



Klystron modulators for ESS

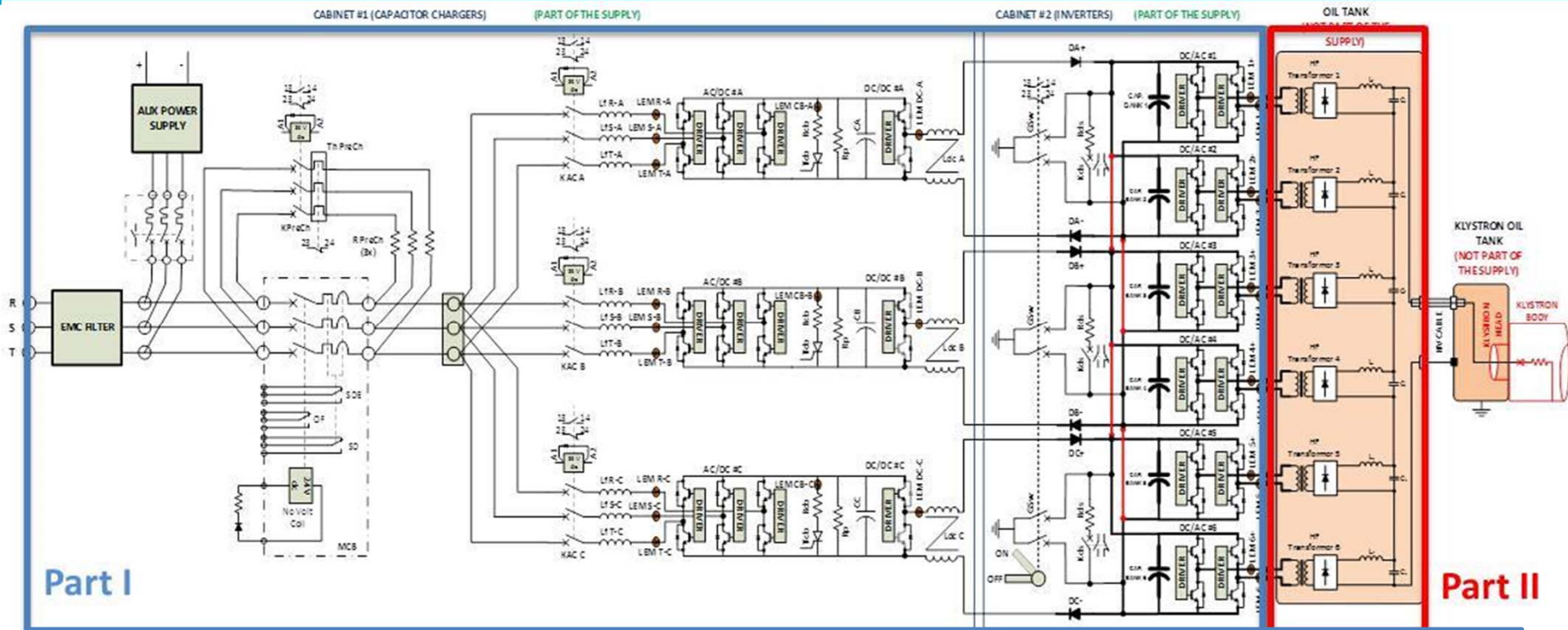
Technical Update

22nd Sept. 2016

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RF power systems, Accelerator Division

ESS klystron modulator topology and prototype

– Recall Slide presented on PCP meeting, Oct. 2015, Paris



Part I – Low Voltage power electronic stage :

- Successfully tested on resistive loads (@1kV) by Feb 2015;

Part II – High Voltage oil tank assembly:

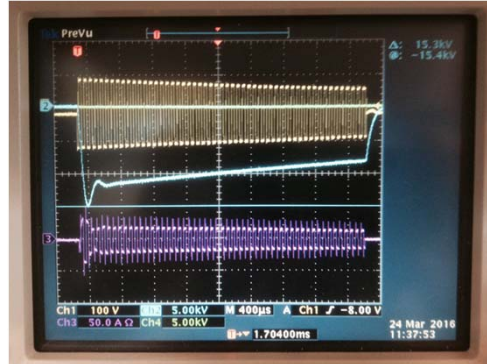
- Design is finished;
- Construction and validation of one HV module prototype done;
- Construction of the entire HV tank assembly currently undergoing;

Reduced scale prototype construction and testing

1. HV oil tank assembly received at test stand - 4th March 2016



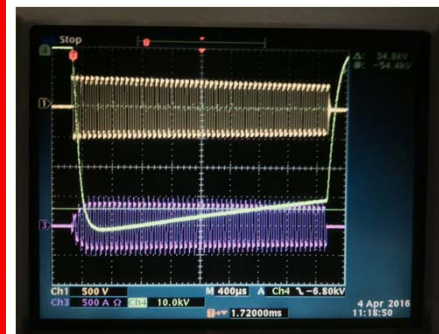
2. Preliminary testing of HV oil tank assembly at low voltage - 24th March 2016;



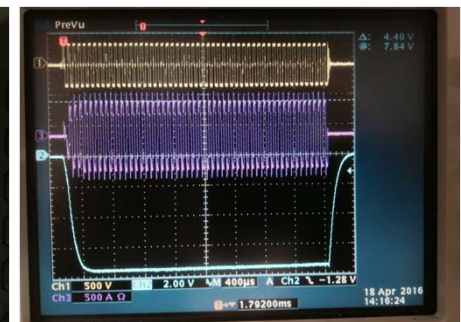
- 3, 4, 5, 6. Testing of complete system



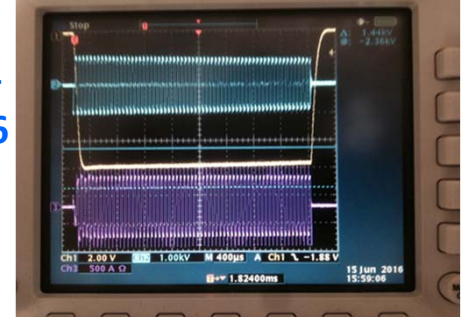
3. 1st testing at High Voltage - 4th April 2016



4. 90kV with droop comp. - 18th April 2016



5. 115kV with droop comp. - 15th June 2016



6. Heat run test of 12 hours consecutively held successfully end June 2016

Klystron modulators for ESS

– Full Scale version (660 kVA)

Main requirements



➤ Functional requirements

Modulator Ratings	unit	value
Pulse voltage amplitude	kV	115
Pulse current amplitude (4 klystrons 704MHz/1.2MW in parallel)	A	100
Average power	kVA	660
Pulse Repetition Rate	Hz	14
Pulse Width (@50% amplitude)	ms	3.5
AC line voltage (phase-phase)	V	600 ± 10% (3-phase, 50Hz)
Pulse quality	unit	value
Pulse rise time (0 .. 99%)	μs	< 120
Pulse voltage droop or slow variation wrt pulse voltage amplitude	%	< 1
Pulse flat-top accuracy (HF ripple, pulse-to-pulse stability)	%	< 0.15 .. 0.2%
Energy in case of klystron arc	J	< 10
Reverse voltage wrt pulse voltage amplitude	%	10

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Main requirements

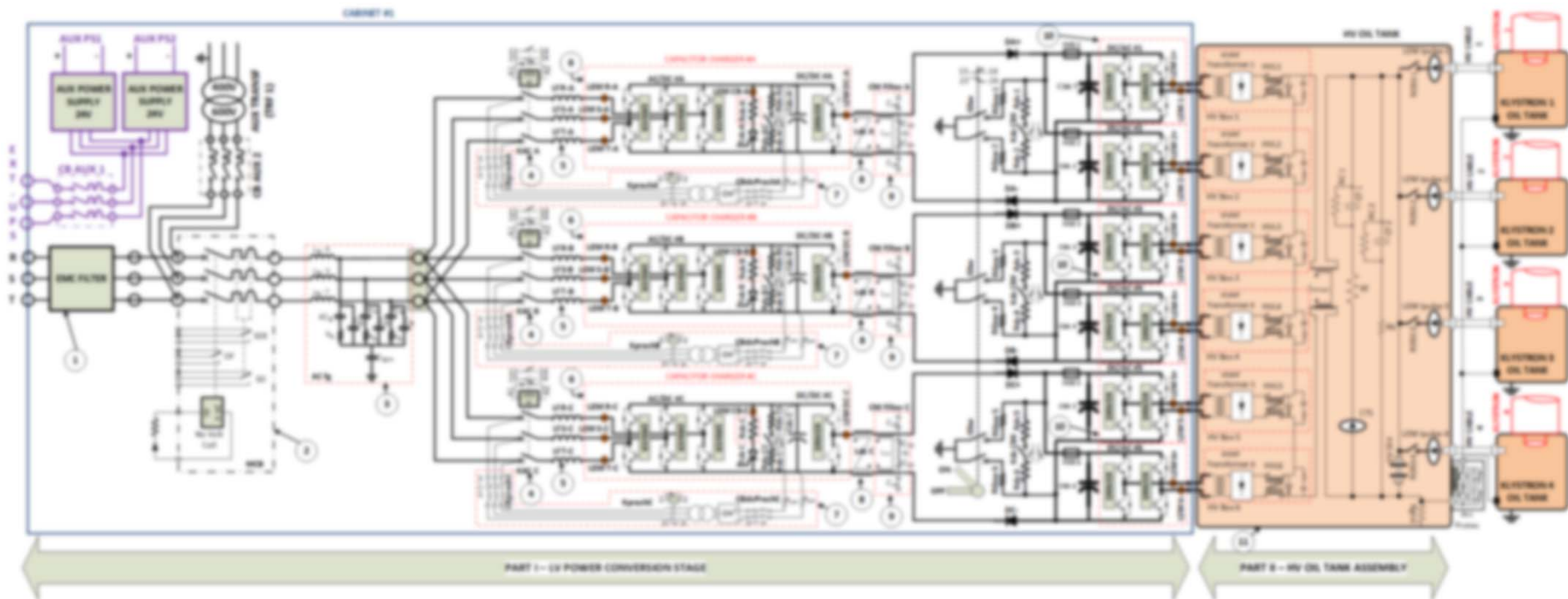


➤ Functional requirements

AC grid power quality and efficiency	unit	value
Flicker @ 14 Hz (i.e. max. voltage amplitude variation wrt nominal)	%	< 0.3
Line current harmonic distortion (THD)	%	< 5
Power factor		> 0.98
Efficiency (i.e. P_{out} / P_{grid})	%	> 91

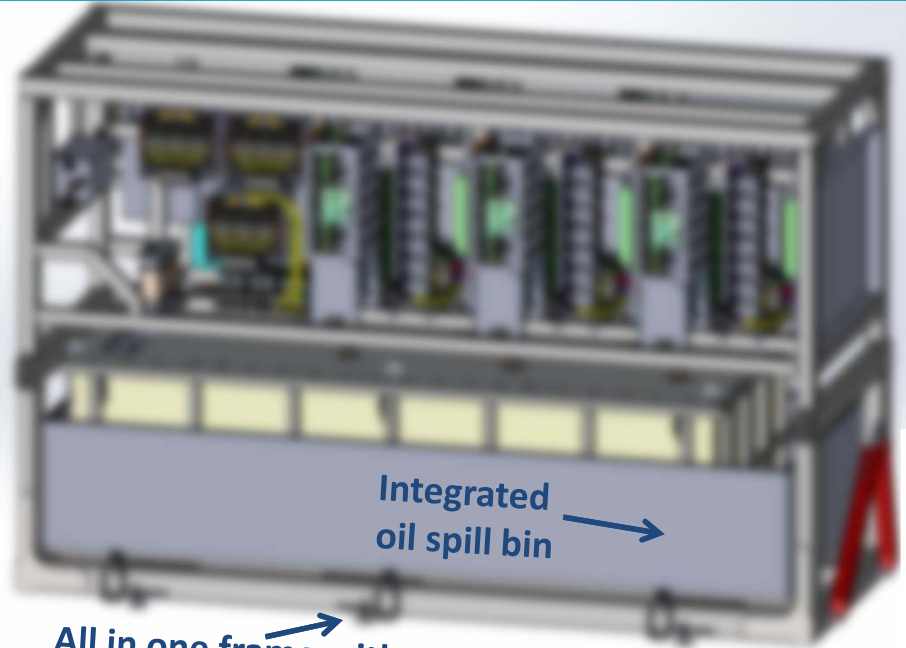
Klystron modulators for ESS

– Full Scale version (660 kVA) *SML Topology*
Schematics :- 4 klystrons $1.4MW_{pk}$ in parallel



Klystron modulators for ESS

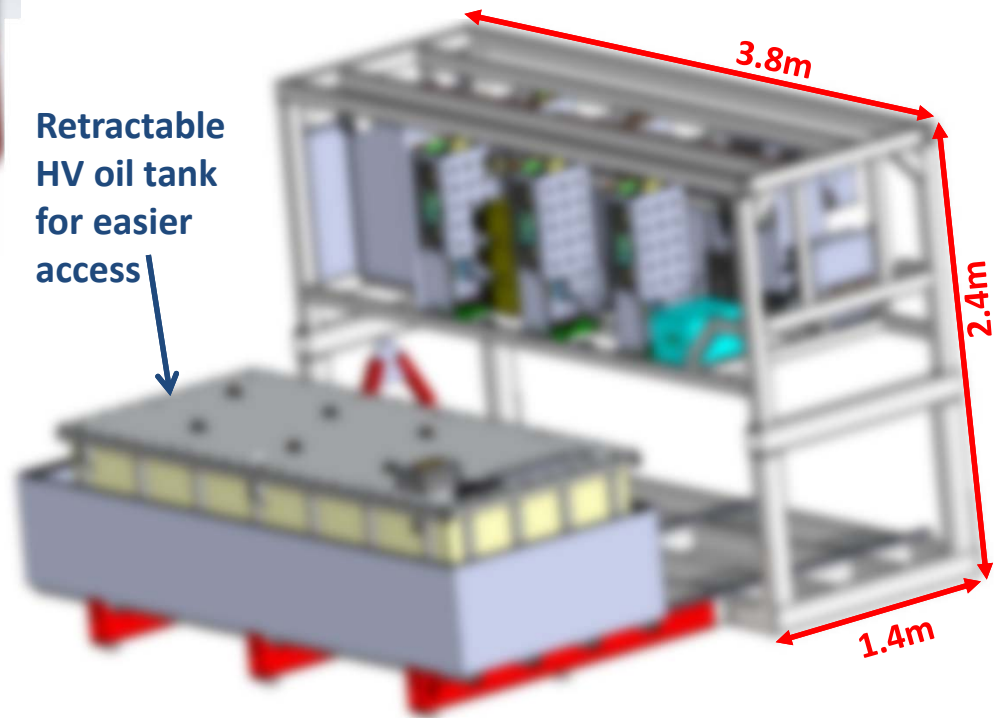
– Full Scale version (660 kVA) *SML Topology*
3D mechanical drawings



Integrated oil spill bin

All in one frame with permanently mounted wheels for easy transportation

- Total footprint: 3.8m x 1.4m
- Total weight: ~ 7.5 tons (with oil);
- Total volume of oil: ~ 2000 liters;



Retractable HV oil tank for easier access

Klystron modulators for ESS

– Statement Of Works



- **Technical Specification oriented towards a “build-to-print” production based on ESS design**
 - **Functional requirements;**
 - **Detailed electrical schematics;**
 - **3D mechanical layout and drawings;**
 - **Bill Of Materials;**
 - **HMI and control systems are just functionally specified (not build-to-print).**