Klystron Modulator

INTRODUCTION

-Company presentation

-JEMA background in HV, High Power

-Main Goals for the long pulse Klystron Modulator

-Possible approaches for high power, long pulse , high repetition rate

-JEMA's approach for meeting the design Goals

-Design Status

JEMA

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Company Presentation

Activity

JEMA designs and manufactures industrial customized power supply static electronics systems, for clients worldwide

Markets

Secure Power Systems

- Conventional Power Plants
- Nuclear Power Plants
- Oil & Gas facilities - Petrochemical
- Air & Naval maintenance facilities, telecom

Advanced Power Systems

- Nuclear Fusion Experimental Facilities
- Particle Accelerators
- Railways
- Grid Quality
- Test facilities

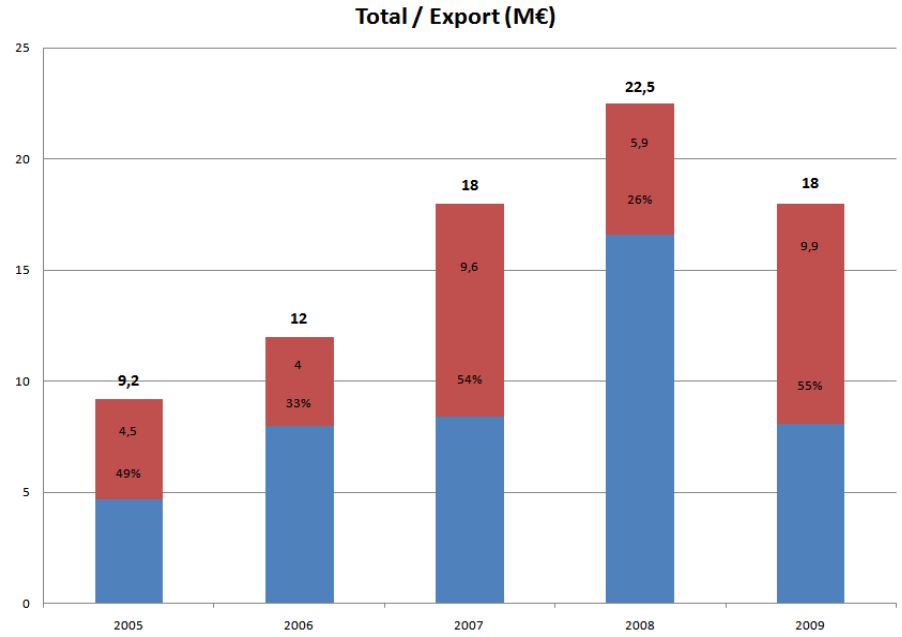
Renewables Power Systems

- Photolvoltaic and Wind Energy Plants

Company Presentation

Location

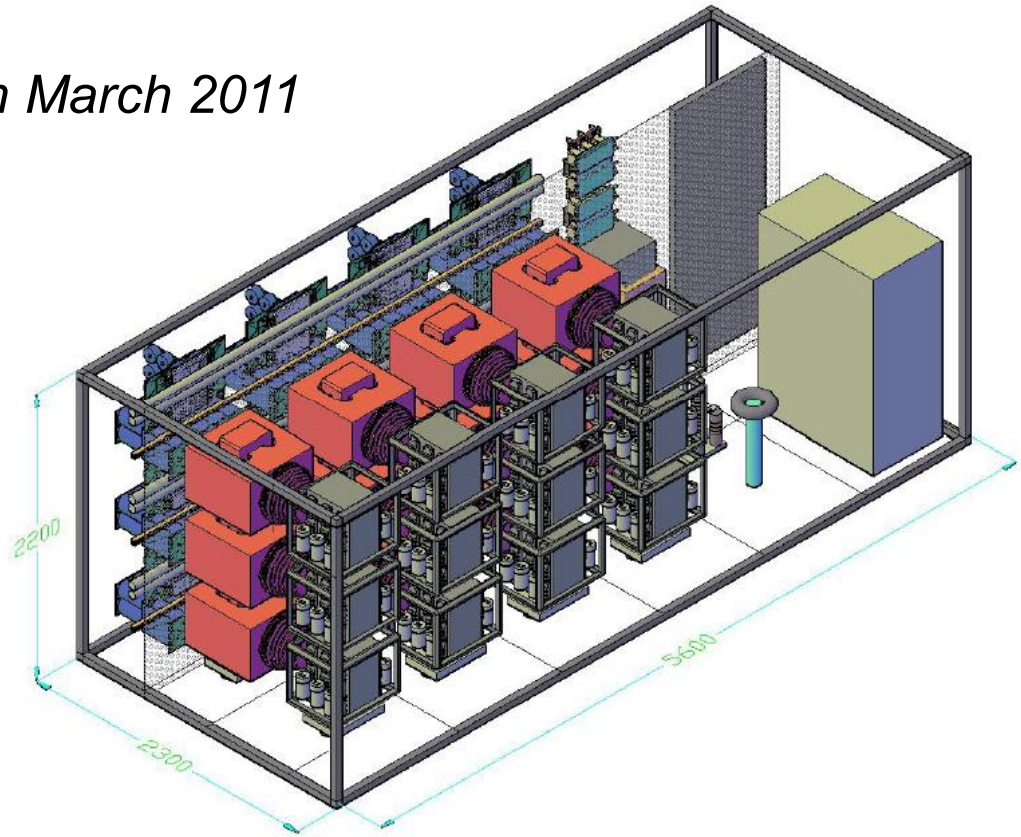
- Founded in 1953
- Located in San Sebastian, north of Spain
- Representative Offices & After Sales Services
  - Oman
  - Abu Dhabi
  - Dubai
  - México



JEMA Modulator Prototype

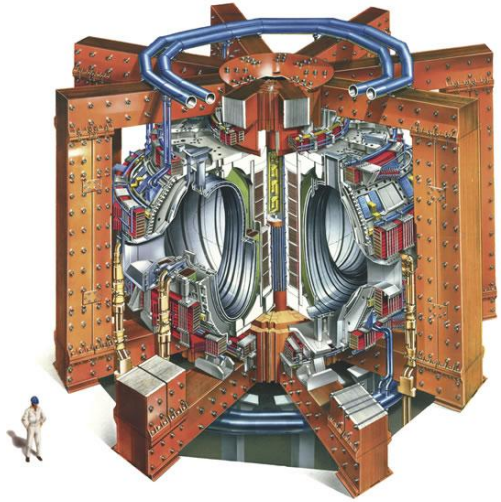
JEMA is designing a Klystron Modulator prototype with the following features:

- *85kV, 160A. Compatible with 110kV 50A*
- *1.5ms pulse length*
- *60Hz operation*
- *To be tested in SNS (USA) in March 2011*

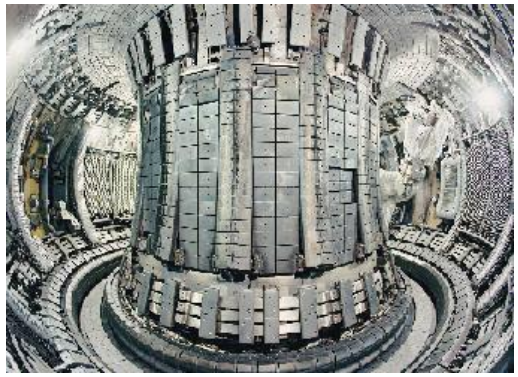


JEMA Background in HV, High Power

EFDA-JET, EUROPEAN NUCLEAR FUSION LABORATORY (CULHAM, UK)



Two + Four High Voltage Switch Mode Power Supplies for PINI loads



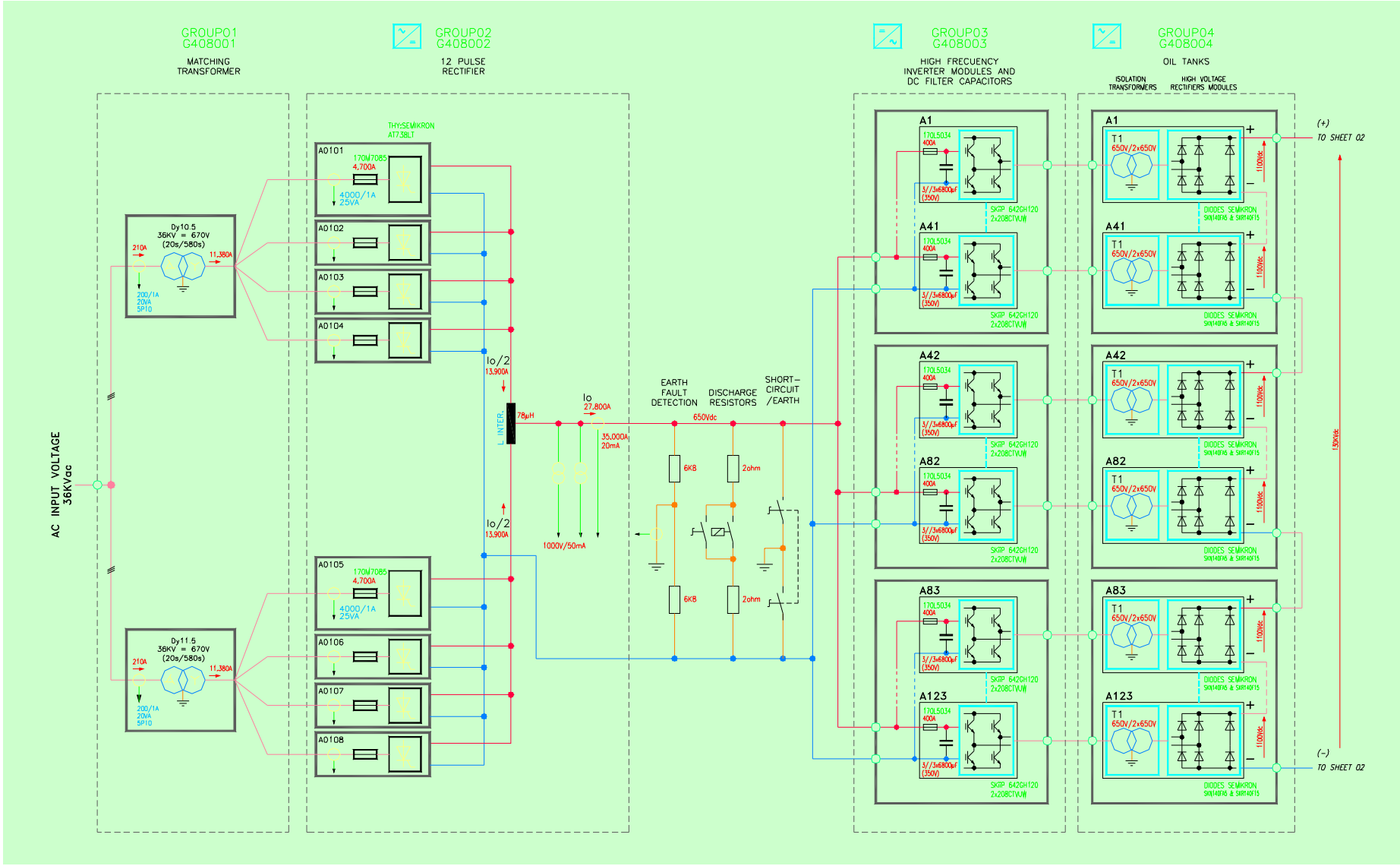
- 130 kV DC, 130 A, 20 MVA input, 17 MW output
- Maximum overshoot <1%
- Voltage raising ramp from 150 to 500 µsec
- Fast switch off time of 7 to 4 µsec
- 256 short-circuits at the output during 20 sec
- 260 kV insulation compact transformers
- Solid state crowbars based on LTT's
- Cooling plant providing demineralised water
- Totally mounted and tested at JEMA facilities, at full power

JEMA Background in HV, High Power

NBI Power Supplies for JET

JEMA Background in HV, High Power

NBI Power Supplies for JET



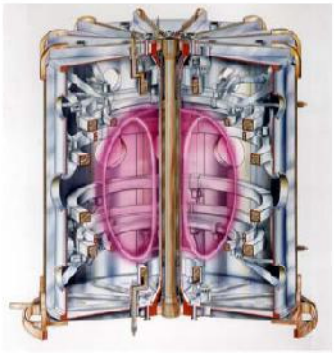
JEMA Background in HV, High Power

NBI Power Supply for MAST (UK)

UKAEA, UK FUSION LABORATORY (CULHAM, UK)

Neutral Beam HVPS for MAST (Mega Ampere Spherical Tokamak)

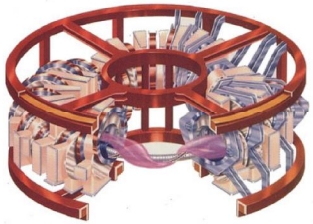
- 80 kV, 70 A DC
- Duty Cycle 10 s ON / 590 s OFF
- Ouput voltage rise time 200 to 500 µs
- Switch OFF time < 7 µs
- Maximum number of reapplications: 500 per pulse
- Insulation test voltages: 160 kVDC, 110 kVAC
- 100% of the control in the low voltage side
- Modular solution
- Low stored energy in the HV side
- Intrinsically safe system
- Low voltage ripple

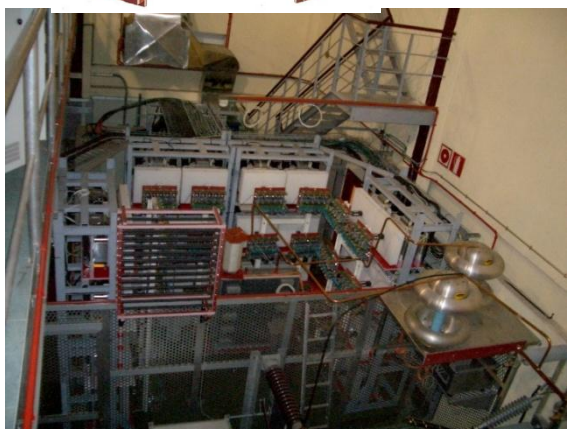


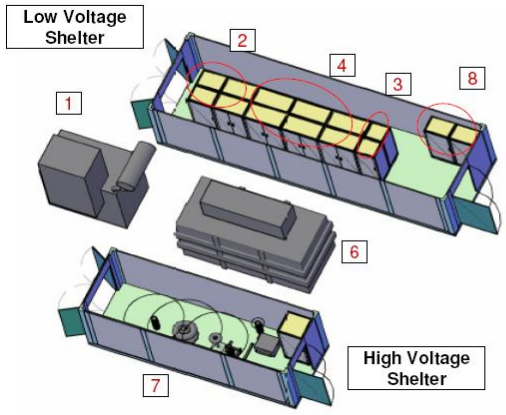
CIEMAT FUSION LABORATORY (Madrid, Spain), TJII STELLERATOR

High Voltage Switching Mode Power Supply for 2 Gyrotrons (ECRH heating)

- HV Power supply (-80kV, 50A, 4MVA) for the ECRH heating system in the TJ-II Stellerator fusion experiment.
-Regulation from -30kV to -80kV
-Maximum output current: 50A
-Very low energy released in case of short circuit in the load (<15mAs). Blocking time < 5us







1. Matching Transformer
2. SCR Rectifier
3. DC Link Maneouvre
4. Inverters
6. HVHF Transformers + Diode Bridges
7. Output Measurement + Grounding
8. Control Cabinet

JEMA Background in HV, High Power

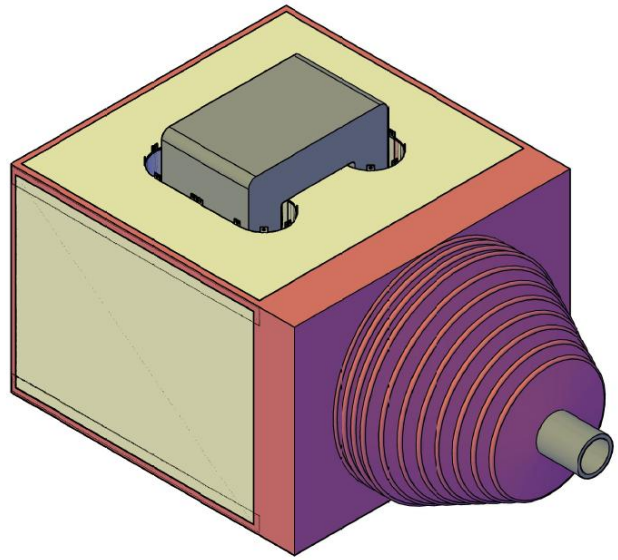
High Insulation Transformer

High Insulation High Frequency Transformer (JET PSs)

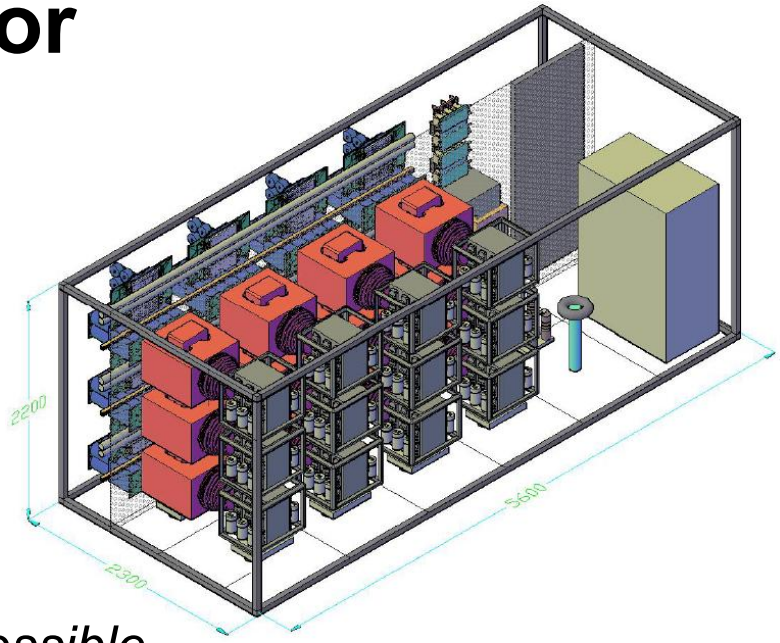
- Polyethylene Insulation, in oil
- Silicon amorphous core
- Insulation rating:
    - 260kVdc 1'
    - 170kVac 1'
    - 350kV 1.2/50us

New High Insulation High Frequency Transformer

- Insulation: Cast Epoxy Resin
- Silicon amorphous core
- Insulation rating:
    - 220kVdc 1'
    - 120kVac 1'
    - 250kV 1.2/50us



Main Goals for the long pulse Klystron Modulator



- ***Meet Key performance requirements***:
  - *-Low output voltage ripple*
  - *-Low output voltage droop*
  - *-Low stored energy*
- ***Modular Design***. *Incorporated spares if possible*
- ***Dry solution***: *No oil*
- ***Easily re-configurable solution***
- ***Reliability***. *High security margins for high MTBF*
- ***Maintainability***. *Easy and fast maintenance for high MTTR*
- ***Costs reduction***

Possible approaches for high power, long pulse , high repetition rate

Pulse Transformer + Bouncer:

Limitations:

- Pulse transformer size for long pulse, high repetion rate

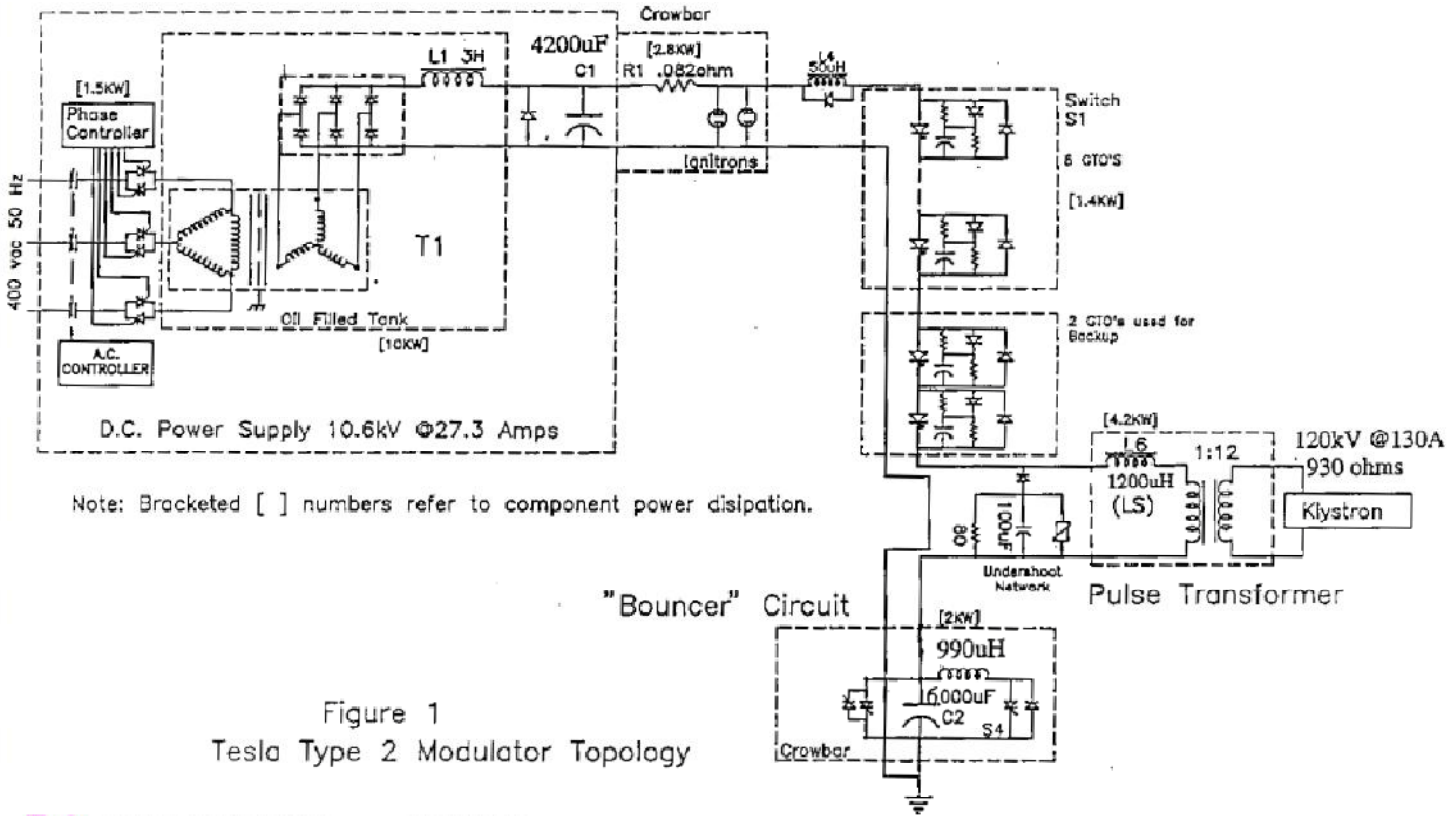


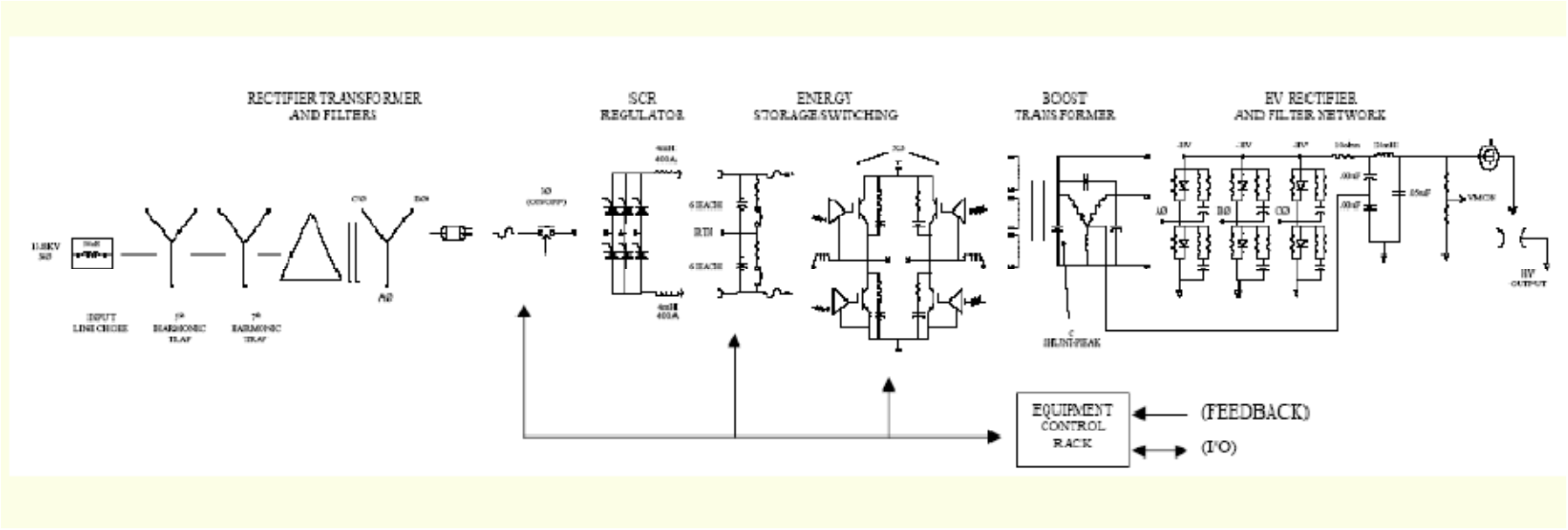
Figure 1
Tesla Type 2 Modulator Topology

Possible approaches for high power, long pulse , high repetition rate

HF transformers + Rectifiers

Limitations:

- HF switching needed for minimizing output filter.
- Complex insulation transformer design

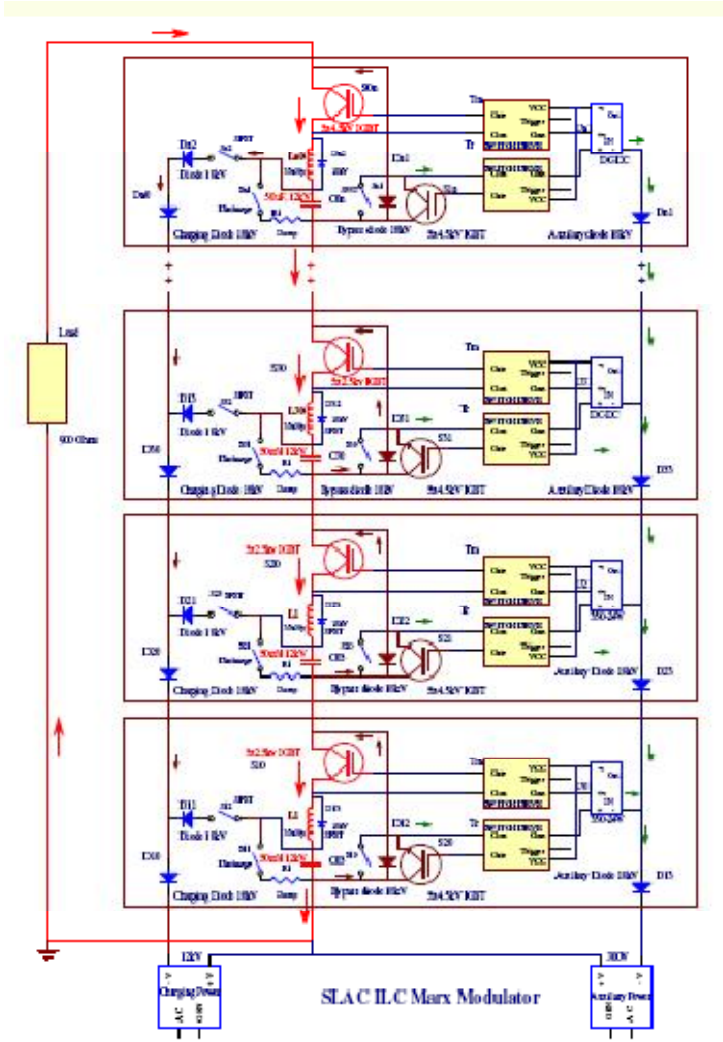


Possible approaches for high power, long pulse , high repetition rate

Marx Modulator

Limitations:

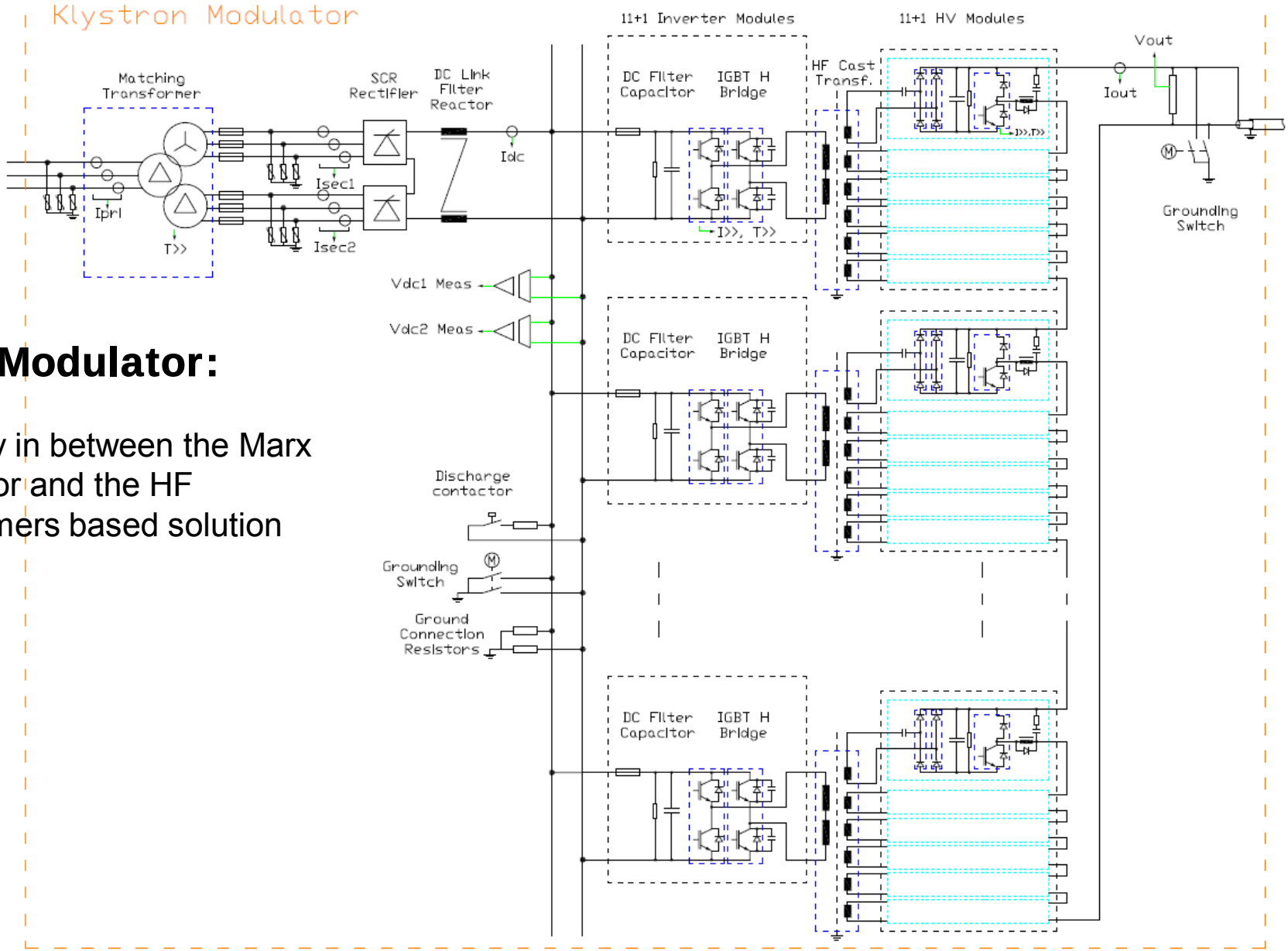
- Complex droop compensation
- Complex charging of capacitors with high repetition rates
- Large capacitors required in HV



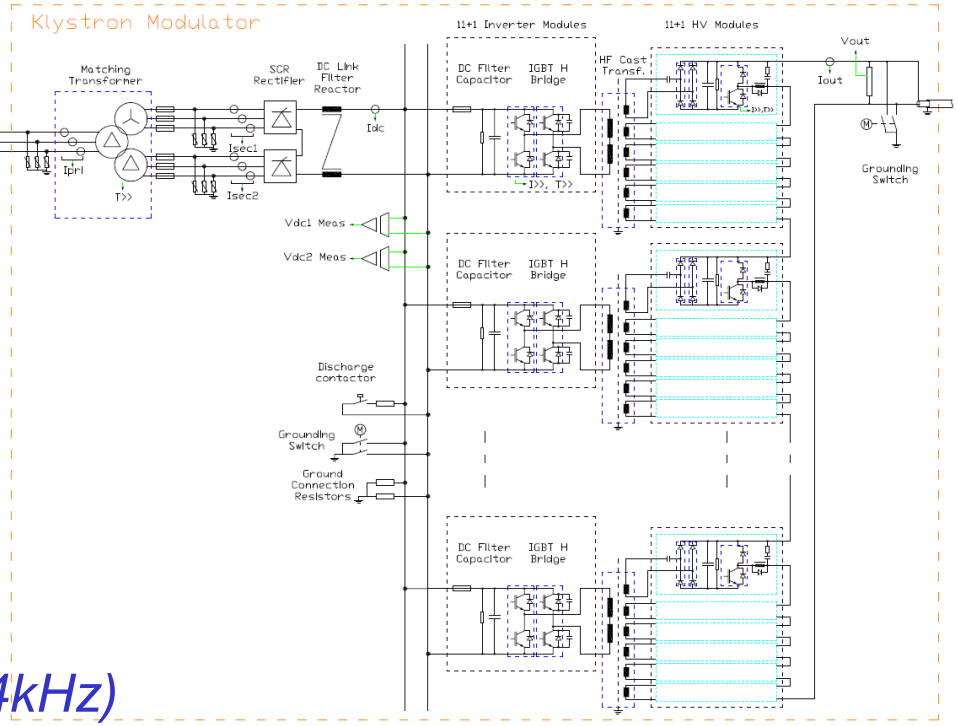
Possible approaches for high power, long pulse , high repetition rate

JEMA Modulator:

Topology in between the Marx Modulator and the HF transformers based solution



JEMA's approach for meeting the design Goals



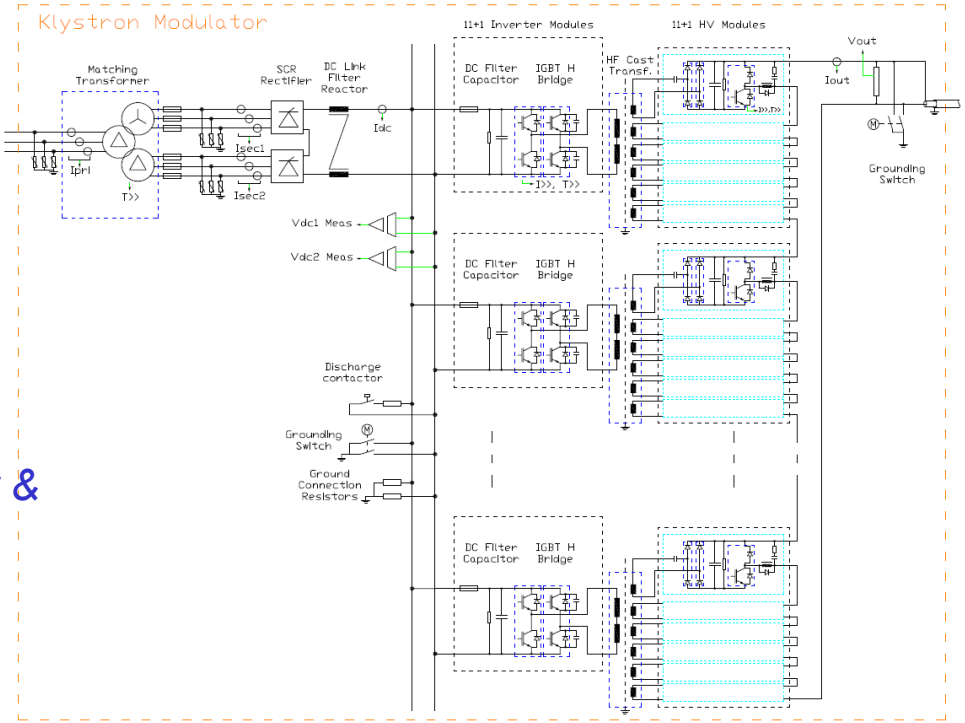
-*Low output voltage ripple:*
  - *Medium Frequency switching (4kHz)*
  - *'Intermediate' C value in HV stage*
  - *Phase shift of the inverter modules -> ripple compensation*

-*Low output voltage droop*
  - *Capacitors in HV stage actively charged during the pulse*

-*Low stored energy*
  - *IGBT at the output blocks energy transfer*

JEMA's approach for meeting the design Goals

- *Modular Design. Incorporated spares if possible:*
  - *11 + 1 Modules: Inverter +Transformer & + HV stage*
  - *No intervention required for enabling spare module*
- *Dry solution: No oil:*
  - *Cast Epoxy Resin Transformers*
  - *Air insulation*
- *Easily re-configurable solution:*
  - *Modular solution enables easy dimensioning to higher / lower voltage, current and duty cycles*
  - *Rated Voltage Limit: 130kV (to be confirmed)*



JEMA's approach for meeting the design Goals

- Reliability. High security margins for high MTBF:

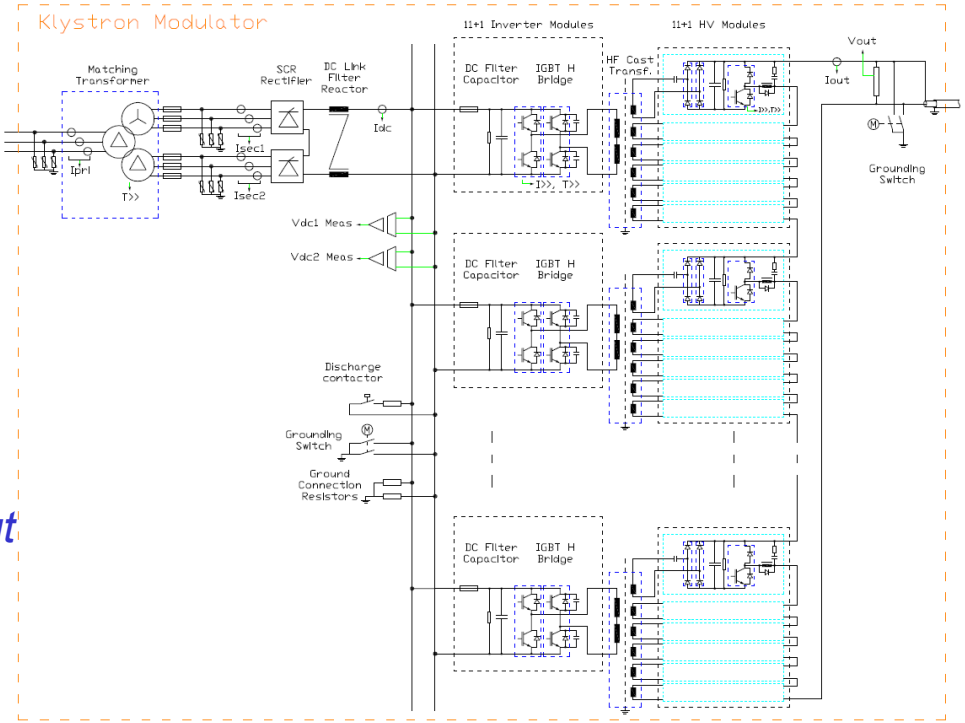
- Resonant Inverters switching at medium frequencies (4kHz)

-Conventional Transformer + Rectifier input stage

- Only industry standard components are used. No components at the limit of the state of the art (¿HV transformers?)

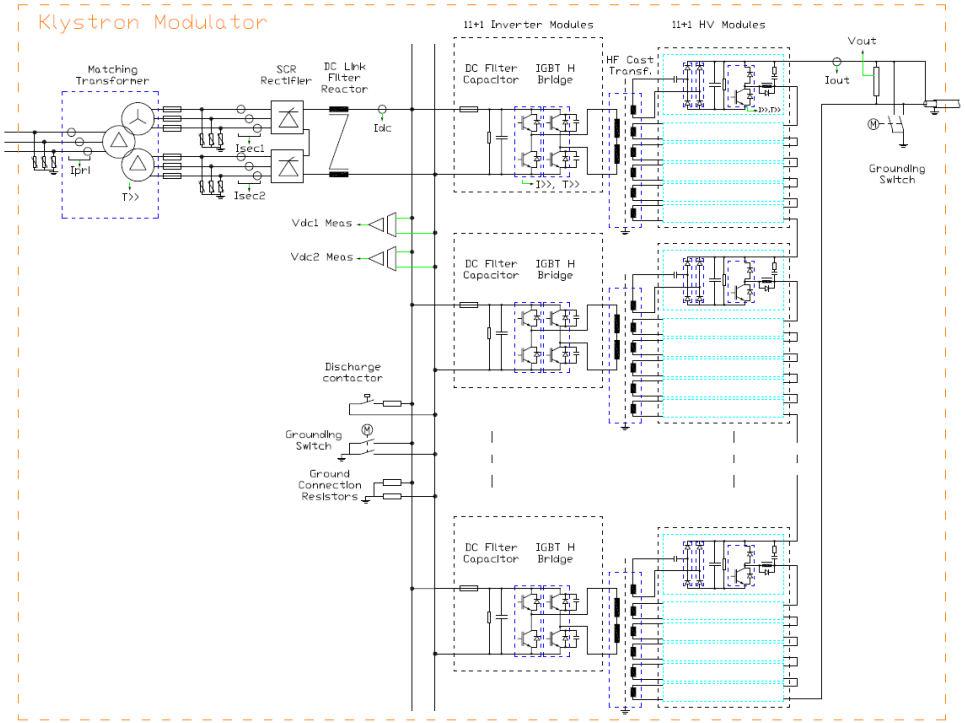
- HV stage active components are self protected. No series connection of transistors or diodes

-High security margins in V and I rating



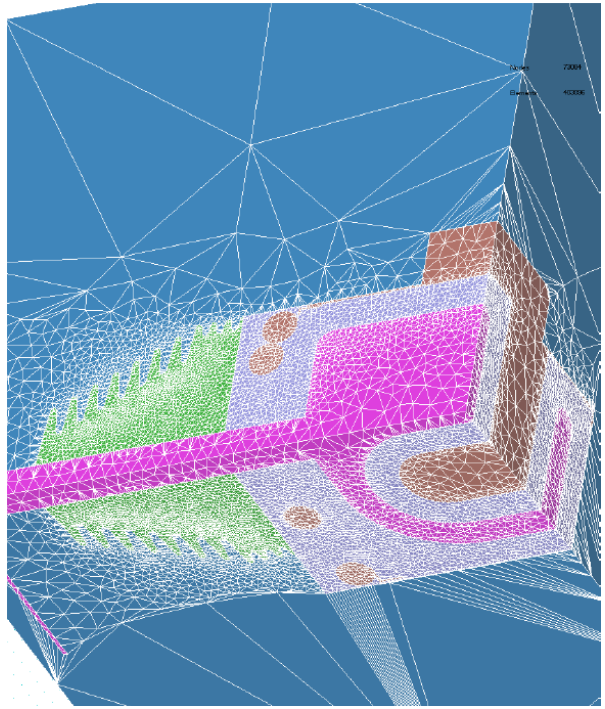
JEMA's approach for meeting the design Goals

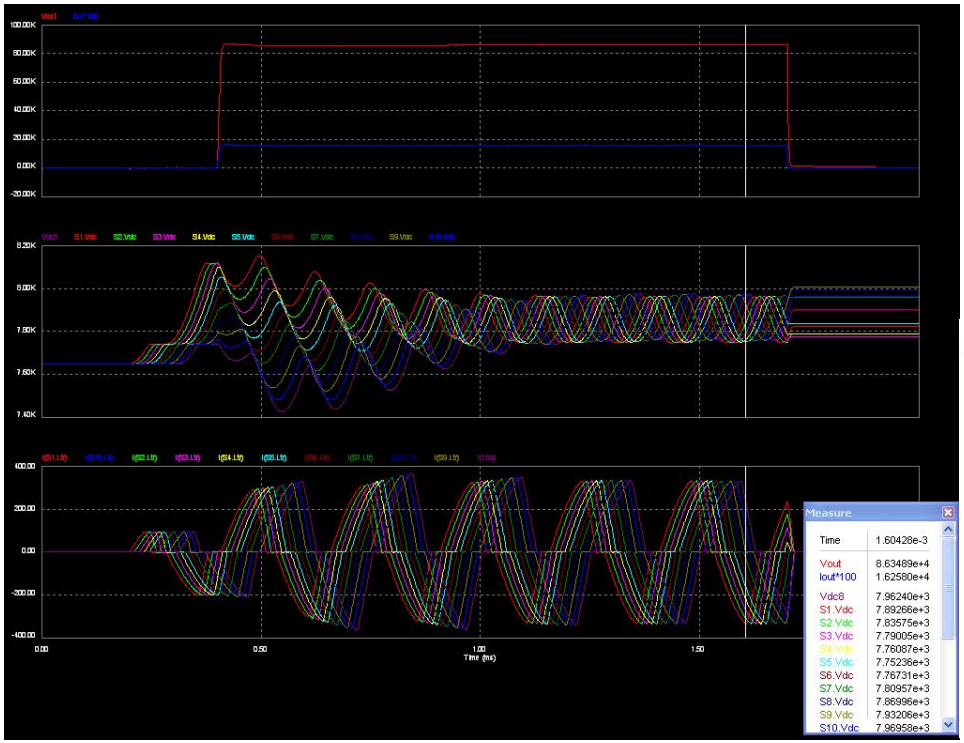
- *Maintainability. Easy and fast maintenance for high MTTR:*
  - *Modular construction. Reduced spare parts requirement*
  - *No elements inside oil tank*
  - *Water connections do not need to be removed for faulty parts exchange.*
- *Costs reduction:*
  - *Modular components*
  - *Industrial standard components used*
  - *HV transformers calculated for higher power rating (1.3MW peak, 120kW average)*

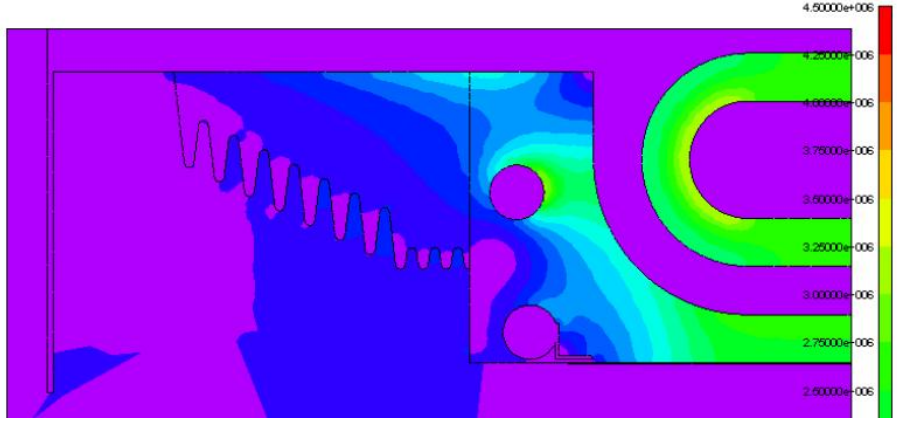


DESIGN STATUS

- *General calculations performed*
- *Electrical simulations in open loop*
- *Electric field simulations for the Cast Resin Transformer performed*
- *1 module prototype built and in test stage*
- *1 cast transformer in manufacture stage*







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