Klystron Modulators Outcome from Market Consultation

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26 September 2016

Market Consultation

An open market consultation with industry was held last 27 October 2015 in Paris

Thank you!

Context

ESS accelerator project requires klystron modulators with capacity to power **four** klystrons rated 1.4MW in parallel.

Current state-of-the-art modulators can power **two** klystrons rated 1.4MW in parallel.

Design, development, prototyping and manufacturing of 660kVA modulators are needed for the successful operations of ESS accelerator.

First klystron modulators are needed Q1 2018

Objective

The market consultation was organised in order to:

1. Formulate the innovation challenge involved in:
   A. upgrading current modulator technology to 660kVA enabling to power 4 klystrons rated 1.1MW in parallel,
   B. while maintaining size/volume of commercially available 160kVA modulators,
   C. while safeguarding quality of power performance and efficiency,
   D. and optimal serviceability and reliability.

2. Obtain feedback from specialised industry with regards feasible technological solutions and design choices.

3. Assess the potential risks involved, both technologically and commercially.

4. Help defining a suitable procurement strategy for ESS.

Approach

Participants in the consultation were given baseline requirement tables, both non-functional and functional, and with a different degree of flexibility.

Key requirements and potential solutions were presented and opened for discussion, evaluation and risk assessment by participants.

Risk assessment of these requirements was done by participants using the following scoring ranges:

0	No worries, **off-the-shelf** standard solutions exist.
2-3	**A frequent problem**, potentially some hazardous cases, but certainly solvable.
5-8	**Significant attention, effort and risk reduction** required to be successful.
13	**Absolutely not a standard problem.** A solution requires important choices, thorough elaboration, and specific expert effort. Success can be achieved with significant time and effort.
20	**Very complex, not solved today, not even sure it can be solved in the (near) future**
100	**Impossible**, requires physical laws breakthroughs.
?	**Don't know**, no experience with this subject.

Key Requirements and Risk Assessment (I)

Requirement		Average Risk Assessment	Comments
1. Human Machine Interaction		1-2	Little risk in designing an HMI although it isn't core business of power electronics companies
2. Insulation	Oil	2-3	Best option and very feasible
	SF6 Gas	40	Not optimal due to volume required
	Air	40	Not optimal due to volume, cost and operation risk
	Resin	20-40	Not optimal due to cooling and degradation
3. Component Configuration	Active-Cabinet / Passive HV-Tank	3-5	Both configurations are feasible with slight preference for the first option in order to safeguard serviceability. Components in place in the oil tank complicate service and maintenance.
	LV-Cabinet / HV-tank	5-8	
	Mixed of both	n/a	
4. Front-End – Static VAR Compensator	Active Front-End (PFC)	3-5	Best option and very feasible
	Passive Front-End (Diode/H-bridge)	5-8	Feasible but not the preferred option

Key Requirements and Risk Assessment (II)

Requirement		Average Risk Assessment	Comments
5. Voltage Amplification	Pulse	0-1 / 13-20	Already done (450 kVA) / Can't be done without compromising volume and size
	HF	0-1 / 13-20	Higher efficiency / Risk of fire (SNS)
	LF	40	Only feasible for 8 klystrons and that is not an option
	MARX	5 / 40	Feasible option / Problematic when submerging all components in oil
	CASCADE	40	Only feasible for 8 klystrons and that is not an option
6. Transistor Type	MOSFET	40-100 / 13	Very challenging and affecting design and size
	IGBT	1-2 / 13	Optimal, they can handle higher power levels
7. Main Capacitor	Polypropylene	1 / 8	Very feasible and little risk / More expensive and requires larger volumes
	Electrolyte	13 / 2	Thermal cycle/stress issues influencing MTBF, series resistance involve higher losses / it is feasible, cheaper and smaller
8. Droop Compensation	Active	3-5	Best option and very feasible
	Passive	13-20	Efficient passive droop compensation very challenging

Key Requirements and Risk Assessment (III)

Requirement		Average Risk Assessment	Comments
9. Modularity	Monolithic	20-40 / 0	Large bulky components difficult to handle and requiring heavy equipment for service / In theory it is possible
	5-25 identical components	1-2 / 20	Best option and very feasible
	+ 100 identical components	100	Not possible

Conclusion

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1. HMI shall not be underestimated although it is not a critical risk if treated properly.
2. Insulation material should be oil and preferable with only passive HV components submerged.
3. Active front-end is preferred as it simplifies controlling harmonics generated on the grid.
4. Voltage amplification preferences are with pulse-based transformers and high-frequency-based transformers.
5. IGBTs are recommended for switching components taking into account high current requirements.
6. Polypropylene material is preferred for the capacitor bank.
7. Droop compensation should be active in order to achieve better control over temperature drift and pulse width.
8. A suitable configuration would consist of 5-25 identical modules.
9. A substantial R&D would be required for combining these choices into an efficient and high-performing klystron modulator.

ESS Topology

ESS modulator topology can be considered a valid design taking into account the following choices:

1. HMI and control solution improving the control system.
2. Insulation material choice is oil, and with only passive HV components submerged.
3. IGBTs for switching components.
4. Polypropylene material for the main capacitor.
5. Active droop compensation.
6. Voltage amplification architecture is modular using high voltage high frequency transformers, involving a reduction of footprint/volume.
7. Modularity and configuration including 3 identical building blocks including many standard low voltage components, involving a reduction of footprint/volume and price.

ESS Topology - Conclusions

On top the technology choice associated risks, the following risks/issues were referred during the market consultation:

1. Time schedule. Participants in the market consultation indicated that extensive testing is required as part of development process, which could cause delay given the tight schedule provided for the manufacturing and delivery of the modulators.
2. R&D effort in different phases of design validation, prototyping and manufacturing shall not be underestimated, which could cause additional delay.
3. Liabilities and IPR are crucial contractual aspects to carefully reviewed in case ESS imposes a design. This approach may increase legal/commercial risks associated with the procurement of modulators.
4. Market potential is limited which may involve a significant impact of R&D costs in the total cost of ownership.
5. Close cooperation between ESS and chosen supplier is recommended in order to reduce risks via efficient transfer of knowledge.

Recommended Procurement Strategy

As a result of the market consultation the following procurement strategies were identified:

1. Competitive procedure with negotiation (Article 15, ESS ERIC Procurement Rules), which allows flexibility to adapt negotiations in a similar way than a PCP.
2. Pre-Commercial Procurement invoking the R&D exemption (Article 14, EU Procurement Directive 2014/24/EU) if ESS would procure R&D services jointly with other procurers and/or under an EU funded programme.
3. Continuation of internal R&D followed by an open procurement procedure.

ESS decision, taking into account in-kind contribution status of negotiations, degree of internal development and time schedule constrains was to proceed with recommendation number 3.

Thank you!

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