SIEMENS
Ingenuity for life

Generator Service

Uprate of Air-Cooled Generators

Gas turbines are becoming increasingly more efficient as a result of advanced engineering and analysis methods as well as material innovations. Output can be significantly increased by the use of new technologies and new developments in blade technology. These optimizations are not only included in the construction of new turbines, but many can also be implemented in gas turbines which are already in service.

If the increased output of the gas turbine is converted to just active power output (MW) from the generator, the reactive power output (MVAr) must be reduced to stay within the generator capability curve unless the generator is also modified. However, the power system operator often places tight restrictions on any changes in power factor. Thus the capability (MVA) of the generator must be increased.

By opening up the capabilities of the gas turbine and the generator at the same time one can achieve the wanted synergy effects and thus the payback period for your investment may be reduced.

Using specially developed analysis measures, our Siemens experts can very quickly assess various options for uprating your generator and can present you with an individual and optimum solution. This can be done within five days, depending on the generator model and manufacturer.

Our solution
Uprating of air-cooled generators is possible both by modernization measures on the generator as well as by improving the cooling.
A further uprating option for your power plant is provided by the implementation of an additional generator in synchronous condenser operation.
In some cases, the more cost-effective alternative can also entail replacement of the previous generator with a higher-capacity model.

Fig. 1 shows the performance curves for the various uprating possibilities.

In detail, Siemens offers the following measures for uprating your generator, respectively your power plant:

- Modernization measures
  - Generator rotor rewind
  - Installation of a new generator rotor with improved design
- Reducing cold gas temperature in generators with closed air-cooled systems
- Addition of a generator as synchronous condenser
- Alternative: generator replacement

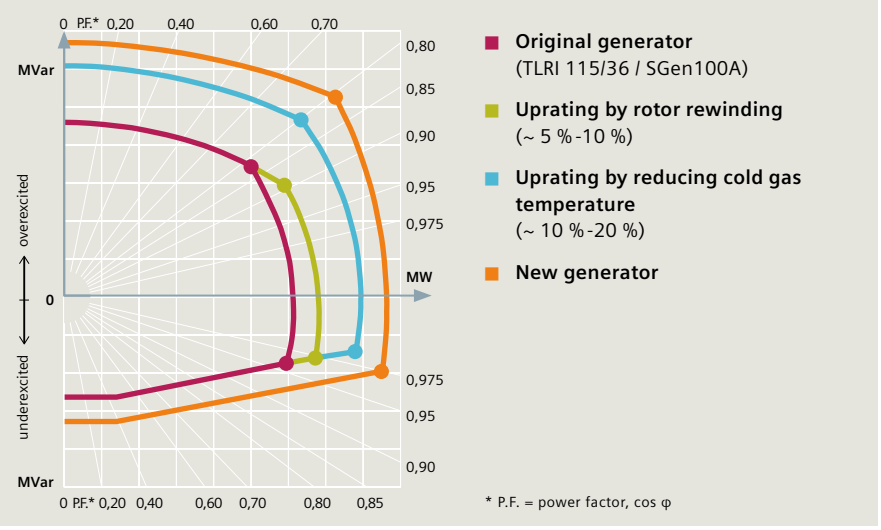

Fig. 1: Schematic showing various uprating options based on performance curves

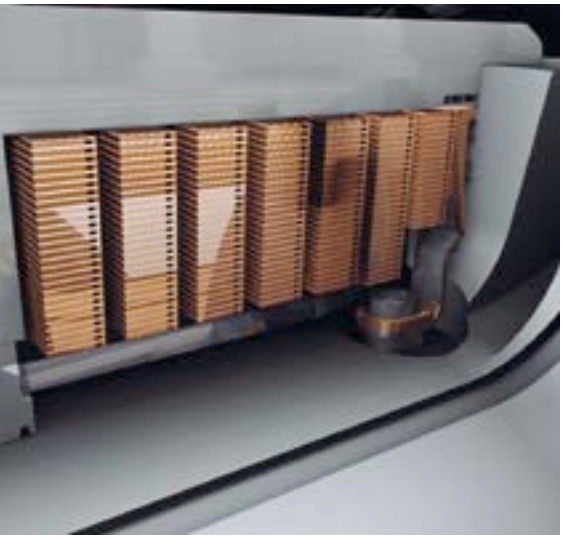

Fig. 2: Inner-cooled winding design

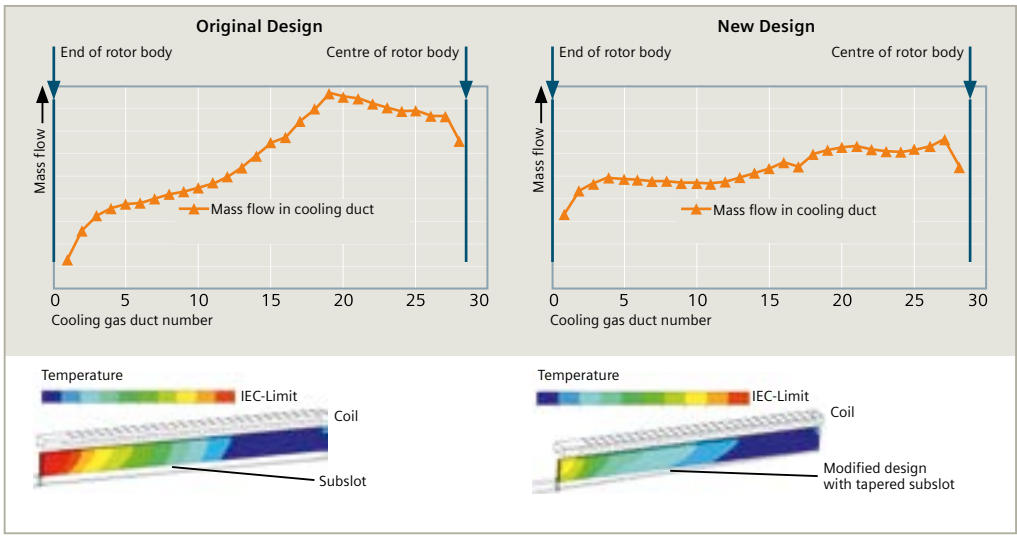

Fig. 3: Homogeneous cooling air flow, particularly at rotor ends and reduced temperatures based on modified subslot design (at right) versus original design (at left)

Uprate by modernization

Siemens offers the following modernization measures:

Generator rotor rewind

Over time, the insulation in the rotor can exhibit aging phenomena. Rewinding is important if it is desired to maintain functionality and performance. Rewinding with improved design and/or materials is also a verified effective uprating tool.

Air-cooled generators are highly utilized machines. Improved cooling of the rotor winding can help to further increase the output. Siemens has developed an optimized rotor winding that can support increased exciter current and can lead to a higher generator output. To improve cooling, the rotor end turns are provided with innercooled transverse conductors (see Fig. 2). By increasing the content of copper in the slot section heat generation at constant output can potentially be reduced. Efficiency is improved by increasing the utilization factor (e.g. by increased air flow). When performing a rewind with innercooled transverse conductors it may be necessary to modify the field current leads and the excitation equipment.

Depending on the condition and the history of your rotor, new design elements (such as improved J-straps or a modified retaining ring shrink fit) which can contribute to greater operating reliability and availability of your generator can also be implemented during the rewind. In addition, according to your needs Siemens offers different concepts for rotor rewinding.

Please also see our associated publication on "Modernization Measures for Radially-Cooled Generator Rotors" and "Rewind Concepts for Generator Rotors – Solutions Tailored to your Needs".

Installation of a new generator rotor with improved design

Instead of a rewind, you can simply replace your rotor with a new rotor with improved design.

A key element of the new rotor design is its highly-efficient cooling system. It was developed to address higher exciter currents in order to enhance the magnetic field that is needed to step-up generator output by up to 20% depending on the generator type and plant operation. To optimize the distribution of the cooling air, Siemens has developed and patented a special subslot that tapers toward the center of the rotor body. The new design accounts for the pressure drop along the axial length and is intended to provide a more evenly distributed cooling.

The cooling air is circulated in the unit by axial blowers on each shaft end. The special rotor design causes the rotor rotation to pump the cold air automatically through the radial cooling gas ducts of the winding (see Fig. 3).

Unlike with a rotor rewind, you do not need to modify field current leads or excitation equipment when opting for a rotor replacement. Furthermore, the rotor is available right at the start of the overhaul thus helping to reduce standstill times.

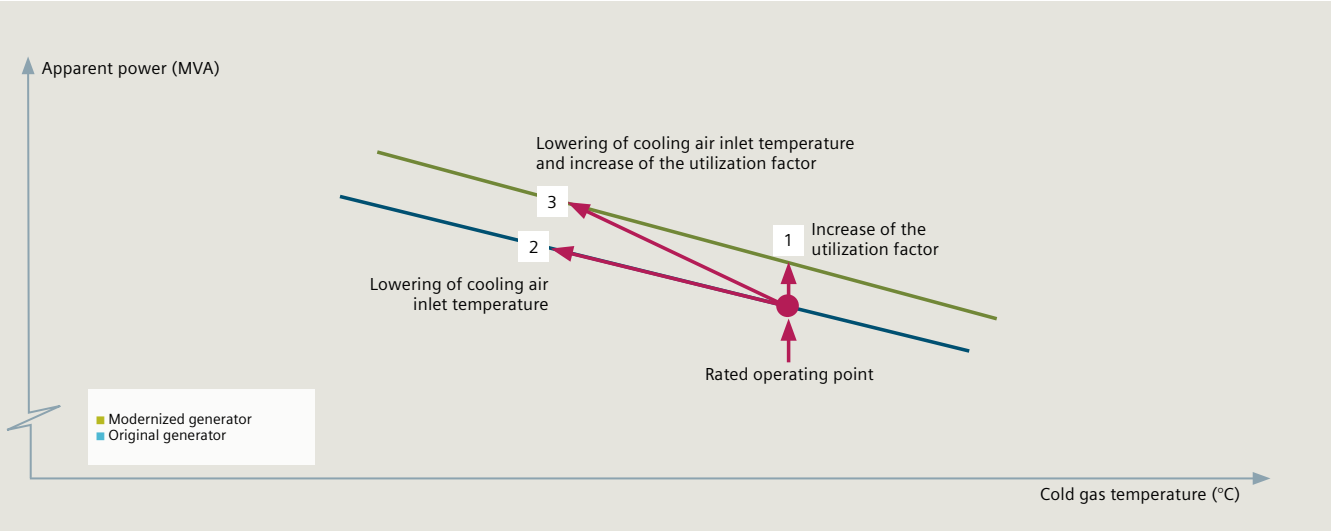

Fig. 4: Uprate as a function of cold gas temperature

Uprating by reducing cold gas temperature in generators with closed air-cooled cooling systems

As an alternative or supplement to increasing generator utilization by rewinding or the implementation of a new rotor with improved design, a reduction in the cold gas temperature bears even greater uprating potential, but is more complex to implement in many cases. A maximum can be achieved by combining both possibilities (see Fig. 4).

In air-cooled generators with a closed cooling cycle, a chiller is implemented to increase cooling capacity. This is an air-cooled fluid cooler with a screw compressor attached to the existing cooling cycle to reduce the cold gas temperature.

In addition to the demand-specific adjustment possibilities, the design of the system accounted for the fact that operation is also possible with the chiller deactivated.

The following positive aspects must also be observed in the implementation of methods for reducing the cold gas temperature:

- No need for technical modifications to the existing generators
- Complete integration of the I&C in the existing power plant control system
- High flexibility of the cooling system to enable unrestricted fulfilment of load demand from the grid system
- Short standstill period for installation

Uprate by implementation of a synchronous condenser

In power plants with several turbine generator sets, the implementation of an additional generator in synchronous condenser operation may represent the most cost-effective solution for increasing the plant output. The power factor in the existing generators is adjusted to produce more or even exclusive active power (MW). The missing reactive power fraction (MVAr) is to be compensated by the synchronous generator which is operated as a motor at zero load.

The effort associated with the installation of an additional generator in the power plant architecture can be compensated for by the following advantages:

- No need for extensive technical changes to the existing generators
- High flexibility with regard to the provision of reactive power
- Use of an additional generator in power plants with several generators of the same type as a “productive reserve”, e.g. in the event of damage to a generator

Criteria	Solution			
	New Rotor Design	New Rotor Winding	Chiller	Synchronous condenser
Verified technology	✔	✔	✔	✔
Approach for air-cooled generator fleet	✔	✔	Only for completely closed water- and air-cooled generators	✔
Power upgrade independent of climate conditions	✔	✔	✔	✔
No extra energy consumption	✔	✔	Electric power supply to compressor required	Startup converter and excitation required
Efficiency increase achievable	✔	✔	Lower overall efficiency anticipated	Optimized operating point cos φ = 1 in generator
No need to increase the no. of components in the PP	✔	✔	Installation of cold water system	Installation of additional generator
Requires no changes in the excitation system	✔	Depends on reserves of existing system	✔	Additional excitation of synchronous condenser
No structural modification to the generator required	–	–	✔	✔

Fig. 5: Overview of uprating methods

Alternative: Generator replacement (Footprint™ generator)

Complete replacement is often the more cost-effective alternative for many generators, particularly for those which are very old. A detailed cost/benefit analysis can help you decide if and when an Investment in a new generator is cost-effective compared with increasing maintenance and service expenditures for the current generator. With the Footprint™ generator*, Siemens can offer you a costeffective solution in which the existing foundations and connections can be used wherever possible.

Your benefits

With any uprate it is important to verify that all of the measures in the power plant are coordinated. As a power plant supplier, Siemens can offer you solutions which are optimally matched to your plant. Siemens provides project management and can coordinate and harmonize the various scopes of supply and services (gas turbine modernization, generator rotor modernization, I&C, implementation of cooling technology).

Your overall benefits can include:

- Increased output
- Improved operating reliability/ availability
- Extended service life of your generator
- Improved competitive position

* Footprint Generator is a registered trademark of Siemens AG, Germany.

Published by
Siemens AG 2018

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Article-No. PSPG-B10274-00-7600
Printed in Germany
Dispo 34805
TH 288-170830 DA 1117