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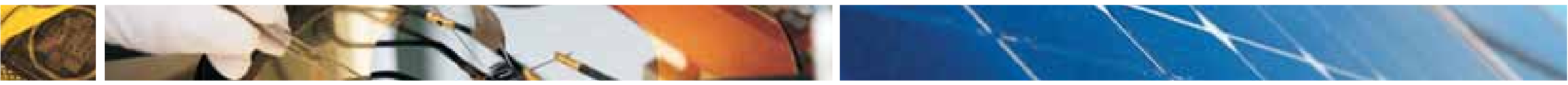

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Medium-Voltage Variable-Speed Mini-Turbine

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2 Executive Summary

During the past decade, renewable energy sources have attracted considerable interest. Particularly wind power and photovoltaic systems are showing high growth rates. Together with hydro, biomass and geothermal energy, these renewable energy sources already account for a significant part of electricity production in some countries of the world. In addition, market liberalization, often combined with incentives to produce electricity whenever process heat is required, has steadily increased the number of small co-generation gas-fired power plants, also called combined heat and power (CHP) units. These CHP plants are using gas engines (power range 0.5 up to 5 MWe) or gas turbines (typically size above 5 MWe) to convert gas in heat and electrical power. While the share of dispersed generation in power systems has notably increased and continues to increase further, questions are being raised concerning power quality and grid stability. Apart from expensive storage systems, such as pumped hydro, electrochemical energy and compressed air, fluctuating electricity production of renewable power sources can also be compensated by coordinating the vast amount of small co-generation power generation units, because they are, in principle, capable of delivering power-on-demand within specified limits.

Although small CHP units may offer fast response times, due to their operation at fixed speed, their efficiency diminishes rapidly under part load conditions. This loss of efficiency is noticeable especially in small, low-cost, high-speed, single-shaft gas turbines. Due to their long life, low maintenance and low investment costs these units would otherwise compete favorably against gas engines, even at power levels down to 1 MW.

Within the scope of this project, a novel variable-speed turbine system was analyzed to start understanding its potentials in the CHP market. In contrast to conventional turbine systems, the considered turbine-generator system has neither gearbox nor transformer to link to the (fixed frequency) power grid. Rather, power electronic converters are used to feed the variable frequency (between 400 up to 500 Hz) electrical power of the low-weight, high-speed generator in the grid and to control turbine speed (dynamically and statically). This reduced component count results not only in significantly lower weight, but also leads to improved reliability. Additional benefits of this compact design is enhanced transportability and minimum installation effort (plug-and-play capability). Furthermore, operating a gas turbine at variable speed could increase the thermal efficiency, leading to fuel savings, by applying maximum power point tracking algorithms.

The overall system under consideration consists of three main components, which are the gas turbine itself, a direct-driven high-speed generator and the power electronic converter. The main objective of this study was to assess the influence of variable speed operation on system efficiency, in particular part load efficiency, of a 15,000 rpm turbine-generator system, rated 1, 5 and 10 MW.

Main result of the study is that the thermal efficiency of low-cost single-shaft gas turbines can be significantly increased (absolute gain up to 3.1 %), if the turbine is operated at variable speed.



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