KLYSTRON MEASUREMENT AND PROTECTION SYSTEM FOR XFEL ON THE MTCA.4 ARCHITECTURE

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Outline

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- System overview
- Protection and measurement functions
- Installation at XFEL
- Installation at Klystron test stand
- Event detection
- Conclusion
Introduction

- The klystron is a specialized linear-beam vacuum tube
  
  XFEL:
  - Multi Beam Klystron providing up to 10 MW, 10Hz, 1.7 ms HV and 1.5 ms RF pulse at 1.3GHz,
  - 27 RF stations
    
    Very expensive device!

- Klystrons undergoing frequent failures and have limited lifetime.

- Lifetime of the tube should be in excess of 60,000 hours,
  - Not easy to achieve,
  - Dispenser cathode with beam loading of 2A/cm² can provide average lifetimes of 145,000 hours!

- There is a few factors which can reduce lifetime of the tube.
Introduction

- **Destructive factors:**
  - Bad vacuum: indicates ions current, RF and HV breakdown;
  - RF breakdowns: destructs cavity surface and can pollute RF window that increases reflected power and probability of RF breakdown;
  - Gun arc: destructs the cathode and anode surface and can pollute HV insulator and cathode
  - Work in deep saturation: beam loss, bad vacuum.
  - High RF reflections: beam loses

- **To prevent occurrence of the destructive factors the fast interlock is required.**
  - System should detect exceptional events and reacts as fast as possible by switching off driving signal;

- **Fast interlock and measurement system was developed in DESY for XFEL. It is called Klystron Lifetime Management system (KLM).**
  - Currently tested at klystron test stand
**System overview**

- **Klystron signals:**
  - 6 RF signal from out and in couplers;
  - 2 DC signals form connection module
  - 1 signal from vacuum pump
  - 1 signal from light sensors

- **Measurement of parameters:**
  - reflected power and phase at first klystron arm;
  - reflected power and phase at second klystron arm;
  - reflected power and phase at klystron input;
  - forward power and phase at klystron input;
  - forward power and phase at first klystron arm;
  - forward power and phase at second klystron arm;
  - klystron high voltage;
  - klystron high current;
  - klystron vacuum pump current;
  - light sensors voltage;

- **Protection:**
  - Switch off RF gate
System overview

- Event detection functions:
  - Correspondence of input and output power: RF breakdown inside tube detection;
  - Reflection power check: detects to high reflection power, RF breakdown detection;
  - Too high input power: saturation check;
  - High voltage breakdown;
  - Bad vacuum detection;
  - Gun arc detection;
  - RF breakdown in waveguide distributing system near klystron output windows;

- Recovery modes:
  - Run after event detection,
  - We use recovery modes to reduce damages that could be made when maximum power is on after error and error event is still on. E.g. slow ions.
For the XFEL the Mi-cro TCA technology (MTCA.4 or xTCA) was chosen to support LLRF system.

Klystron lifetime management (KLM) will be installed in the LLRF system crate.

It consists of a Rear Transition Module and Advanced Mezzanine Card (RTM-AMC) pair with down-converts and digitizer board.

Interlock line on backplane connected to RF gate on vector modulator board,

KLM activate interlock signal on event and switch off RF driving signal,
Klystron test stand

- At test stand klystrons are tested before they will be installed in tunnel,
- For installation at klystron test stand standard hardware for LLRF control system for XFEL was used,
- System components:
  - SIS8300 – AMC with FPGA AND ADC;
  - DWC8300 – RTM down converter;
  - uTC – AMC controller board;
  - uVM – vector modulator RTM;
  - TIMAMC-01 – timing module;
  - GE_ASLP11 – CPU module;
  - NMCH-CM + ELMA 12 slot crate;

Block diagram of the KLM system
Klystron test stand

- Klystron at test stand
- MTCA.4 crate

FRONT

- CPU
- Timing
- uTC
- SIS8300

REAR

- uVM
- RF in
- RF out
- signals from Klystron
Control panels

- Main control window.
- Measurement of klystron voltage and current.
- Plot of detected event.
- Error history.
- Main protection panel.
- Protection functions and status.
Results

- Most important parameter for fast protection system is reaction time,

- Measured reactions time:
  - 380 ns – time from input on ADC to activate interlock line
  - 600 ns – all system including cables, amplifiers.

- Possible to detect several events (next slides),
Error events

- **RF Breakdown**
  - happens inside the tube when beam loses direction,
  - beam hits cavity surface and destructs it,
Error events

- Too high Reflection
  - high power reflection at out is caused by RF breakdown somewhere in waveguide,
  - redistributes the voltage in the klystron output cavity and is a reason of breakdown in cavity,

![Graph showing input and output klystron powers](image-url)
Error events

- **High voltage breakdown**
  - High voltage breakdown happens in the gun area of klystron
  - causes power generation loses, decrease quality of vacuum, destructs cathode and damage the anode surface

![Graphs showing klystron high current and high voltage, and input and output klystron powers.](image)
Conclusion

- The necessary software and hardware for klystron measurement and protection was developed,
- Klystron Lifetime Management System successfully implemented on MTCA.4.
- Installed at klystron test stand on February 2013,
- Possible to detect several of exceptional events,
- Reaction time of system is around 380ns,
Thank you for attention