EUROPEAN SPALLATION SOURCE

Reliability and Availability at ESS

Reliability of a high power neutron source in the design phase

Enric Bargalló

4th International Workshop on ADSR systems and Thorium

www.europeanspallationsource.se
16-09-01

Outline

- RAMI definitions
- RAMI goals at ESS
- RAMI studies at the ESS Accelerator
- Reliability and availability for ADS
- Summary and conclusions

RAMI definitions

RAMI definitions

- **Reliability**: Probability of success over a certain period of time

  E.g. probability that the proton beam will not have any trip for one hour

- **Availability**: $$Availability = \frac{Uptime}{Scheduled\ uptime}$$

- **Maintainability**: capability of performing maintenance to a system or component.

- **Inspectability**: capability to inspect, test and monitor a system and its possible failures.

RAMI goals and requirements at ESS

ESS RAMI goals: science production

- ESS users’ and stakeholder’s needs
  - High brightness neutron beam
  - High availability and reliability of the neutron beam

- RAMI goals
  - Available beam for users: 4000h/year
  - At least 90% of the users should receive a neutron beam that will allow them to execute the full scope of the their experiments in their first attempt.

User's needs

- It is considered that the users will be able to execute the full scope of their experiments when the following needs are fulfilled:
  - **Kinetic experiments**: the kinetic measurements need a continuous neutron beam. For this reason, the proton beam can't have trips that reduce its power to less than 50% of the scheduled power for more than $1/10^{th}$ of the measurement length.
  - **Integrated-flux experiments**: the experiments need a neutron beam with at least 90% availability and on average more than 80% of the scheduled proton beam power for the duration of the experiment. The neutron beam will be considered unavailable when the proton beam power is less than 50% of its scheduled power for more than one minute.

ESS downtime definition

- The beam will be considered unavailable when the proton beam power is less than 50% of the scheduled beam power for more than one minute.

- The average proton beam power over 10 days shall be higher than 80% of the scheduled beam power.

ESS RAMI requirements

- Maximum tolerable number of events with certain duration

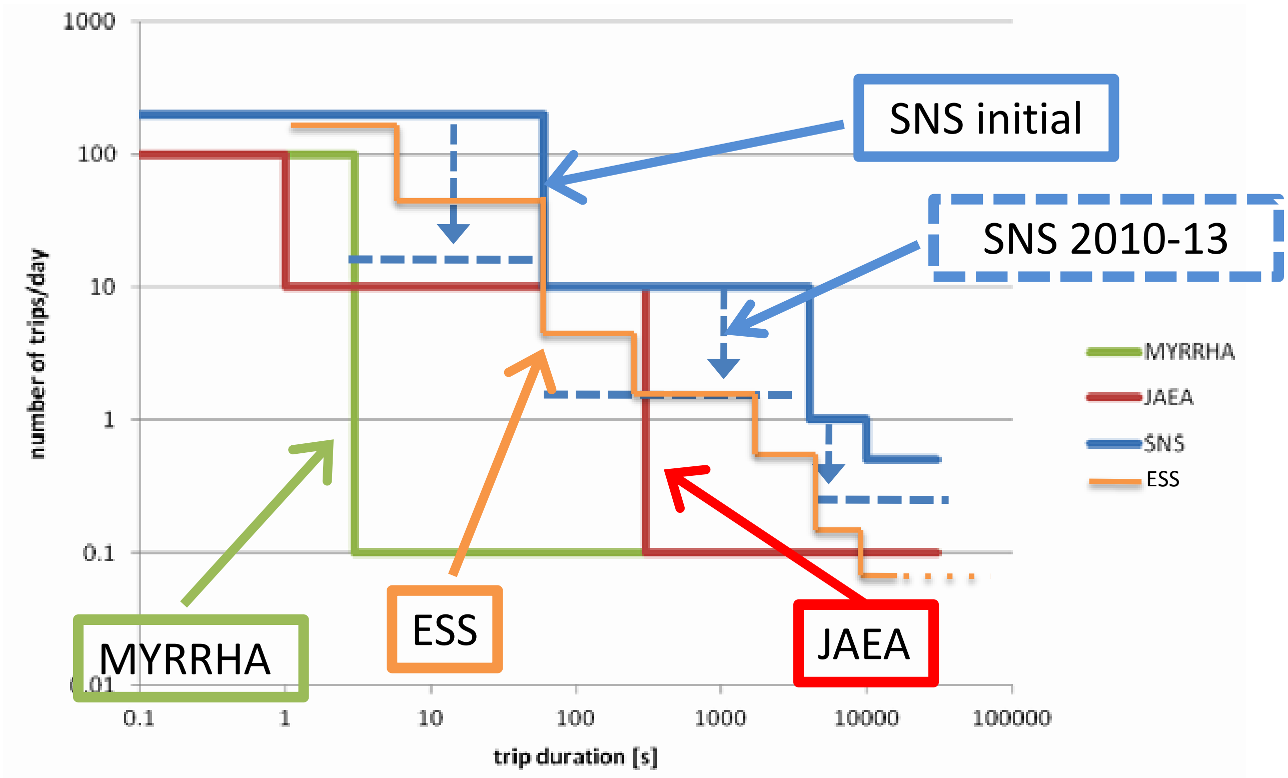
No-beam duration	Maximum occurrence
1 second - 6 seconds	24000 per year
6 seconds - 1 minute	8000 per year
1 minute - 6 minutes	1000 per year
6 minutes - 20 minutes	350 per year
20 minutes - 1 hour	100 per year
1 hour - 3 hours	33 per year
3 hours - 8 hours	17 per year
8 hours - 1 day	9 per year
1 day - 3 days	2 per year
3 days - 14 days	1 per year
14 days - 3 months	1 in 5 years
3 months - 10 months	1 in 100 years
more than 10 months	1 in 500 years

Orders of magnitude more relaxed than ADS requirements!

- Events from 1 second to 14 days can occur and the year users' and stakeholder's requirements would be fulfilled. If an event of more than 14 days occurs, that years goals would probably not be reached.

Comparison with MYRRHA goals

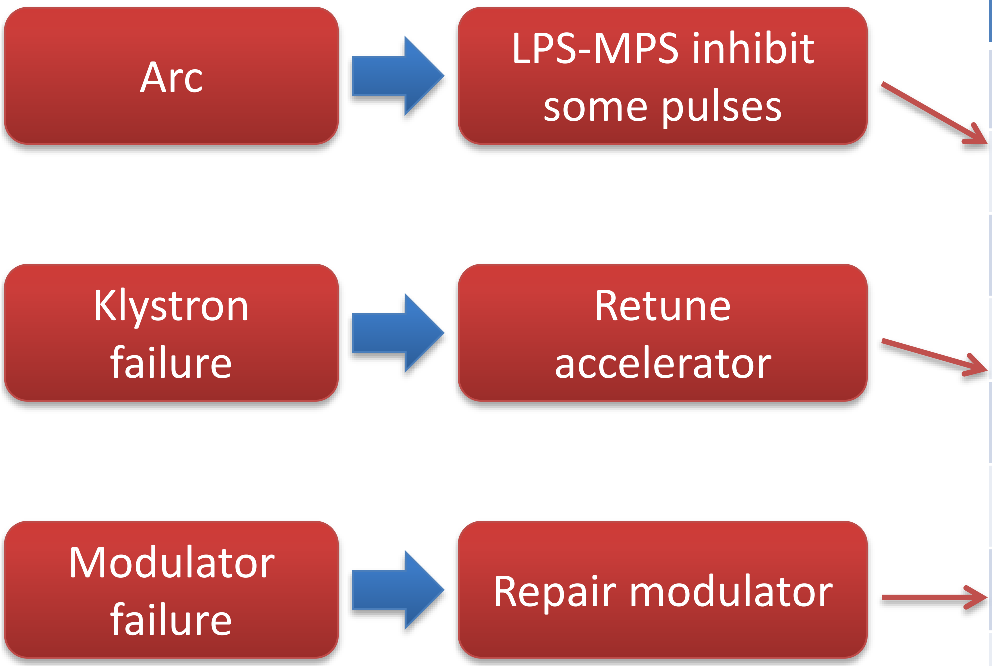
- From Tomas Junquera's presentation from yesterday:



Comparison is very difficult: goals are different, relevant parameters are different, operation is not the same and design is not reliability oriented

RAMI at the ESS accelerator

Requirements at AD: Failure examples



Downtime duration	Accelerator
1 second - 6 seconds	120 per day
6 seconds - 1 minute	40 per day
1 minute - 6 minutes	4.8 per day
6 minutes - 20 minutes	1.7 per day
20 minutes - 1 hour	90 per year
1 hour - 3 hours	29 per year
3 hours - 8 hours	15 per year
8 hours - 1 day	5.5 per year
1 day - 3 days	2.3 per year
3 days - 10 days	1 every 5 years
more than 10 days	3 every 40 years

Many things to be considered:

- Manpower
- Spares
- Access time
- Cavity affected
- Retune time
- …

RAMI focus

- Reduce number of failures (improve reliability)
  - Quality of the components
  - Simplicity of the design
- Avoid stops (Failures of components do not imply to stop ESS)
  - Redundancies
  - Flexibility (overcapacity, operate at reduced performance…)
  - Be able to foresee it (inspectability)
- Reduce consequences (If implies to stop ESS)
  - Reduce duration of the downtime (maintainability, spare parts, manpower…)

RAMI in the design phase

- Some things can't be foreseen or we can't deal with them
  - We have to start commissioning and operation
  - Might be related to very rare events
  - Risks that have been accepted or unknown risks

- **A lot of things can be done only in the design phase**
  - **It might be too painful to be changed afterwards**

- Many things can be highlighted right now and we can start finding solutions
  - The sooner, the cheaper and easier

For ADS it is mandatory that the design is reliability oriented!

How are we doing it?

- Reviews: RAMI deliverables and recommendations
- Contribute in design decisions (e.g. Comparison of design alternatives).
- Accelerator RAMI analysis overview
  - Identify components, their failures and consequences
  - Reliability modeling: ReliaSoft and AvailSim
  - Put it together and compare with the requirements. Identification of weakest points.

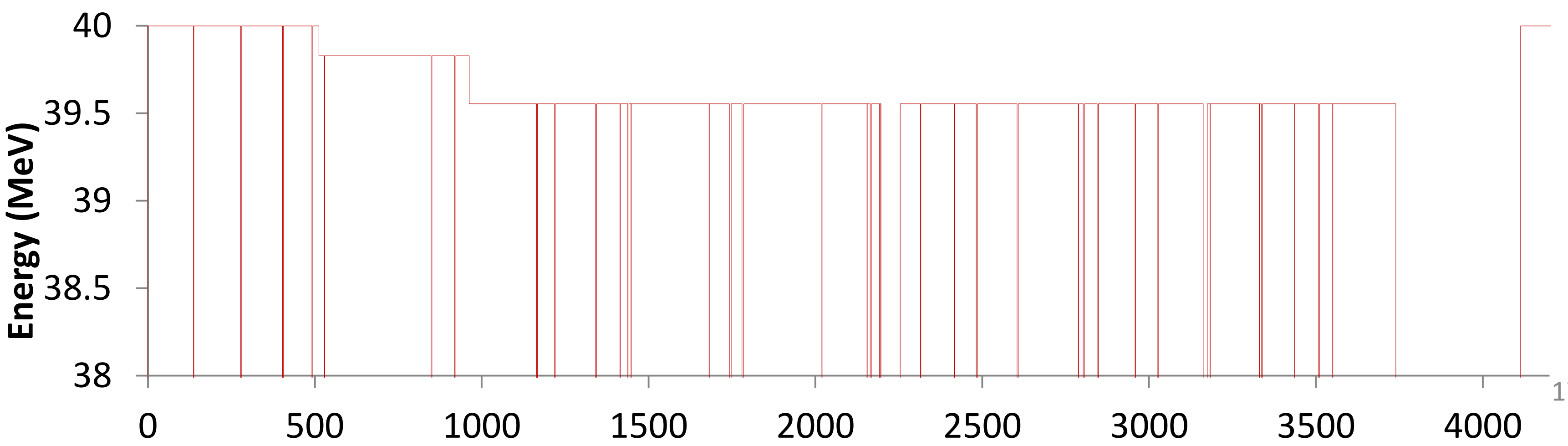
Accelerator flexibility

- Failure acceptance trying to keep at least 50% of the nominal beam power
  - No failures acceptable in the NC section
  - Quadrupoles: very painful to accept any failure
  - SCL failures acceptance (tuning required, few minutes expected for ESS):

	Spokes				**Medium beta**			**High beta**				
Sub-sections	S1	S2	S3	S4	M1	M2	M3	H1	H2	H3	H4	H5
Number of cavities	4	10	10	2	20	12	4	4	20	20	20	20
Single cavities that can fail	1	3	3	0	3	5	4		10	15	15	20
Maximum	3				5			20				

Availability Simulation

- **AvailSim** to simulate the whole accelerator considering:
  - Flexibility, Degradation, Operation schedules, Manpower, Spares...
- Very complete and **detailed analysis** which gives a lot of information to understand the weak points for availability
- A **collaboration** with SLAC and CERN to improve the software (common tool for accelerators).
- Example from IFMIF:



Machine protection and RAMI

- MP: Interlocks related to beam induced damage or interlocks from local protection systems

- Risk of having long downtimes must be reduced (hazard analyses, protection functions and PIL…)

- Frequency of the false trips should be minimized

- Restart procedures are very important to keep an available beam (inhibit some pulses automatically vs. operator action required).

Reliability and availability for ADS

My approach for ADS

- Design for reliability: no single points of failure
  - Double NC section, build-in redundancies in cavities, cavities powered by single RF cells, flexibility in magnets and PS…
- Inspectability and mainteinability are very important for high availability (replace before failure, find root cause, replace on-line…)
- Reliable interlocks (e.g. hazard analysis)
  - Optimize protection and beam reliability (e.g. 2 out of 3)
  - Classify the consequences and act accordingly (retune, stop until arc finishes, stop the whole machine…)
  - Identify thresholds, alarms, predictive interlocks, fast post mortem…

How to do it?

- Include RAMI and MP in all design phases
  - Perform RAMI analyses of all individual systems
  - Perform Hazard analyses for all individual systems
- Make reliability models to estimate the RAMI performance of the whole machine (e.g. AvailSim)
  - Identification of weak points, estimation of the future performance, comparison of design options…
- Design an integrated and well thought machine protection system with a smart automated restart system
- Analyze and test flexibility: for most frequent events, check how to use the flexibility fast enough. (Think about how to have the parameters set in case of retuning)
- Optimization during commissioning and initial operations

Summary and conclusions

Summary and conclusions

EUROPEAN SPALLATION SOURCE

- ADS reliability and availability requirements are very challenging

- In my opinion, the ADS reliability goals could be achieved, but, some key points are still to be proved (e.g. fast local cavity retuning or Injector “fast swap”)

- The design approach of the accelerator has to change:
  - Previous projects had no focus on reliability or availability in the design phase
  - Lately, projects are considering it (e.g. ESS, IFMIF, HL-LHC…)
  - For ADS it has to be a main driver

- The cost of reaching the required reliability and availability can be high and should be considered

Thanks!