**Operational Flexibility**

**P. Jansohn, P. Kutne**

Comments from the PB meeting

P. Kutne:

* Add a section on the investment needed for large-scale installation, and consider new production methods or materials.
* Mention mid-term flexibility (1-2 weeks).

O. Bernstrauch:

* There should be a reference to maintenance costs. Furthermore it should be checked if each requirements applies to GT and Steam turbines.

The two main contributors to the increasing share of renewables in the power generation mix are solar and wind. Since both of them are non-dispatchable technologies, back-up solutions are needed in order to assure grid stability. Though large scale energy storage is expected to be used for this scope in the medium to long term, at the present time technologically and commercially viable large-scale energy storage technologies are not available, with pumped storage only possible in site-specific locations. In this scenario, conventional power plants will cover the backup needs for the next decades. Due to the significant time required to modulate, start up and shut down nuclear and coal power plants, they will continue to be mainly suitable for providing base load electrical demand. Although coal is also used to provide back-up, this has been mainly driven by short-term cost of coal in relation to gas. As a consequence, open cycle gas turbine or combined cycle power plants are considered to be the most suitable technologies to provide the major part of flexible back-up to the intermittent renewables in the foreseeable future. To enable this to be commercially viable and reduce emissions, such plants should have higher operational flexibility than the current state-of-the-art. Increased operational flexibility is also prompted by the shift of combined cycle plants’ operation mode from providing base load to load following due to changing gas prices, changing market conditions and market deregulation. Current designs of combined cycle plants were typically not optimised for the required shift from base load to intermediate or cycling requirements.

##### To enable plants to support flexible operation, they need to be designed for:

* Frequent start-up and shutdown
* Fast load changes and load ramps capability, while keeping GT combustion stability and maintaining emissions within the permitted levels.
* High start-up reliability
* Long components life under the above mentioned operating modes
* Suitable frequency control and ancillary services

Historically, the drivers were addressed in the context of risks of fluctuating fuel and electricity prices among other factors related to business opportunities. Hence there have been some related research and development. Thus any research activity requires an extensive review of this fast changing subject to identify areas of future R&D.

##### The following areas have been identified as active R&D topics:

* Minimum environmental load: this is the minimum load at which the gas turbine is able to operate while meeting the environmental limits, in particular NOx and CO emissions, taking into account that these limits will certainly become more stringent in the coming years. This opens the need for further research into combustion technology.
* Efficiency at part load and minimum load conditions: combined cycles are operated at low load for an increasing number of hours. Although for new plants the efficiency penalty for operation at medium load has been reduced, future plants should be designed to further reduce the efficiency penalty at part-load and minimum-load conditions.
* High cycling capability: recently built combined cycle plants are generally characterised by fast start-up (15-30 minutes hot start-up, 60 minutes warm start-up) and shut down, fast load change and load ramps (35-50 MW/minute max), moderate start-up emissions, high start-up reliability. R&D is required on further reduction in start-up times and increasing load ramp rates while ensuring minimum impact on the lifetime of critical components.
* Operational flexibility at low operating costs: this means high part-load efficiency and short start-up time. This also requires addressing R&D to the entire plant including the bottoming cycle.
* Energy storage solutions: integration of energy storage solutions in thermal power plants is a field which needs to be further explored, in order to increase ramp capabilities and allow operation at nominal maximum and minimum load though maintaining the possibility to provide ancillary services.
* Renewable energy storage through hydrogen: a different path requiring further R&D is related to utilising excess energy from renewable sources or from conventional power plants during off-demand (e.g. night) hours for hydrogen production. There is a significant drive to use the gas grid to accommodate a higher hydrogen content which helps to maximise renewable energy storage. It is thus imperative to conduct research and development to increase the tolerable level of hydrogen in natural gas to be fired in existing gas turbines or new designs (see “Fuel Flexibility” chapter).
* Reliability under fast cycling: to prevent increased outages due to fast cycling, the following topics need to be addressed:
* Key equipment design, materials and corrosion aspects
* Component replacement, maintenance and operating costs
* Strategies for optimising cyclic operation
* Effect on thermal barrier coating
* Effect on Creep-fatigue of turbine blades, cracking and degradation of combustor
* CCS for flexible operations: incorporation of CCS leads to restrictions on operational flexibility due to constraints in the part- load operation of the CO2 capture and compression train, which is typically limited to 70% turndown. The impact is increasing the hot start-up to 1-2 hours and cold start-up to 3-4 hours. Strategies should be developed to reduce the impact of CCS on operational flexibility.
* Computational tools: there is a strong need for the development of high fidelity computational tools to model the power plant allowing for virtual simulations leading to lower cost system optimisation and development.
* Technologies for improved control: an area of increasing interest for R&D is the use of more instrumentation and new sensor technologies to monitor and improve the control of operation of the power plants. This is combined with developments in the processing and visualisation of the large data sets resulting from the arrays of sensors, a field of research known as ‘big data’ (see “Sensors and Instrumentation” chapter).

