Elettra Sincrotrone Trieste

Present Status of Elettra RF Systems

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- ✓ RF Power Sources Statistics
- ✓ Elettra Up-Time
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- ✓ Conclusions

The Elettra Facility

- ✓ 3rd generation light source **2.0 GeV** - **2.4 GeV**

  Full Energy Injector (2008):

  100 MeV conventional LINAC + 2.5 MeV Booster

  Storage Ring (1994) double bend achromat

  Ring circumference 259.2 m

  Emittance 7 nm-rad & 1% coupling

  Beam Dimension @ IDs 250/14 μm

  Beam Length nat. = 25 ps, with 3HC > 100 ps

- ✓ **310 mA** (2.0 GeV) and **160 mA** (2.4 GeV)

  Standard filling 410/432 bunch train

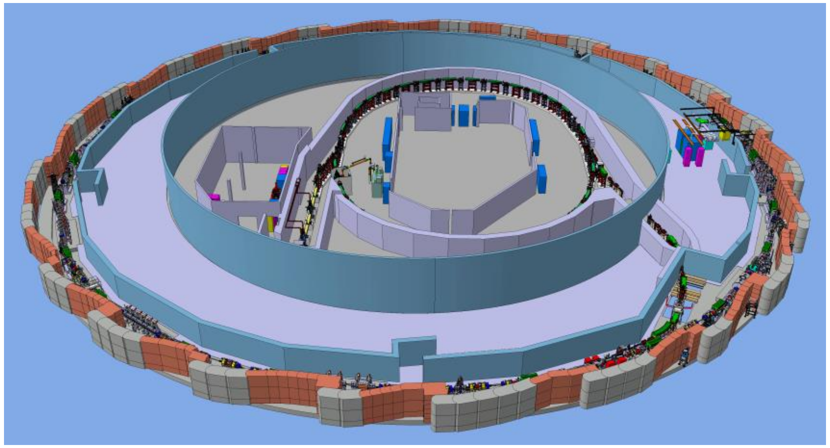
  Hybrid filling 410 bunch train + single bunch

- ✓ **Top-Up** , ΔI =1 mA, time span= 5 ÷ 20 min
- ✓ 5000 hours/year, scheduled for the user
- ✓ 27 beam lines + 1 under commissioning

  *22 ID segments + **1 SCW 3.5 T***

  6 bending magnet sources points

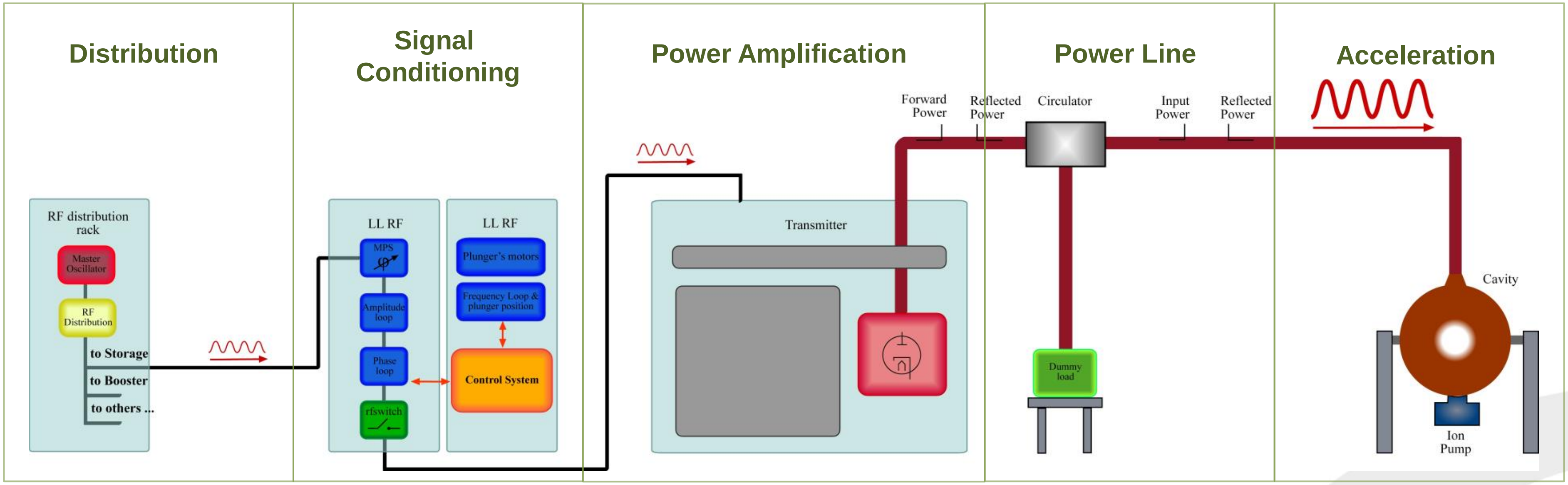
- ✓ **Goal: User Up-Time > 95%**



The RF Systems

Nominal Frequency 499.654 MHz   Storage Ring ΔE/turn ~300 keV

	Booster	Storage Ring
RF stations	**1**	**4**
Cavity type	Petra / 5-cell	Normal Conducting / single cell / copper
RF power sources	60 kW klystron	3x 60 kW klystron + 1x 150 kW 2x IOT
Power dissipation @ Vacc	14 kW	120 kW
Power to the beam	2 kW @ 2.4 GeV	100 kW @ 2.0 GeV
Max Available Power	55 kW	310 kW



RF Power Sources Statistics

Transmitter	Tx-A		Tx-B	
Heater hours	53800		52700	
IOT model	E2V D2130		E2V D2130	
Serial number	302 -1017		368 – 1208	
Installation date	2010 June		2012 June	
Year	operating hours	trip	operating hours	trip
2010	3700	7	X	x
2011	10700	4	X	x
2012	15500	3	3250	3
2013	20650	0	9650	1
2014	25580	0	15110	2
2015	31800	0	21500	0
2016	36900	0	25950	0

150 kW IOT-based Tx, since 2006
2 twin Tx (80+80 kW) combining
on a switchless WG hybrid

60 kW klystron-based Tx

Data for year 2016 are up to the end of October

RF station	klystron	SN	tube hours	heater hours
Booster	K3672 BCD	1083-0351	**47000**	120900
RF #2	K3672 BCD	1184-0823	**41900**	133900
RF #3	YK1256	14105.265	**30050**	135950
RF #8	K3672 BCD	1184-0823	**42150**	135450

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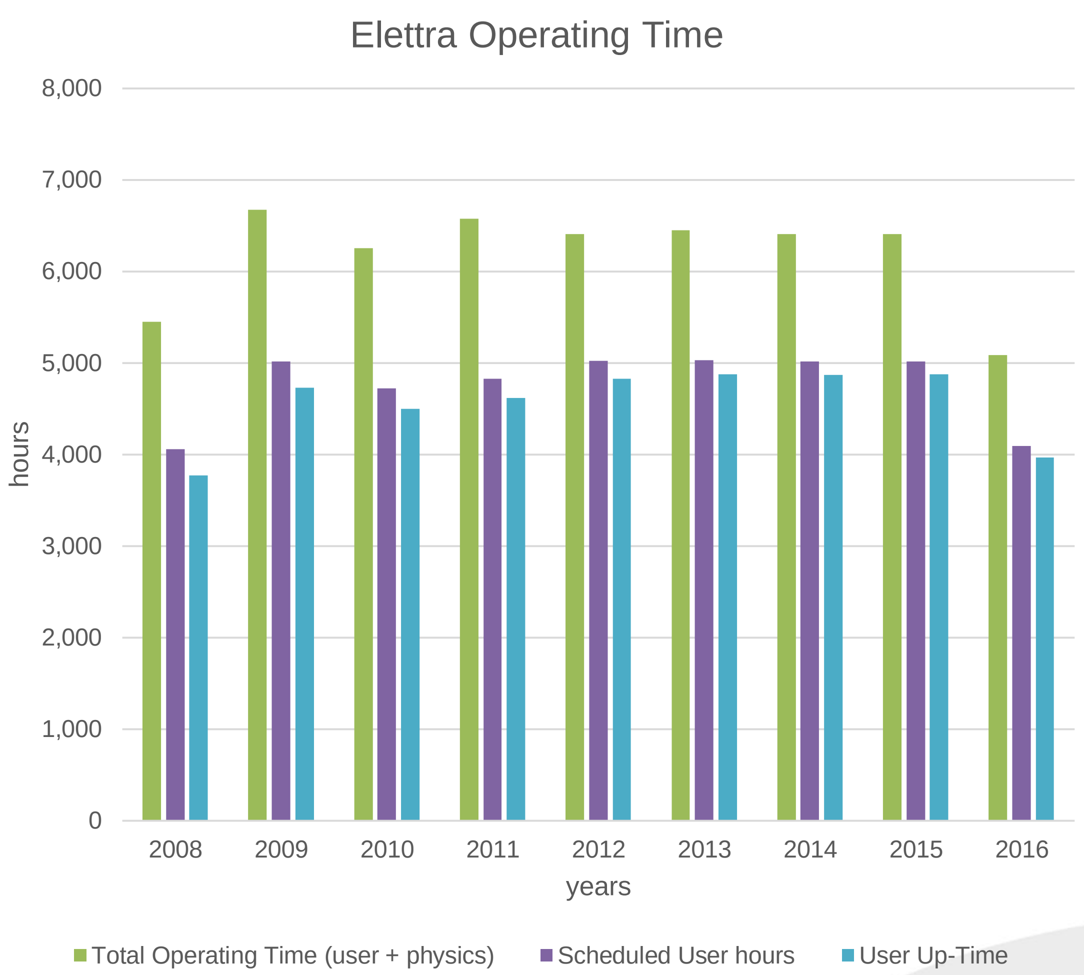
Elettra Up-Time

- ✓ Statistics from 2008 (full energy injector)
- ✓ **Top-Up operation** from 2010: after an early phase marked for 95%, the machine runs in Top-Up mode for **98%** of the User Time
- ✓ **Power Outages** (caused by storms or electrical grid issues) are

  ≈ **3%** of total failures

  ≈ **25%** of down time
- ✓ **Mean failure duration** ≈ 1.5 hour
- ✓ So far, **User Up-Time > 95% goal always achieved**, but statistics do not include electrical grid failures and outages
- ✓ Statistical data for 2016 up to the end of October

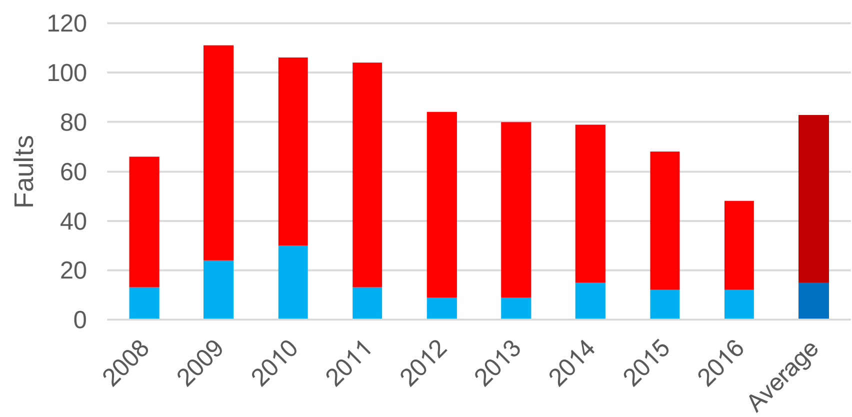


MTBF during User time

✓ **M**ean **T**ime **B**etween **F**ailure is Scheduled User Time divided by the number of Fatal Failure events, which means ***beam lost or its intensity below 50%*** (but power outages)

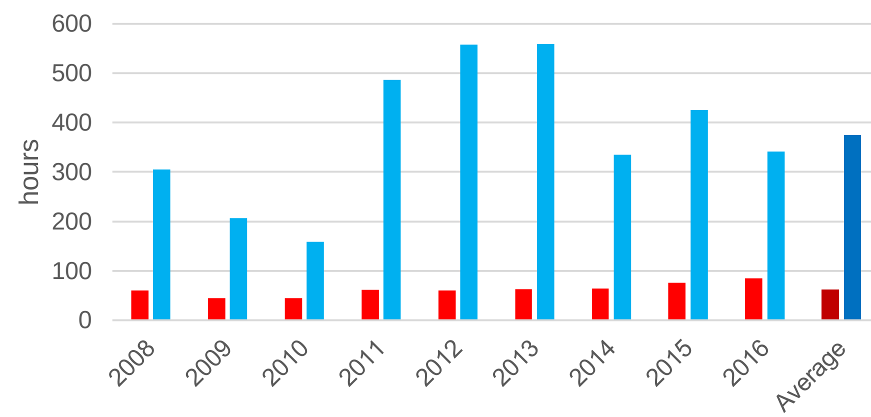
Average per year	Faults		MTBF	
	Events	Trend	Hours	Trend
Total	80	↓	60	↔
RF	15	↔	375	↓

Elettra Fatal Faults during User Time



RF Fatal Faults   Total Fatal Faults

MTBF in Elettra User Time



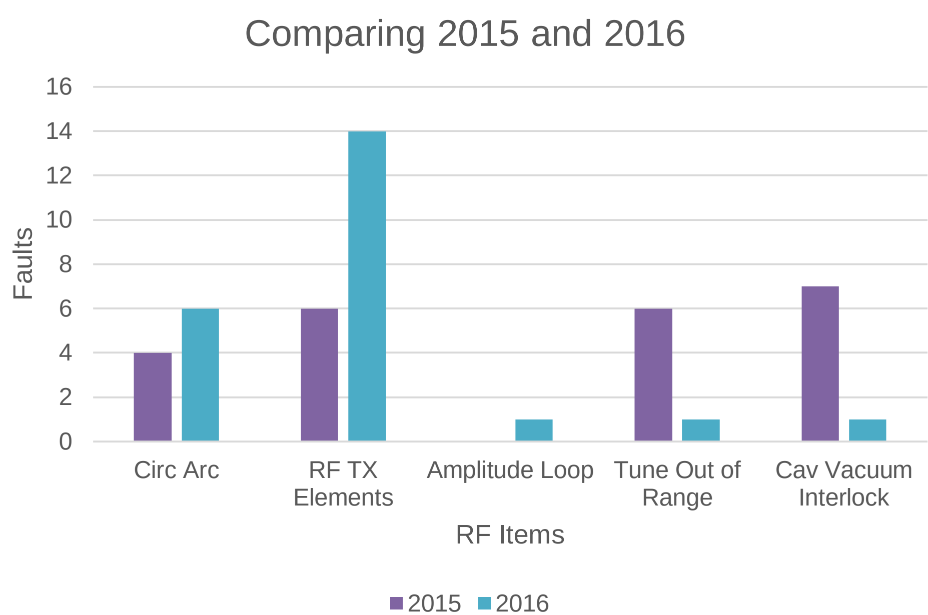
Total MTBF   RF MTBF

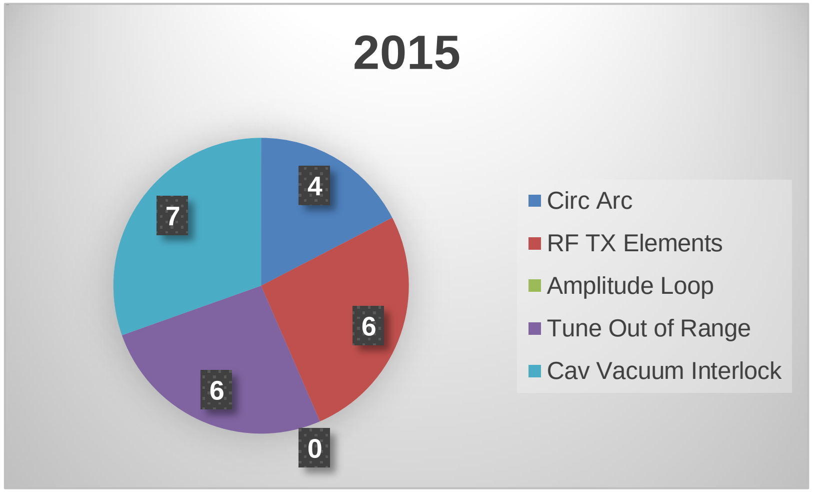
Data for year 2016 are up to the end of October

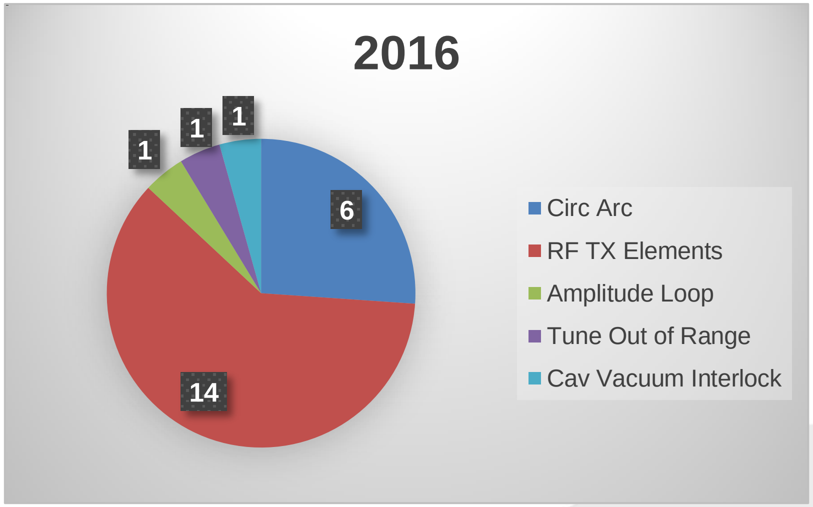
RF Fault Survey

Comparing data for RF Fault items on 2015 and 2016 so far, we can underline:

- ✓ **RF TX Elements** item is more than doubling
- ✓ **Tune Out of Range** item is decreasing
- ✓ **Cavity Vacuum interlock** item is decreasing







RF Fault Survey

"Tune Out of Range" Fault

- The **A**utomatic **T**uning **L**oop on each cavity is inheriting a phase detector with an excessive sensitivity (dynamic range > 50 dB).
- One of those ATL is now provided with a smarter detector, running a more robust algorithm for smoothing the fast and sudden phase difference glitches. It is performing fine for our goal.
- Troubling event on cavity, it leads to manual retuning and so some downtime to take in account. Teaching and coaching control room operators is a must.

Action: *apply the smarter detector also on the other ATLs.*

"Cavity Vacuum" Trip

- The trigger is into a vacuum system on cavity, far from being under control of RF people.
- Often causing beam loss.

Action: *no culprits so far, most of probably due to beam instabilities.*

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RF Fault Survey

“RF TX Element” Fault

- Events or damages into transmitter elements, including active components (klystrons, IOTs, solid state drivers, power supplies, cooling systems…) and passive components as well (RF combination/distribution, up to the circulator before the cavity).
- More often causing beam loss, randomly present on transmitters alongside the ring.

Action: *checking and monitoring the operating parameters of the transmitters*

preventive maintenance (particularly on supply/cooling)

Aging is a huge factor for long running facilities as Synchrotrons

Inspecting a Klystron output line after a RF power level reading mismatch (no beam loss)

The original insulator is damaged and has to be replaced

Homemade insulator to replace the damaged one

HV Power Supply Faults in RF IOT Tx

This is a brief report about some faults during runs in mid-late 2016, causing both fatal faults and user downtime:

- ✓ the 150 kW transmitter in Storage Ring is composed by 2 twin IOT 80 kW (TxA + TxB)
- ✓ each Tx has its own HV power supply, feeding 4 A @ 36 kV
- ✓ each HV power supply unit is composed by HV inverting and HV multiplication stages

Both the HV power supply units expressed severe faults during the runs, in internal stages or in bleeding resistance.

Poor diagnostic features on the transmitter didn't help in investigating such causes.

HV multiplier (front) with damaged capacitors and broken bleeding resistance (back)

The availability of a spare HV power supply has guaranteed no dramatic impact on User Up-Time,

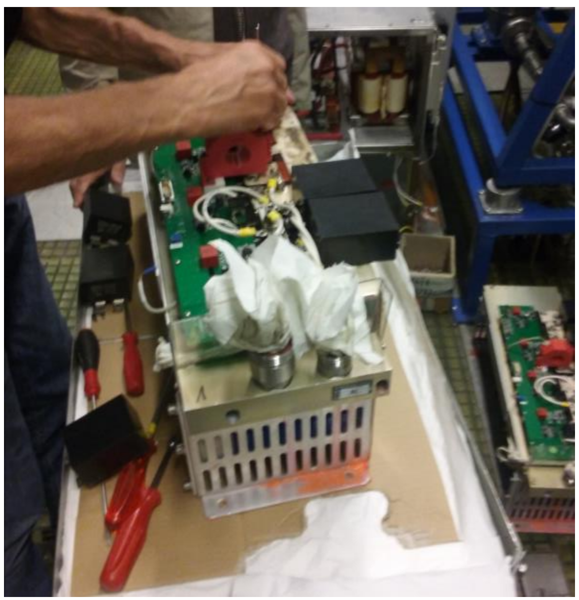
running one IOT at 68 kW for more than 470 hours (>2 weeks) continuously...

and saved RF people from being fired!

Broken bleeding resistance in detail

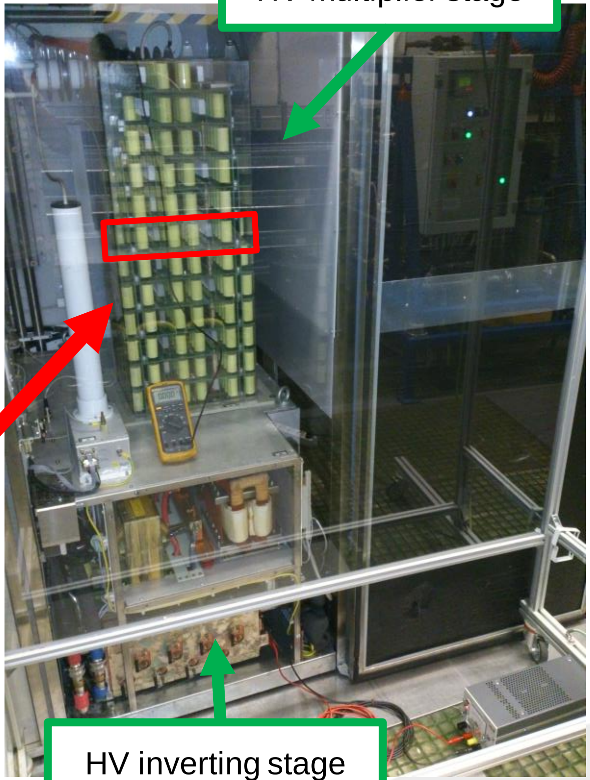
HV Power Supply Faults in RF IOT Tx

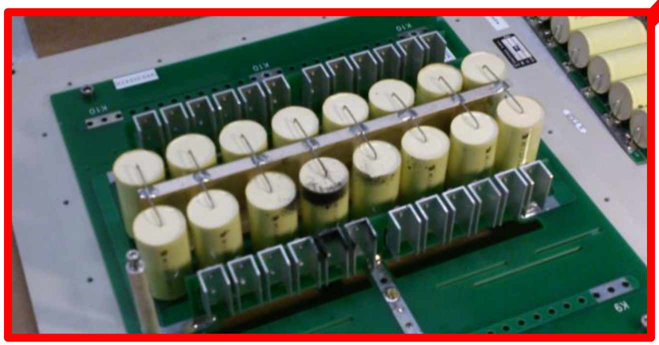
Though not directly related to RF operations, and luckily not generating consequences on IOTs, the faults on the HV power supply units were really challenging, and repair operations involved technicians from the transmitter manufacturer.



HV inverter module with broken current sensor and cooling liquid flooding

Performing a test on a repaired HV power supply feeding up to 36 kV





Damaged capacitors in HV multiplier bank

Conclusions

- ✓ RF Systems impact Elettra User Up-Time with limited effects
- ✓ Aging in Electronics and RF Systems is a huge problem, both for development and servicing, and for faults statistics
- ✓ Parameters monitoring and preventive maintenance help in increasing systems availability
- ✓ Redundancy into design and into warehouse is essential in long-running systems, saving time and money (and people...)
- ✓ Teaching and training operators reduce faults occurrencies and severity
- ✓ Still experiencing sporadic events to be explained, needing more data and deeper study... To be continued!

Thank you!

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