CONTROL OF SYNCHRONOUS GENERATORS

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Keywords: Synchronous generators, voltage control, compounding, emergency power stations

Contents

Summary

Voltage and frequency control of singly operated synchronous generators for electrical power generation is quite different from control schemes for machines in power stations, linked to an interconnected system. The different possibilities applied today are presented.

1. Introduction

For large-scale production of electrical power in general electromechanical power generators are applied. The generators of numerous power stations in wide areas are joined to large interconnected systems, mainly to ensure a reliable supply of electrical power to industrial and private customers.

Just recently the high-voltage transmission network additionally forms the backbone for the electrical energy market. The generators are driven by thermal or hydraulic turbines.

In interconnected electrical systems all generators have the same frequency and nearly the same voltage. Both quantities are rather belonging to the system than to the individual generator and its turbine. In power stations there are two possibilities for generator control: Torque control from the drive and reactive power control by the excitation of the magnetic field.

The control problems of an individual generator in the power station are part of the overall control philosophy for the interconnected power system. These questions are discussed in more detail (see *Automation and Control of Electrical Power Generation and Distributed Systems: Steam Turbines*).

Individual operating generators nevertheless play an important role in technique and economy. They have a very wide field of applications. There are emergency-power generators, which are backup systems against power failures for sensitive applications in industry, hospitals, power stations, traffic constructions, airports or for military equipment.

They cover the range from few kilowatts to several ten megawatts. Depending on the special application these facilities have to ensure the power supply under severe conditions with absolutely no interruption; but normally a short interruption time of some few seconds is allowed, to start up the device.

The quality of the electrical power, the frequency, voltage, capacity for delivering reactive power and the ratings for unsymmetrical load have to meet the standards common for the mains.

Another, somewhat different application of individual electrical power generators are vehicles, vessels and airplanes. Here a great variety of standards are found. DC or AC systems with different frequencies are found with mains on board. With the rotational speed of the generators the power-to-mass ratio and in the same relation the frequency are increased. This is why the standard frequency on airplanes is 400 Hz.

If an individual generator is used independent of the mains with other generators, a frequency and voltage control is absolutely necessary. DC-voltage generators are not further considered despite the fact, that these are standard on road vehicles and widespread.

But these always have a battery for the stand-still situation and for buffering, so in principle, trucks and cars have two source systems. Electrical power supply for road vehicles is very special in design. Within this, generator control is a relatively simple task.

The frequency of an AC generator is exclusively given by the rotational speed of the generator shaft. This means that the mechanical drive has to be equipped with a speed controller to keep the angular velocity within close limits independent of torque fluctuations, initiated by variations of the electrical load.

With constant speed the voltage of the generator is a function of the excitation of the generator and of the magnitude and power factor of the load. Speed variations are in any case relatively small, for a generator with voltage control the compensation of this kind of disturbances would be absolutely no problem.

For investigating problems of voltage control the complete model for the synchronous machines, as developed by PARK and others is not necessary. It has been proved theoretically and by practical experience that modern generator control is very robust with respect to the nonlinear model elements as well as to variations of the active load.

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Biographical Sketch

Jörg Hugel, born in Stuttgart in 1938, studied electrical engineering at the Stuttgart Technical University and wrote his doctoral thesis on the subject of control engineering under the guidance of A. Leonhard. His subsequent activities in industry in the fields of plant engineering and power electronics were broad in scope and internationally oriented. Since 1982 he has occupied the Chair of Electrical Engineering Design at the ETH Zurich.