Demands on Materials and Components for Existing and New Conventional Power Plants

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Abstract

The application of high performance materials for high-temperature pressure parts in conventional power plants is controlled by the pressure equipment directive (PED). EN standards like the EN 12952 are widely used in Europe to fulfill the PED. More restrictive VGB standards like the materials specification VGB-R109 are applied especially for critical components.

Within the last ten years, renewable energy production in Germany increased by a factor of approximately 3 and this progression is predicted to continue. The priority of this renewable energy supply leads to a high demand on flexible energy production from conventional power plants.

The flexible service conditions of conventional power plants may differ from initial design criteria and may produce different damage characteristics compared to the established practice such as non-destructive investigation procedures. Therefore a VGB working group was founded to analyze and develop calculation methods especially for thick walled components, for weldments, for start-up and shut-down procedures and for the interaction of static and cyclic loading of critical components. The current status of these activities is presented and demands for future work are addressed.

1 Introduction

In Europe, the application of high performance materials for high-temperature pressure parts in conventional power plants is controlled by the PED [1]. The presumption of conformity with the PED is given if applicable EN standards are used for the calculation of component loading history due to power plant service loads (i.e. internal pressure, temperature) and if these component loads do not exceed material properties which are defined within the EN standards, respectively. The EN standards EN 12952, EN 13445 and EN 13480 are mainly used for the design of high-temperature pressure parts. More restrictive VGB standards like the materials specification VGB-R109, the specification for fabrication and installation of pipe works in conventional power plants VGB-R508L, or the specification for repeated inspections VGB-R509L are applied especially for critical components.

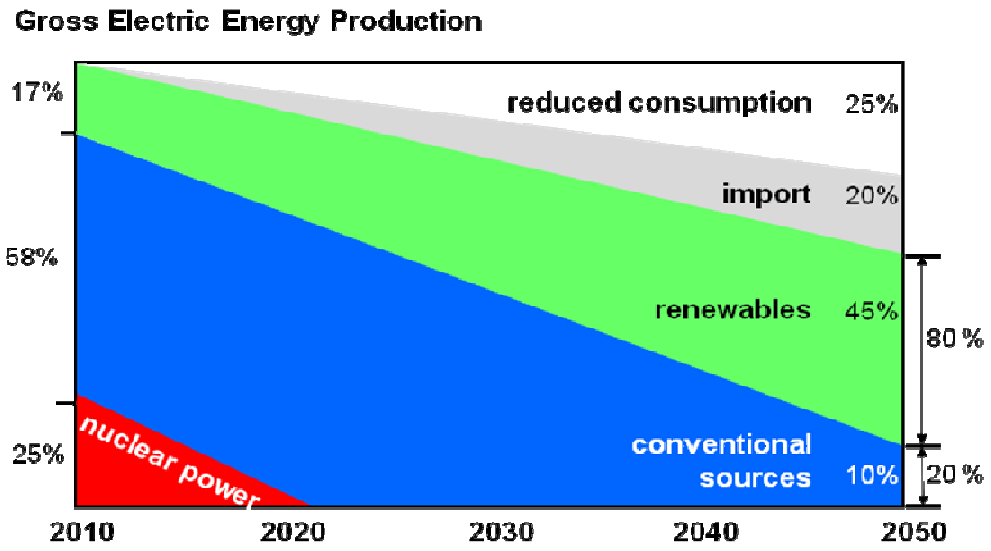

Figure 1: Gross Electric Energy Production in Germany [2]

Within the last ten years, renewable energy production in Germany increased by a factor of approximately 3 and this progression is predicted to continue. Figure 1 summarises the plans of the federal government of Germany for the gross electrical energy production until 2050.

The priority of this renewable energy supply leads to a high demand on flexible energy production from conventional power plants. Figure 2 compares the residual load characteristics, which is the current difference of electric energy consumption and the supply by renewable sources, for week 6 to 9 in 2008 with a prediction for the same period in 2050.

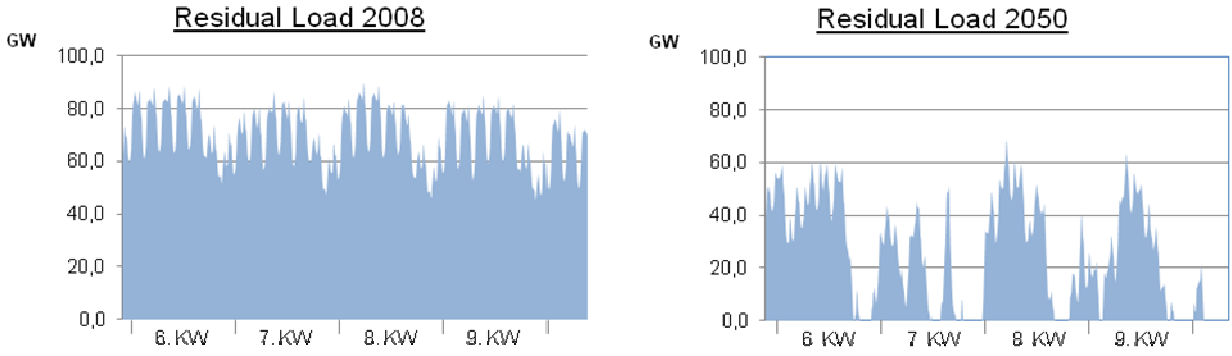

Figure 2: Residual Load characteristic for week 6 to 9 in 2008 (left) and in 2050 (right).

For the residual load in 2008, a power plant fleet with base load, mid-load and peak-load power plants was needed the ensure the electric power supply. In 2050 a power plant fleet designed for many load changes, high load gradients and low minimum load needs to be available.

2 Demands on Materials and Components

In the future, the flexible service conditions of conventional power plants may differ from initial design criteria and may produce different damage characteristics compared to the established practice such as non-destructive investigation procedures. Therefore a VGB working group was founded to analyze and develop calculation methods especially for thick walled components, for weldments, for start-up and shut-down procedures and for the interaction of static and cyclic loading of critical components.

2.1 Thick Walled Components

The analytical stress calculation methods implemented in the EN standards assume linear elastic materials behaviour in the whole temperature range and were developed mainly for thin walled components. Therefore alternative analytical stress calculation methods which are more appropriate for thick walled components and which allow stress redistribution due to the materials' creep behaviour are in the focus of the VGB working group. These methods will allow calculating more realistic (lower) stress values and as a consequence will reduce the minimum required wall thickness for thick walled components and will allow more flexible power plant service.

2.2 Weldments

Welded pipe to pipe connections and other weldments undergo a complex loading history due to the gradients of material properties of base metal, heat effected zone material states and the weld metal, respectively. In addition, geometric and process details like the orientation of the weldments with respect to the orientation of maximum principle stresses, pre- and post-weld heat treatment and the resolution of non-destructive testing should be considered consistently. Here, the VGB working group aims for a concept with separate weld reduction factors, one for material degradation and another for geometrical details including details of non-destructive testing.

2.3 Start-up and Shut-down Procedures

During start-up and shut-down procedures of conventional power plants, thermally loaded (thick walled) components undergo a superimposed fatigue load due to the constrained of components' thermal expansion. The resulting stress ranges are calculated and limit the number of allowable start-up and shut-down procedures. This allowable number differs in case of thick walled components comparing the (old) TRD standard, which is the current one for older power plants, with the EN standard up to a factor larger than ten, although they refer to the same data base. The VGB working group addresses the underlying calculation methods and the data base, respectively.

2.4 Interaction of Static and Cyclic Loading

For quantitative lifetime assessment of critical power plant components, the component loading is split in static (creep) and cyclic loading parts. If both parts of this lifetime consumption are relevant, the interaction has to be taken into account. The (old) TRD standard and the EN standard EN 12952-4 proposes a linear superposition of the results for

static and cyclic loading, respectively. This superposition method differs substantially from the method implemented in the ASME code [3]. The ASME code proposes a strong non-linear interaction of creep and fatigue lifetime consumption, where the interaction is reported as material dependent [3]. The strongest interaction is found for low alloyed ferritic material, where a cyclic lifetime portion of 15% will reduce the allowable creep lifetime portion down to 15%. The comparison given is valid only for the superposition methods implemented and not for the material properties implemented. The VGB working group addresses a strong need for a verified calculation method applicable for the interaction of static and cyclic loading and for specific test results for materials used in existing power plants at relevant load levels.

3 Summary

The future service of conventional power plants is controlled by the growing demand on flexible production of electric power. The power plant fleet should allow more load changes, high load gradients and low minimum loads. Specific attention should be given to the calculation methods for thick walled components, weldments, start-up and shut-down procedures and the interaction of static and cyclic loading portions. Therefore a VGB working group was founded to analyze and to develop further these calculation methods.

References

[1] Pressure Equipment Directive: 97/23/EG

[2] EWI/Prognos/GWS Studies

[3] ASME Section 8 Devision 2 (API FFS 1)