SRS: THE STANDARDIZED REPOWERING SOLUTION FOR 300MW STEAM POWER PLANTS IN RUSSIA

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1 Introduction

Deregulation and competition are further fueling the demand for new power generation equipment worldwide. Due to the availability and cleanliness of gas, and the ease of consent, gas turbine applications have increased over the last few years. This development is driven by the addition of capacity, but also by major replacement programs. In this market in particular, Siemens has been realizing that repowering of existing units is taken into consideration due to its reduced land, infrastructure, existing permits, capital cost and time requirement compared to greenfield projects.

Especially with the expected reform of the Russian power market into a competitive, liberalized market, repowering of existing units is an attractive opportunity not only for extending the lifetime of existing plants, but also for reducing the life-cycle costs in order to remain competitive with new power plants entering the market.

The fact that Russia has a big fleet of gas-fired steam power plants which went into commercial operation more than 20 years ago and major equipment of these plants exceeded or is close to their design lifetime even more supports the idea of repowering. Last but not least the rising electricity demand and Russia's ratification of the Kyoto Treaty will have implications to power plant economics as well.

In a joint effort RAO UES Business Unit Service and Siemens Power Generation started in 2004 the development of a standardized repowering solution (SRS) for 300MW gas-fired steam power plants for the Russian market. Even though each repowering or modernization project does have its unique facets the commonality in the layout and steam turbines allow for a standardized concept for full repowering using two SGT5-4000F gas turbines. Full repowering replaces in this case the old gas-fired boiler with gas turbines and HRSGs as heat input to the existing bottoming cycle.

This paper will take a closer look to the technical features and challenges of the standardized repowering solution.

Repowering targets existing gas/oil- or coal-fired power plants under certain conditions to make such an effort viable for competitive power generation costs. The levers to fulfill the goal of modernization and repowering to increase the economics and dispatchability of existing power assets are:

- Increase of efficiency and power output
- Extension of lifetime
- Increase of availability and reliability and reduction of O&M costs
- Increase of operational flexibility
- Reduction of specific emissions

2 Repowering Concepts

There are several alternatives to combine and integrate a gas turbine into an existing steam power plant. A detailed assessment of the existing plant equipment as well as technical and economic boundary conditions of a specific project determines the optimal approach and the selection of the repowering concept. The main alternatives of repowering are illustrated in Figure 1.

- **Full Repowering:**
  Full repowering is defined as complete replacement of the original boiler with a combination of one or more gas turbines (GT) and heat-recovery steam generators (HRSG), and is widely used with very old plants with boilers at the end of their lifetime. It is considered as one of the simplest ways of repowering an existing plant. In most cases repowering projects include the modernization of the steam turbine and I&C.
- **Parallel Repowering:**
  In the parallel repowering concept the boiler stays in operation for peak and intermediate load. The steam from the boiler is added to the steam from the HRSGs at several pressure levels depending on the condition and capability of the existing steam turbine.

- **Topping:**
  Topping or also called hot windbox repowering refers to the conversion of a straight-steam cycle to a fully fired combined cycle. The exhaust gas from the gas turbine is used as preheated vitiated air to burn the main fuel in the furnace of the fired boiler. In other words, the gas turbine assumes the role of the forced –draft fan in a conventional steam boiler/turbine unit.

- **Boosting:**
  Boosting is a limited form of parallel repowering because the added HRSG is not designed to raise superheated steam for the existing steam turbine, but only to preheat the condensate and/or feedwater flows to the associated boiler.

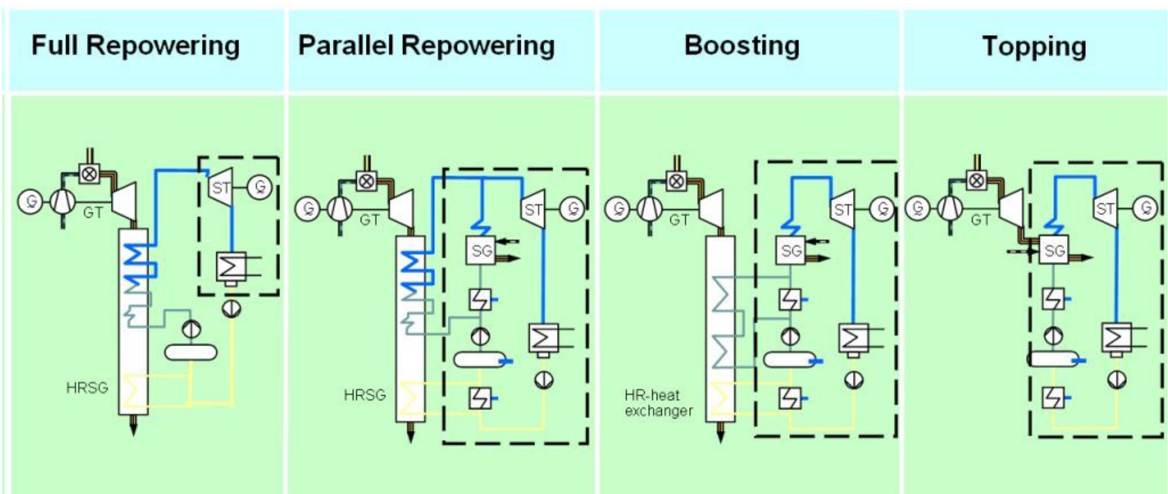

Figure 1: Simplified schematic diagram of repowering concepts of an existing steam power plant (dashed black frame represents reused portion of existing steam power plant)

Figure 2 illustrates the efficiency levels which can be reached with the different repowering applications depending on the ratio of gas turbine output (P_{GT}) to total power plant output (P_{unit}) of the repowered unit. The efficiency level of an old steam power plant (SPP) is typically around 37% to 39% in this case. Since the existing SPP does not include a gas turbine the ratio P_{GT}/P_{unit} is zero. The efficiency level of a new combined cycle power plant CCPP is typically between 52% and 58% depending on the implemented gas turbine and the water-/steam cycle configuration. For a CCPP the ratio P_{GT}/P_{unit} is approx. 0,67. Since for repowering concepts an existing steam turbine and further plant equipment is to be reused and not optimized to the new process the achievable efficiency level is slightly lower than for a new CCPP. This effect is taken into consideration by the dashed black line in figure 5. With this diagram the achievable efficiency of the repowered unit can be easily estimated depending on the selected gas turbine(s).

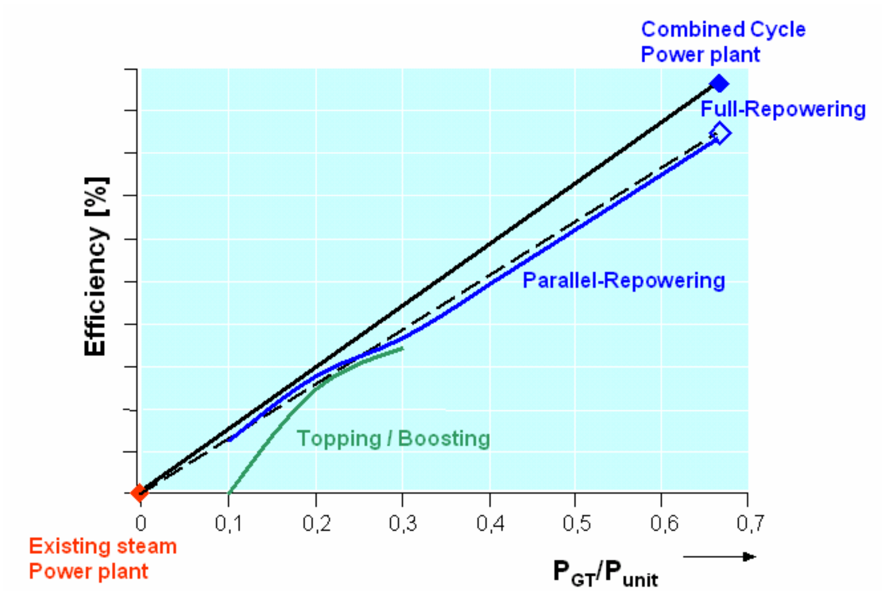

Figure 2: Characteristic of achievable efficiency levels of different repowering concepts

Besides the performance increase there is a direct impact on emissions (Figure 3). For an old existing gas-fired SPP which operates e.g. at an efficiency of 38% full repowering might lead to a efficiency of about 55%. The specific CO_2-emissions will drop by approx. 30% from approx. 500 g/kWh to approx. 360 g/kWh.

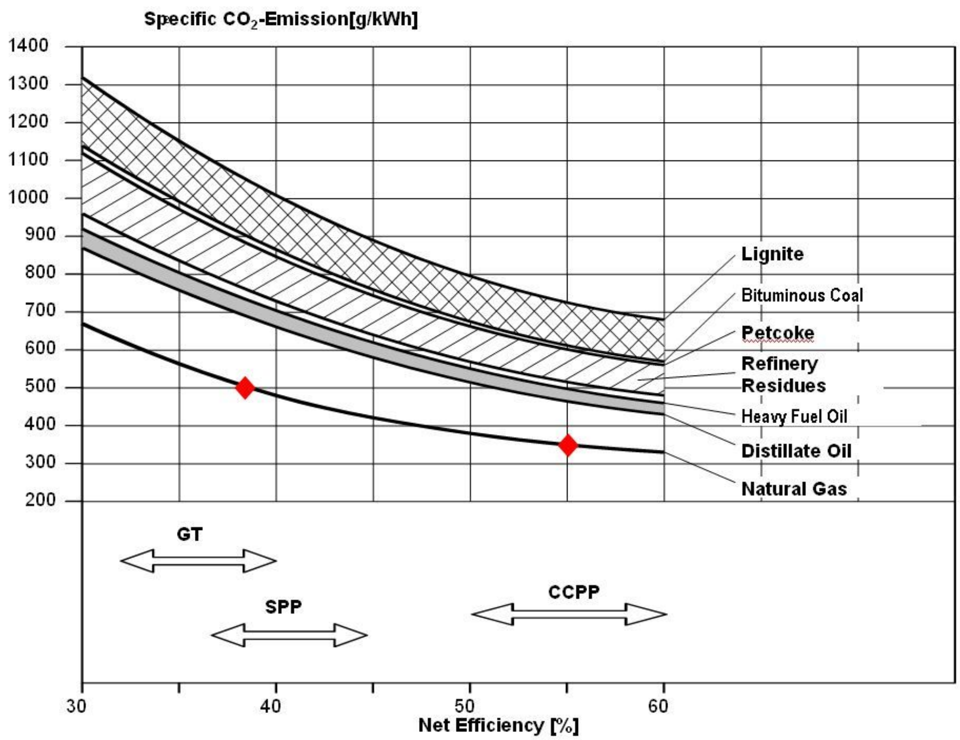

Figure 3: Specific CO_2-emissions for fossil-fired power plants

3 Steam Turbine Capability for Repowering

For economical reasons, it is recommended that the original capability of the ST and the associated BOP systems (transformer, cooling systems etc.) are utilized as much as possible. For full repowering, the available HRSG steam defines the achievable ST output within narrow limitations. As a rule of thumb the thermal cycle of the repowered unit targets approx. 70-80% of the rated steam turbine output in order to achieve a reasonable amount of steam flow through the HP-section of the steam turbine. In combined cycle applications as well as for full repowering concepts the steam flow across the steam turbine increases due to the added steam from the IP- and/or LP-HRSG and the fact that the steam extractions for condensate and feed-water heating are put out of service. Repowering therefore requires detailed assessment of the LP-turbine and the condenser capability to cope with the increased flow.

In many applications the end of the design life of the ST has been reached, and modernization of the ST will take the modified steam flow along the steam path into consideration..

For parallel repowering, the ST capacity is arbitrary. The steam flow characteristics enable full utilization of the ST and BoP systems. The combined-cycle (CC) mode of operation corresponds to full repowering. In the hybrid mode the existing boiler supplies additional steam up to the capacity limit of the ST. This intermediate-load reserve is far higher than what can be achieved by duct firing in the HRSG. The attractiveness of parallel repowering lies in the tremendous load reserve in the hybrid mode at an efficiency that is far higher than simple-cycle GT plants or steam plants.

4 The SRS approach for Full Repowering

For gas-fired 300MW steam power plant units in Russia different alternatives for full repowering were investigated and evaluated. A detailed economic analysis of life-cycle-costs based on key investment figures like NPV and IRR supported the decision making process. Finally Full Repowering with SCC5-4000F 2x1 (formerly known as CC 2.V94.3A) with triple pressure reheat cycle was found to be the most economic approach.

The concept is derived from the Siemens Combined Cycle (SCC™) multi shaft reference power plant SCC55-4000F 2x1. The combination of world class gas turbine technology with trend-setting power plant system integration results in a highly efficient F-class plant that provides reliable low cost electricity.

Full repowering with the SCC5-4000F 2x1 is designed around, proven Siemens equipment, including:

- Two Siemens Gas Turbines (SGT™) SGT5-4000F
- Each connected to an air-cooled Siemens Generator (SGen™) SGen5-1000A
- The Siemens Power Plant Automation System (SPPA™)
- And is combined with a triple pressure reheat water-/steam cycle which delivers the steam to the existing steam turbine.

It combines the Siemens expertise to design and build world-class combined cycle power plants with the local expertise in steam power plants.

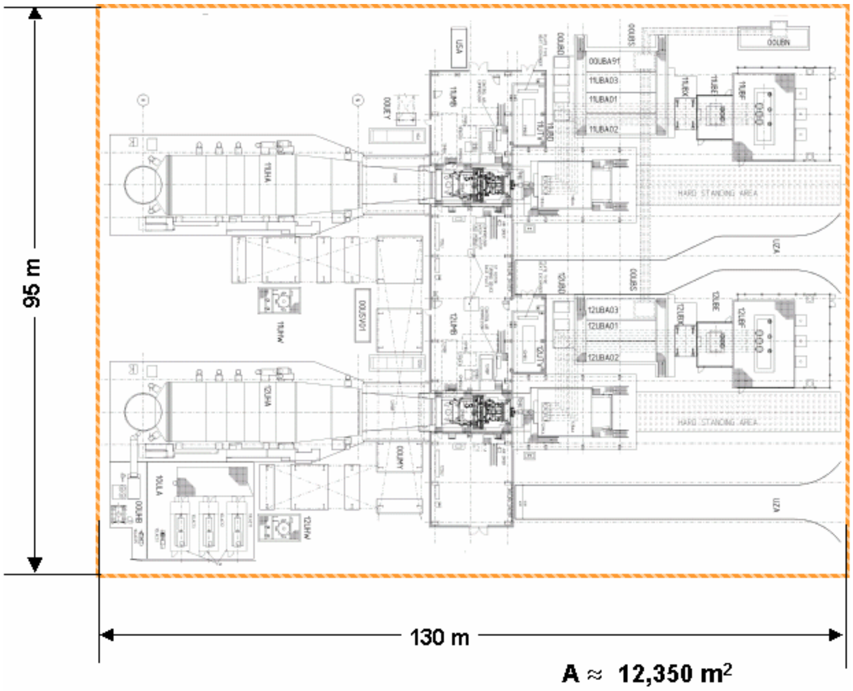

Figure 4: Approximate dimensions for added new equipment

The plant layout is based on a modular approach which allows to integrate optional add-ons. The added new equipment is supposed to be placed close to the steam turbine unit which is foreseen for repowering. The main bay of the turbine building is one compact structural-steel building of simple rectangular design and houses the gas turbine in transverse arrangement. The generators of the gas turbines are arranged in annexes to the turbine building. The inlet filter houses are located above these annexes. To ensure short electrical connections the gas turbine related electrical and I&C equipment is located in pre-assembled power control centres (PCCs) close to the respective generators. Overhead travelling cranes run the full length of the main bay of the building. The HRSG's as well as the feedwater pumps are designed for indoor installation and are arranged in line with the gas turbines. Gas filtering and metering equipment is close beside the HRSG's.

Figure 5 shows a simplified schematic of the water-/steam cycle. The condensate is supplied by the condensate extraction pumps via the condensate preheater sections of the 2 HRSGs to the suction side of the feedwater pumps and to the LP systems. The feedwater pumps deliver the feedwater via the respective IP- and HP-economizers to the IP- and HP-drums. The superheated HP-steam is routed to the HP section of the steam turbine. From there the expanded

HP-steam leaves as so called cold reheat steam (CRH) and is mixed with the superheated IP steam. The combined CRH and IP steam flows enter the reheater sections of the HRSGs and are supplied to the IP steam turbine (HRH steam). After leaving the IP steam turbine LP-steam is added from the LP-HRSG and is expanded further in the 3 LP-sections of the steam turbine and is finally condensed in the condenser.

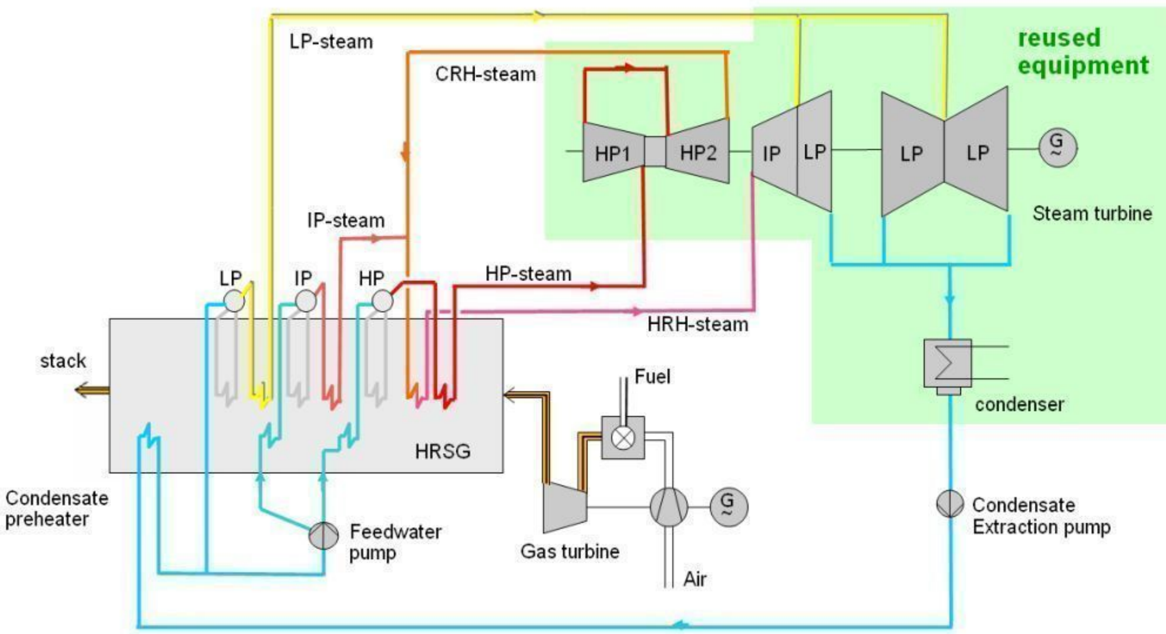

Figure 5: Flow schematic for full repowering with SCC5-4000F 2x1 and triple pressure reheat water-/steam cycle

Parameter	unit	Existing SPP	Full Repowering
GT-model	-	-	SGT5-4000F
No. of GTs	-	-	2
power output	MW	300	815
efficiency	%	38	56,8

Table 1: Performance overview

With the assumption that the existing SPP is operated at a performance level of approximately 38% efficiency and 300MW power output full repowering is increasing the capacity of the existing plant by +170% (Table 1). The efficiency is increased by 19%-points which correspond to a reduction of up to approx. 30% of the specific fuel consumption (kg/MWh).

5 Conclusion

The SRS concept described in this paper allows the conclusion that full repowering is an excellent concept for improving the efficiency and flexibility of older existing fired power plants to survive and compete in the market. Siemens PG initiated the development jointly with RAO UES especially for the Russian market and its specific requirements. The SRS concept combines the Siemens expertise to design and build world-class combined cycle power plants with the local expertise in steam power plants.

There are several benefits which can be derived from such a repowering project:

- The existing station can still be operated while the new part of the plant is being constructed.
- Efficiency increases to competitive levels.
- Specific emission levels are reduced due to the efficiency increase and the low-NOx combustion technology utilized in the state-of-the-art gas turbines.
- Existing assets are further utilized leading to reduced capital costs and lower recruitment costs (as the personnel of the existing plant can operate the repowered plant) compared to new plant on a greenfield site.
- It sometimes might be easier for station owners to obtain permissions to upgrade a plant rather than to construct a new plant on a greenfield site.

Repowering and modernization projects result in economic benefits, while each project has its own unique facets. Investment decisions need to be prepared based on an estimate or proof of an adequate return on investment and payback period. Only the combined assessment of technical feasibility and economic impact leads to the best solution.