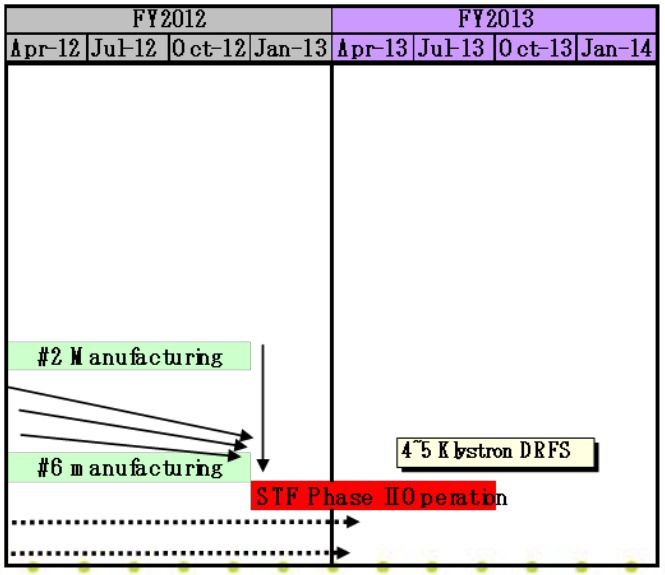
- **R&D study is easy since the DRFS system is not large.**
- **Task force team of DRFS starts and try to solve the problems of DRFS.**
- **Prototype RF unit is manufactured in FY09**
- **Further R&D required for the DRFS RF system is continued from FY09. Three year R&D budget was approved.**
- **Permanent magnet, high voltage SW and IGBT will be studied intensively.**
- **Prototype will be evaluated in the S1 global test (2 Klystron DRFS)**
- **And then installed in the buncher section of STF-II aiming for the realistic operation.**
- **More large scale of DRFS (4~5 Klystron DRFS) is planed for STF-II in KEK.**



S1-Global Plan

Milestone of KEK DRFS R&D





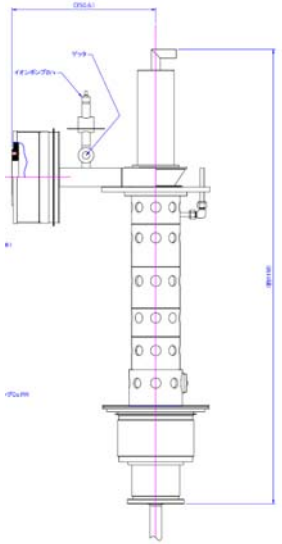
2 big events in KEK employ the DRFS system

S1 global : 2 Klystron DRFS

STF-II : 4~5 Klystron DRFS
(1 Cryomodule)

Prototype DRFS Klystron (S1-G)

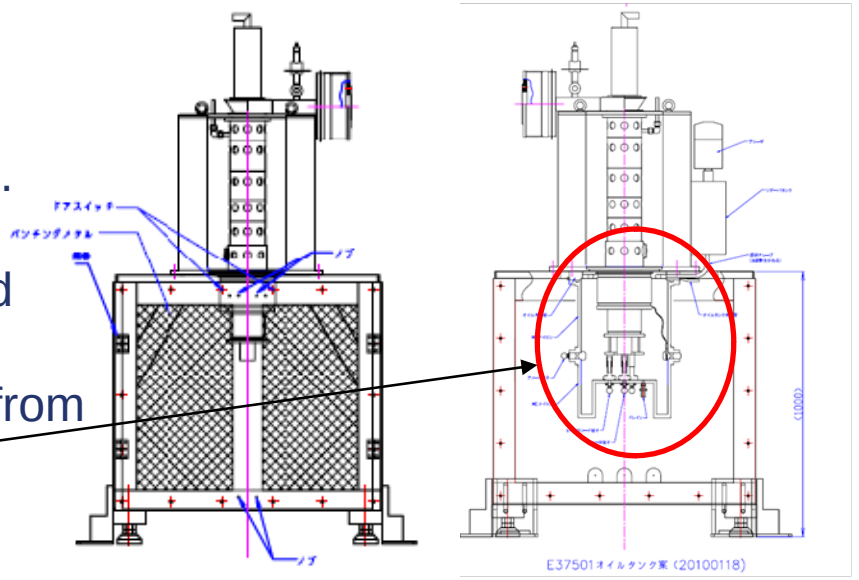
- For S1-global demonstration, KEK will order 2 DRFS klystrons.
- A prototype klystron was ordered in FY09 and will be delivered in around August of 2010. Another klystron will be ordered in April of 2010 and we expect to finish basic performance test till middle of November. Two klystrons and a MA modulator are installed S1-global bench on December and tested.



DRFS klystron

Proto-type employs
Electro-magnet focusing.

HV Ceramic is immersed
In a small oil tank.
Design is now modified from
right figure.



Socket Assembly of DRFS klystron

DRFS Power Supply/Modulator

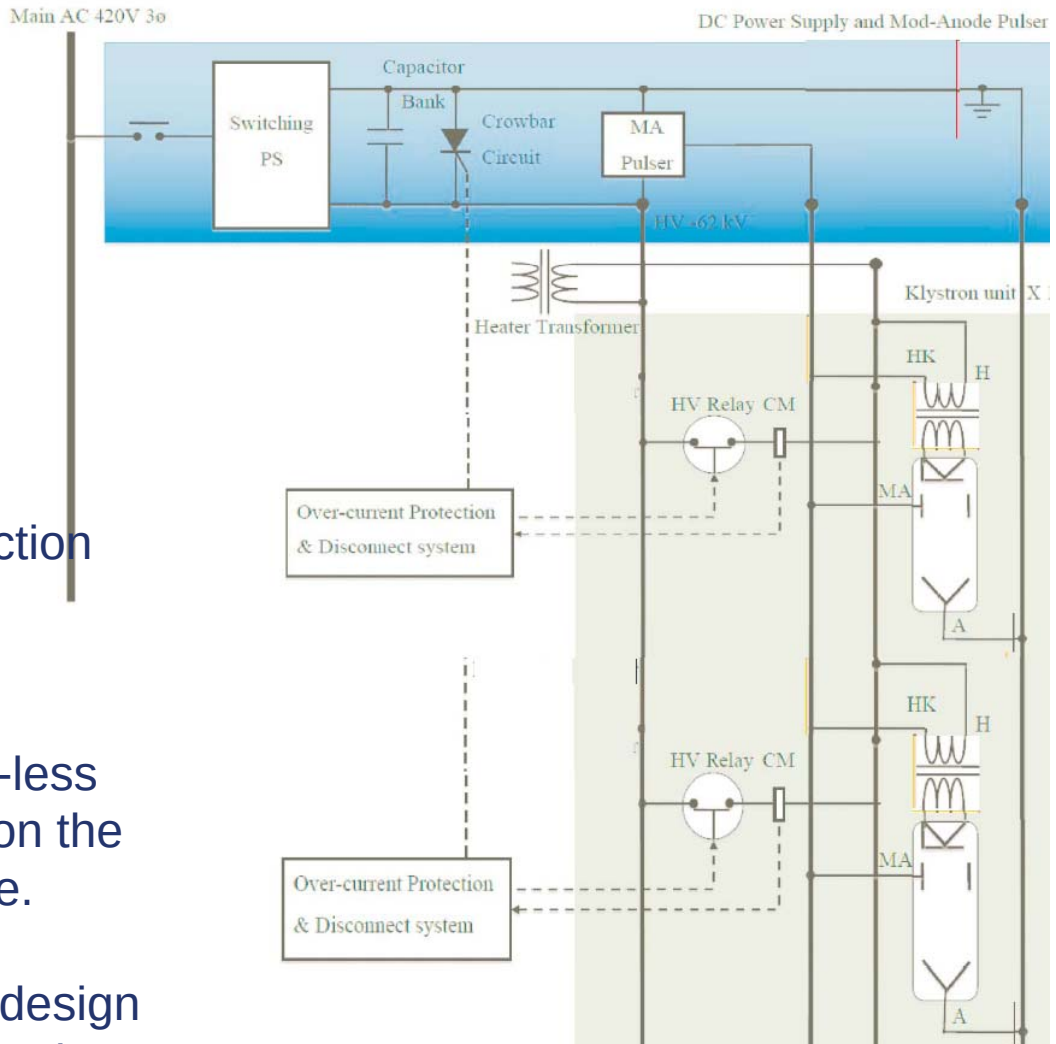
In FY09, prototype DC modulator And MA modulator are ordered.

Capability for 2 klystron loads

Due to small budget, bouncer circuit are not used in S1-G. Compensation of sag for RF is covered by LLRF feedback.
(If this attempt is successful, reduction of capacitors are benefit for cost).

Crowbar circuit using thyratron is introduced. Possibility for crowbar-less is tested. This is strongly depend on the klystron durability for HV discharge.

MA modulator is based on J-Parc design and studied the shunt resistor reduction. (strong effect for cost)



Basic Diagram of P/S& modulator of S1-G

Summary

- R&D plan of Distributed RF Scheme (DRFS) is presented.
- 2-klystron DRFS is almost approved and is demonstrated in S1- global test.
- 4 (5)- klystron DRFS is strongly supported for STF-phase II in 2013 and R&D plan is under establishing.
- A prototype DRFS klystron is now manufacturing.
- A prototype power supply is also under manufacturing.
- Several R&D key issues are descrived.