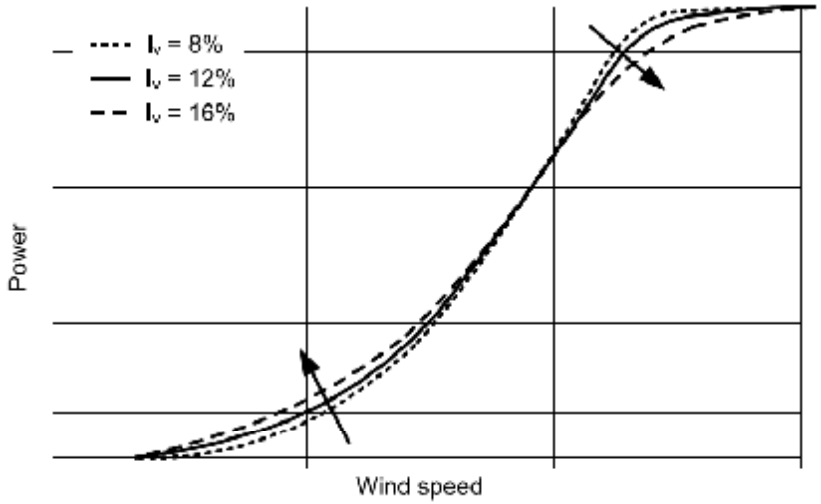
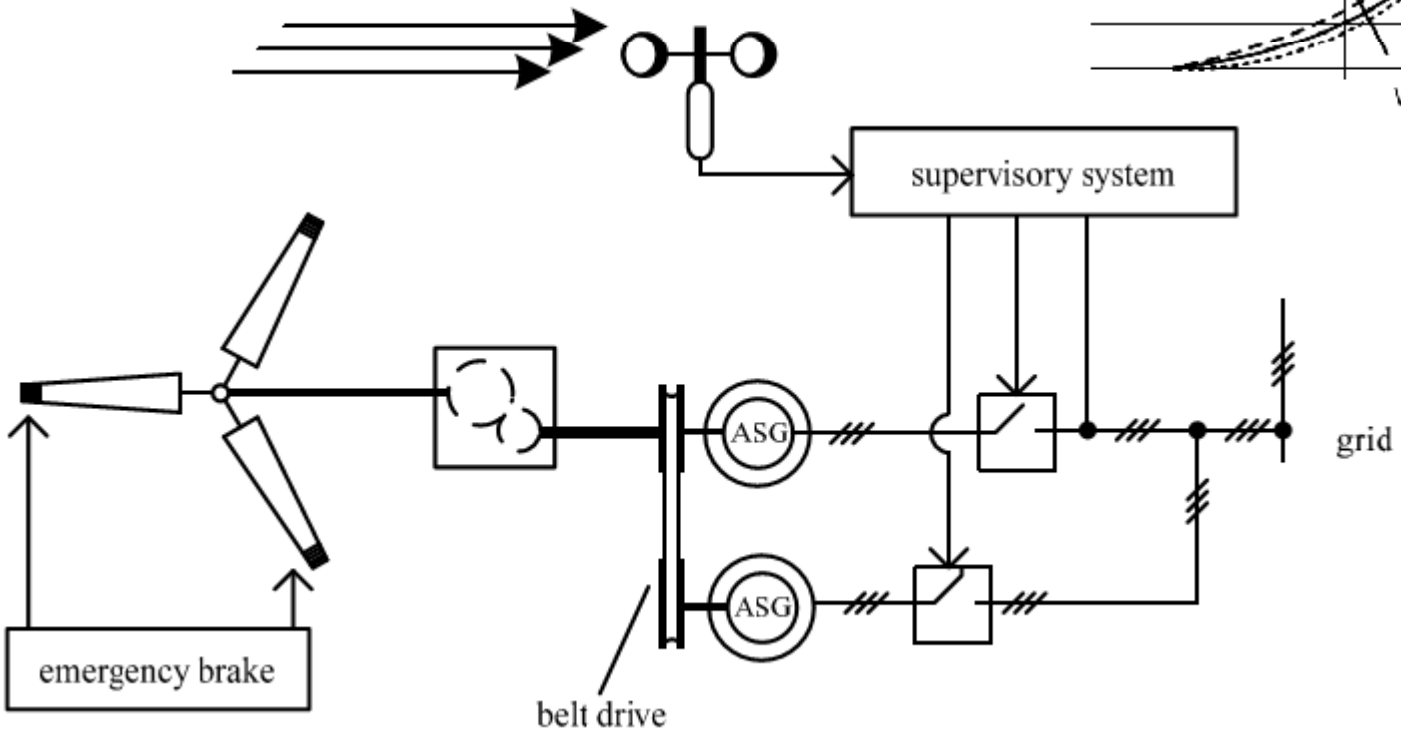
# Electricity generation by wind turbines

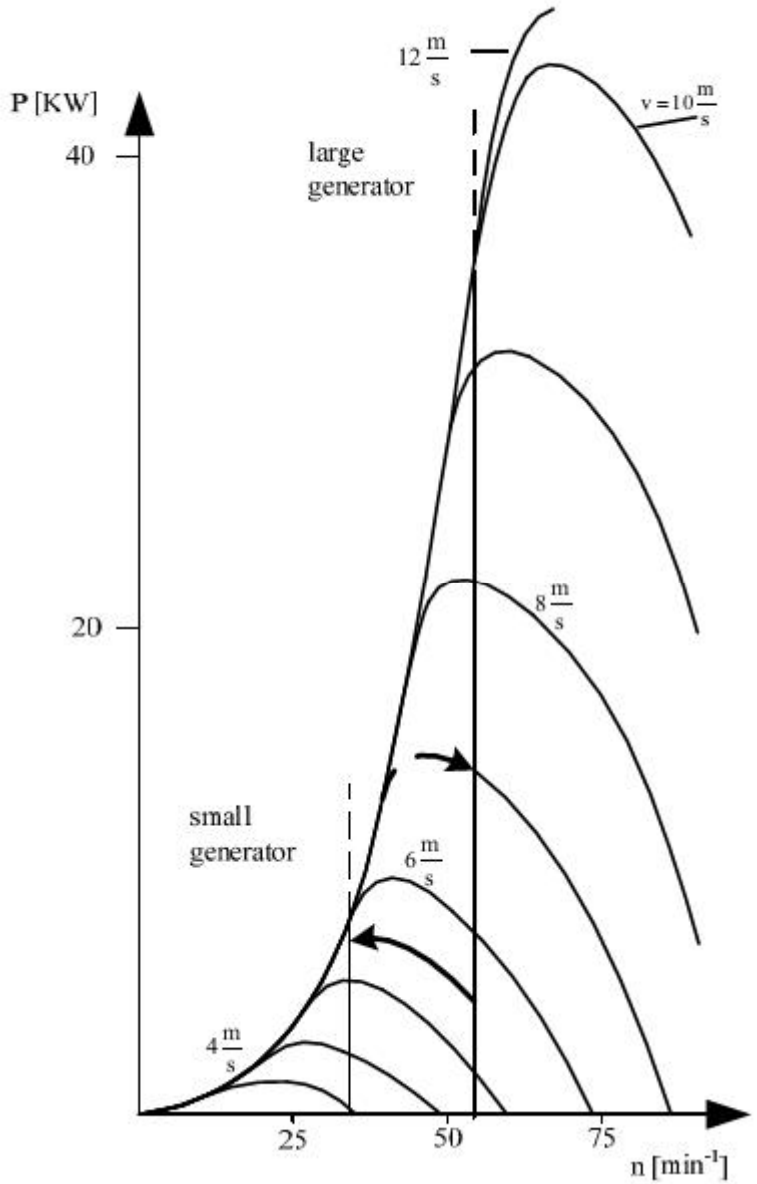
# Wind turbines for power generation

- Grid-connected wind turbines
- Wind turbines for stand-alone operation
- Wind turbines for hybrid systems, e.g. wind-diesel or wind-photovoltaic systems

# Directly grid-connected asynchronous generators




P [KW]
40
20
12 m/s
v = 10 m/s
large
generator
8 m/s
small
generator
6 m/s
4 m/s
25
50
75
n [min⁻¹]

# Directly grid-connected asynchronous generator with dynamic slip control

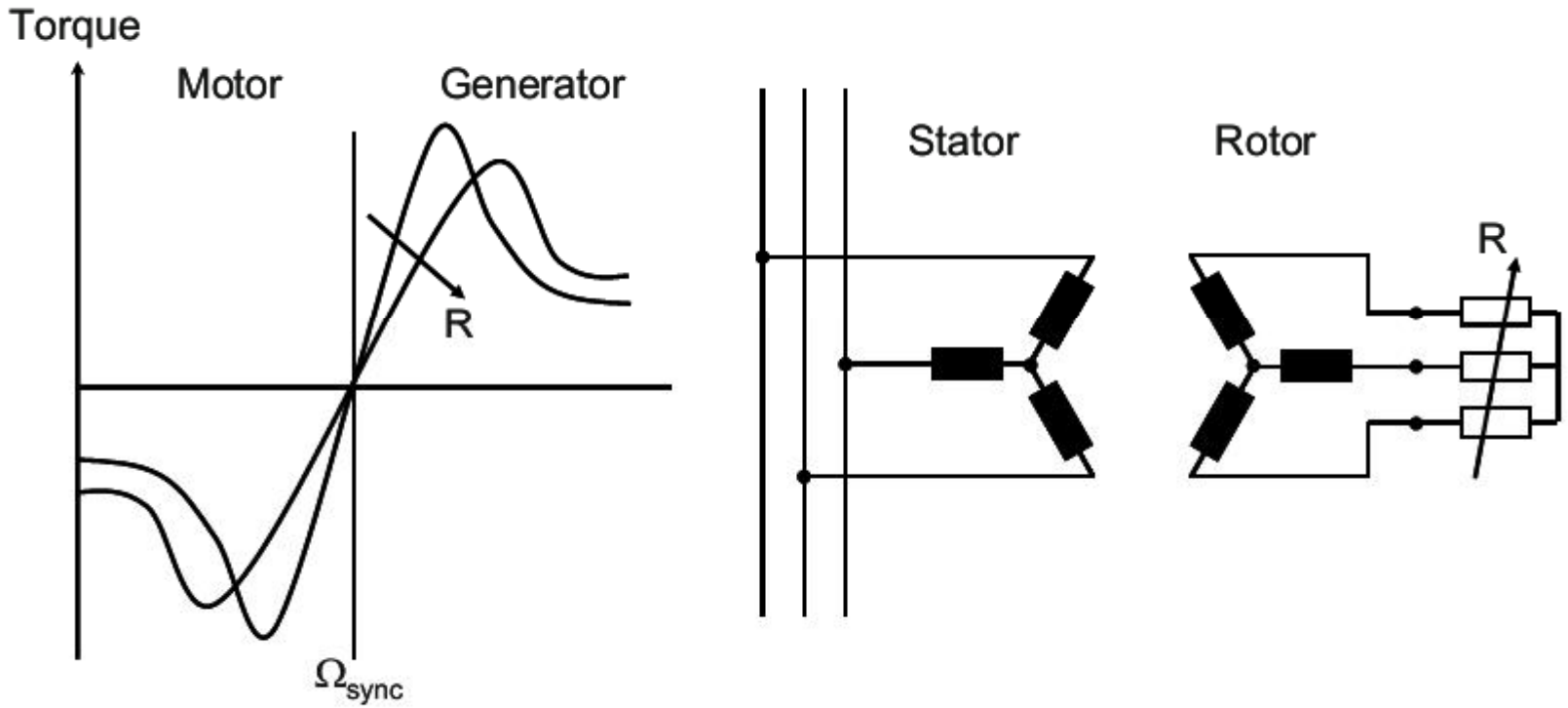



**Fig. 13-6** Influencing the generator characteristic by additional variable resistances in the rotor circuit of an asynchronous machine

For normal winds the bridge at the slip rings is short-circuited mechanically.
For strong winds the mechanical bridge is opened and the additional resistances in the rotor circuit increase the slip, which can now be manipulated.

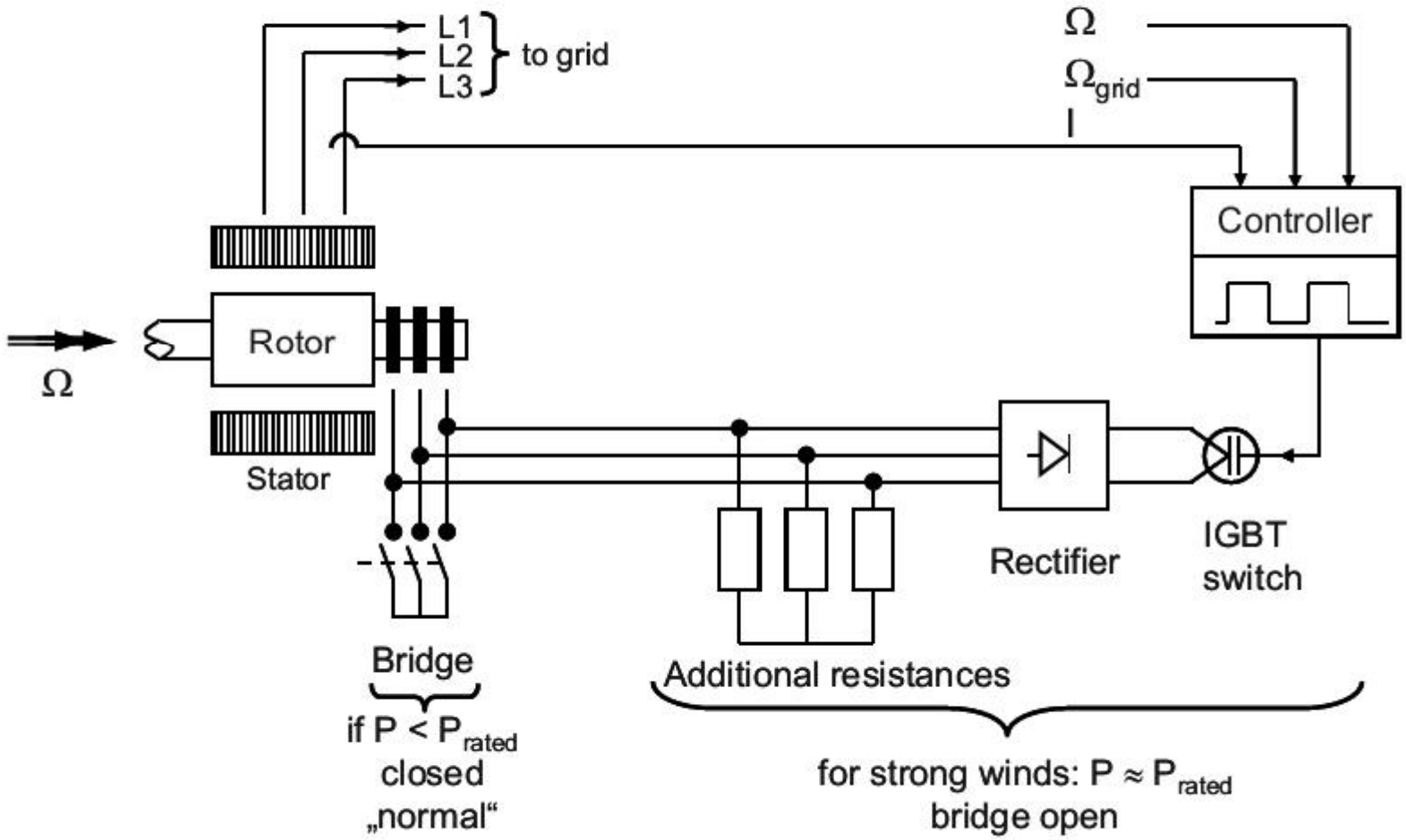



**Fig. 13-7** Block diagram of the dynamic slip control by additional variable resistances in the rotor circuit of an asynchronous machine

The controller will use a clock in the kHz range to prescribe the fraction of time for which the additional resistors are in the control circuits. Thus the mean resis-tance Rmcan be adjusted to values between Ri and Ri+ Radd

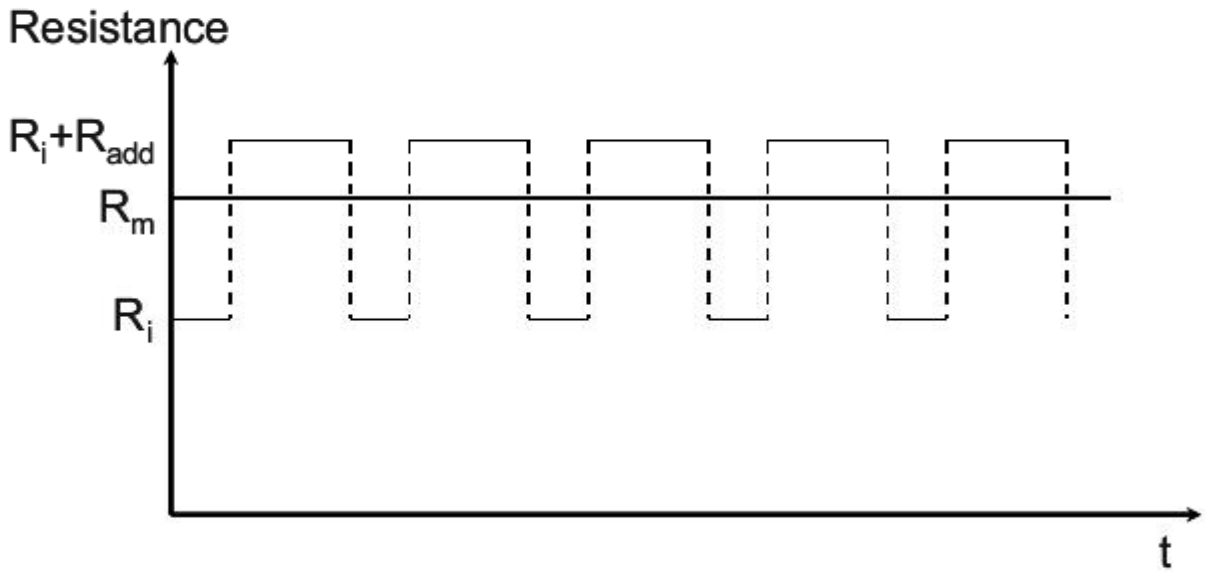



**Fig. 13-8** Slip manipulation through clocked switching of the additional resistance $R_{add}$

# Variable-speed wind turbine with converter and direct voltage intermediate circuit

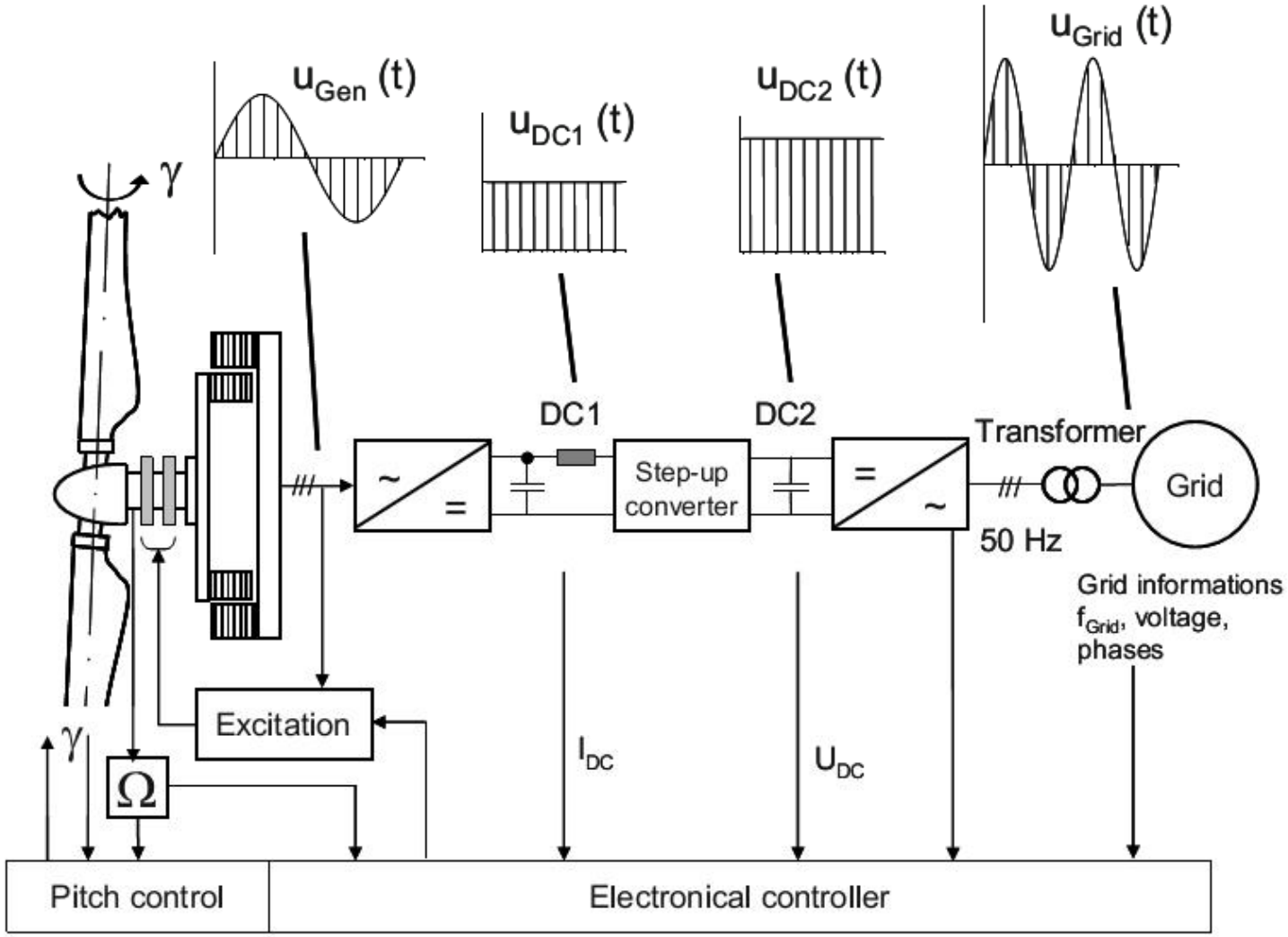



**Fig. 13-9** Concept of a synchronous generator with AC-DC-AC converter

# Variable-speed wind turbine with doubly-feeding asynchro-nous generator and converter in the rotor circuit

- With dynamic slip control it requires the more complex slip ring rotor instead of the squirrel-cage rotor. Since one percent slip equals one percent power loss in the rotor, it is reasonable to allow high values of slip only for brief intervals of time.

- If the power, that was exported from the rotor, is not converted into heat, but is in-stead fed into the grid via an AC-DC-AC converter the problem of heat dissipation is avoided. And the efficiency of the generator is improved.

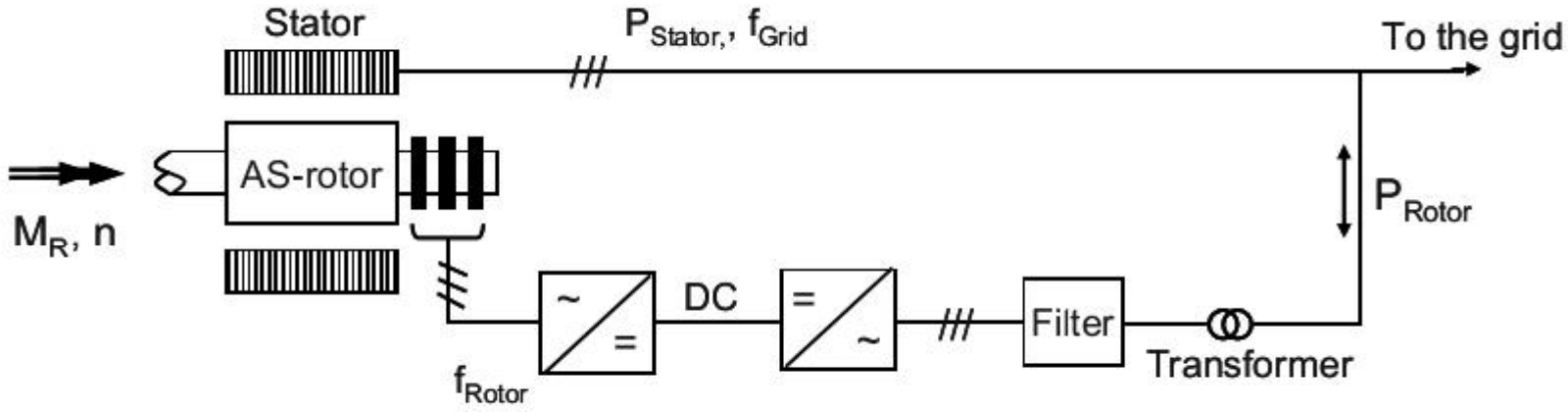


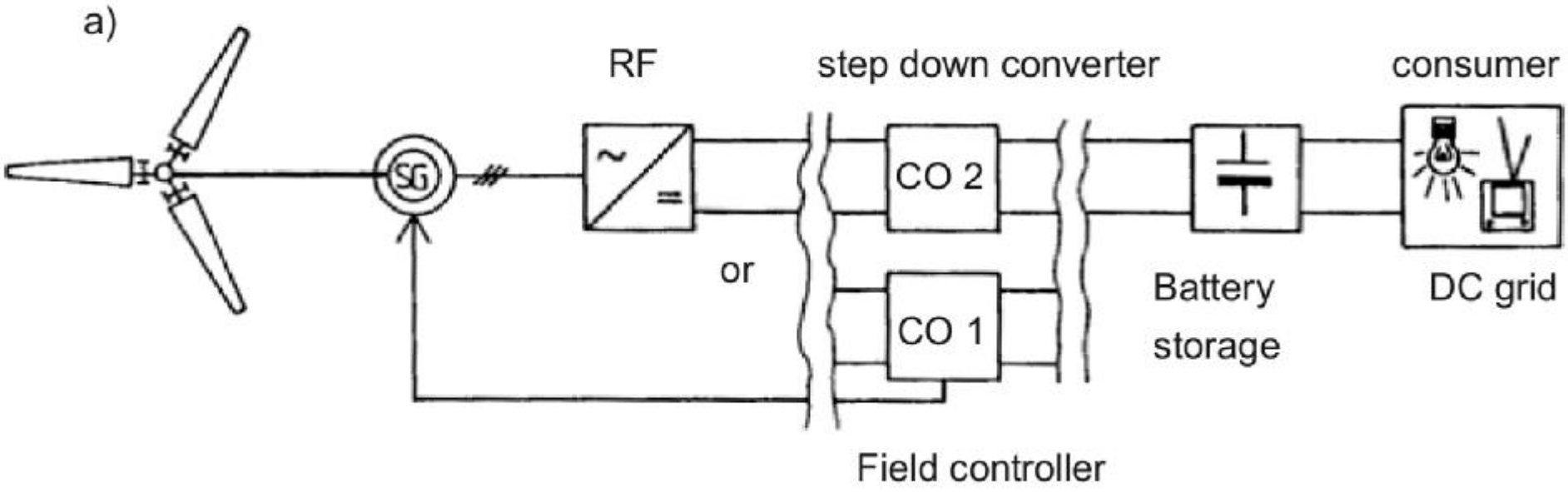

**Fig. 13-10** Wind turbine with asynchronous generator and converter in the rotor circuit

The relevant advantages of the modern variable-speed concepts are not found in their efficiency, but in:

- The reduction of power fluctuations during gusts,
- Significant relief for the structure in the strong wind range,
- The flexibility in adjusting the reactive power,
- The adaptation of the blade tip speed to local conditions

In summary: we gain increased flexibility with regard to the actual on-site conditions.

# Wind turbines for stand-alone operation




Battery chargers

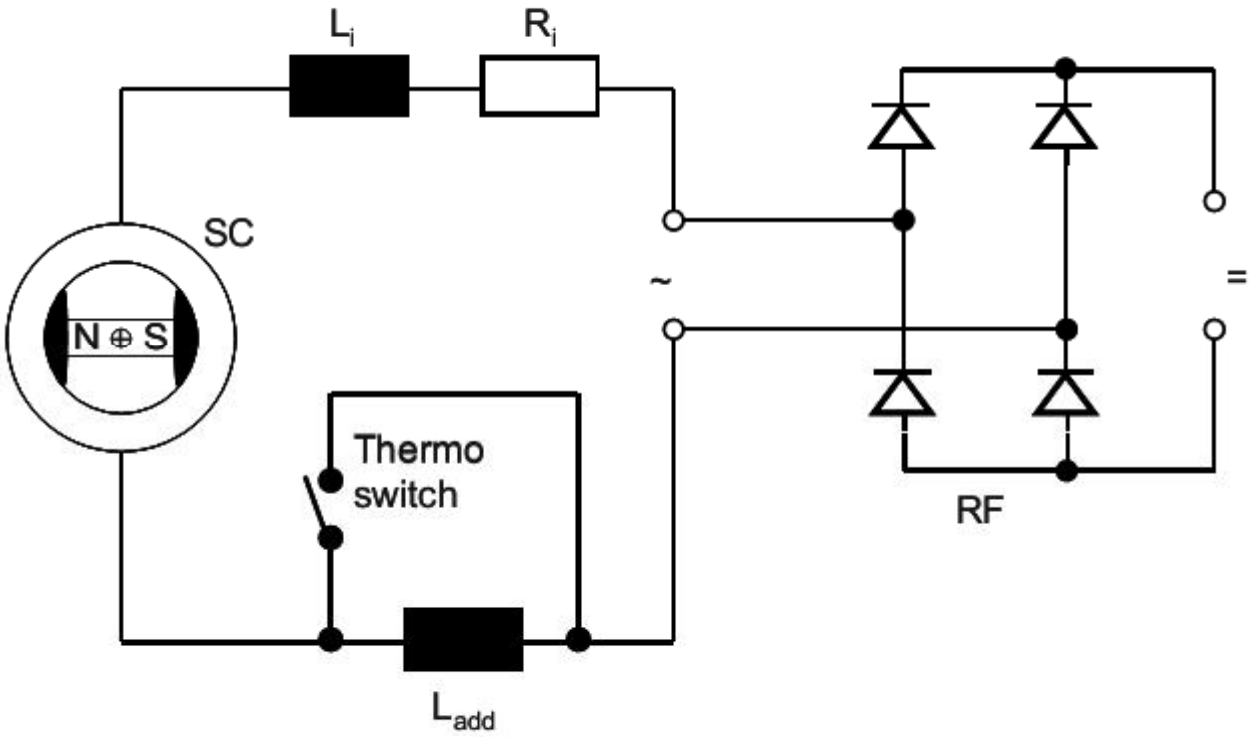
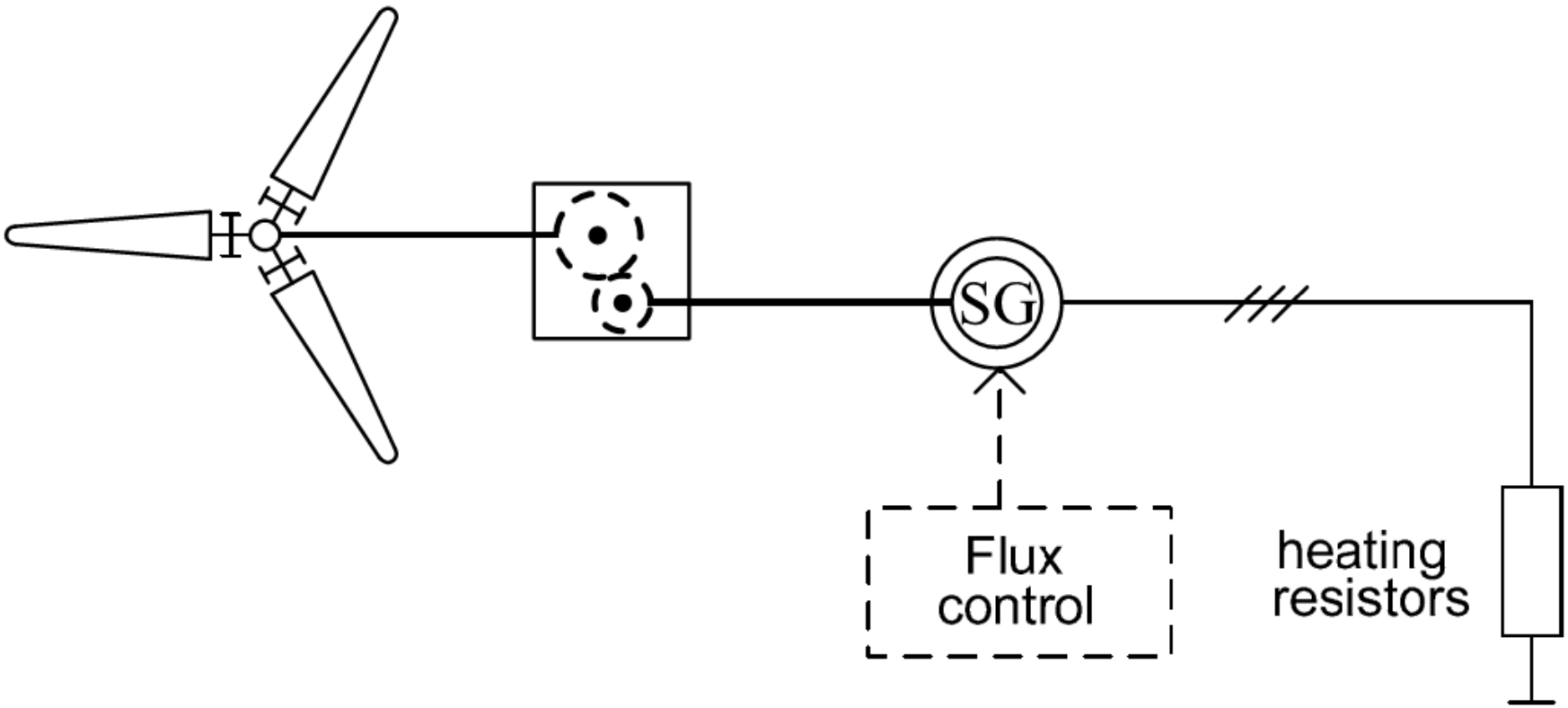


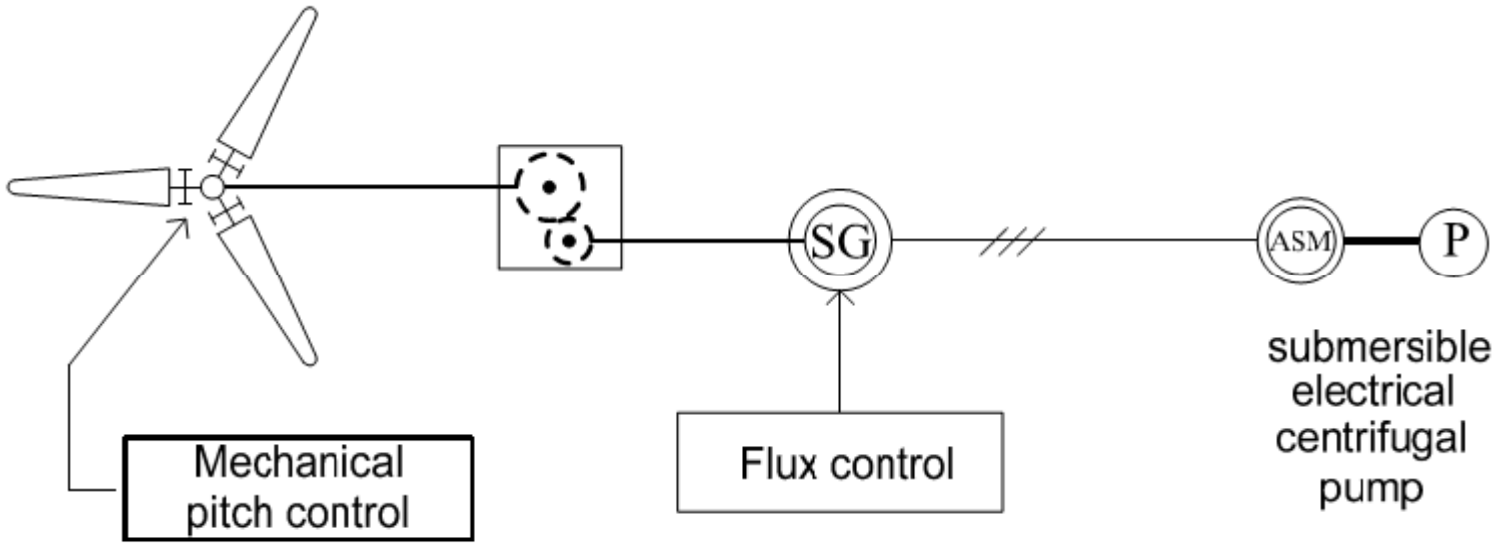

**Fig. 13-15** Battery charger with a thermo element to switch in an additional inductance at high power levels; synchronous generator with excitation by permanent magnets

# Resistive heaters with synchronous generators




Resistive heaters can be used to convert electric energy into thermal energy, for instance to make hot water.

# Wind pump system with electrical power transmission




Wind pumping system operating with variable rotor speeds, a) Block diagram,

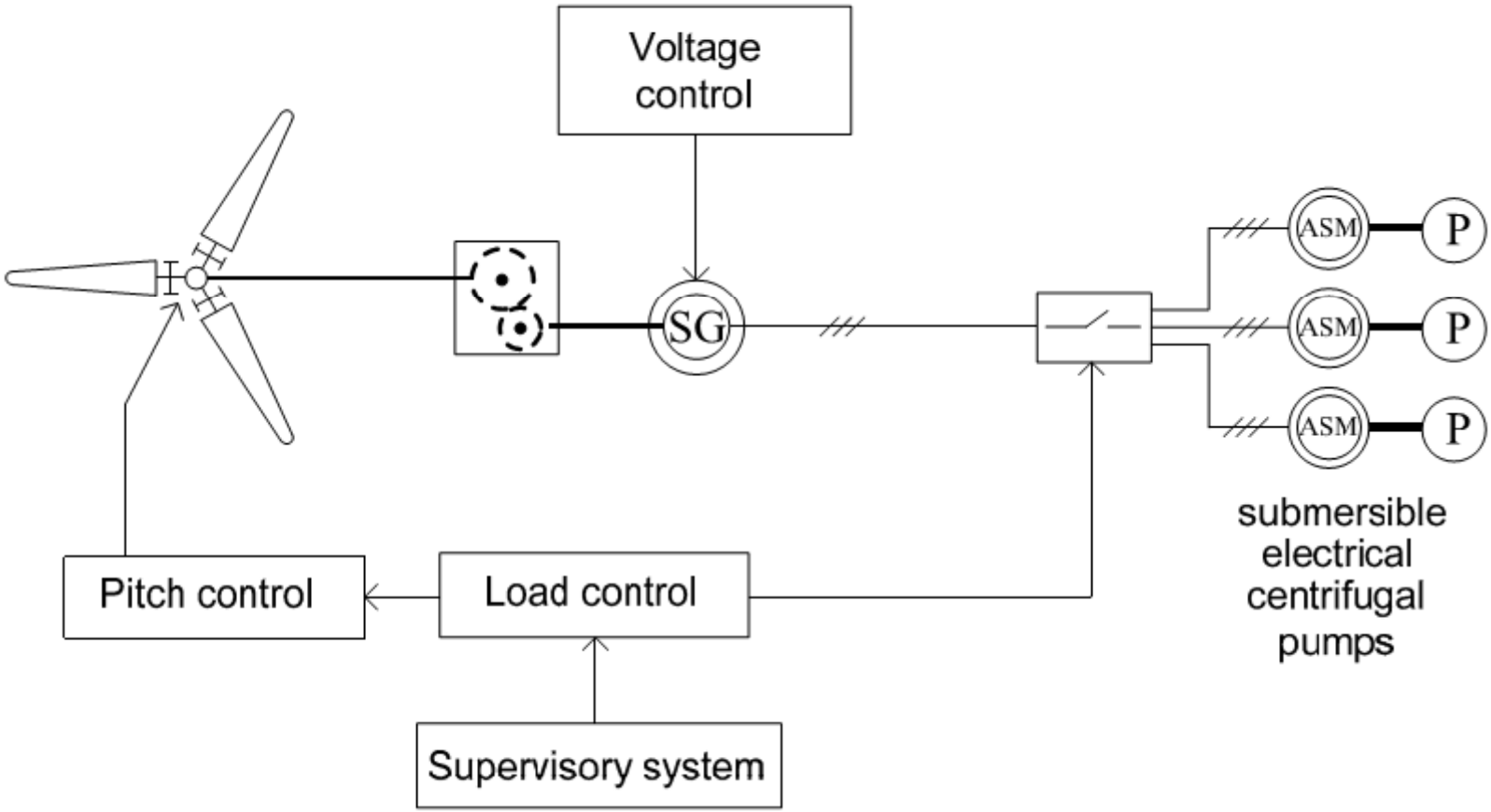
Four ranges of operation can be distinguished:

A Low-speed idling of the rotor, power consumption determined by the friction in the bearings and gearbox, etc.

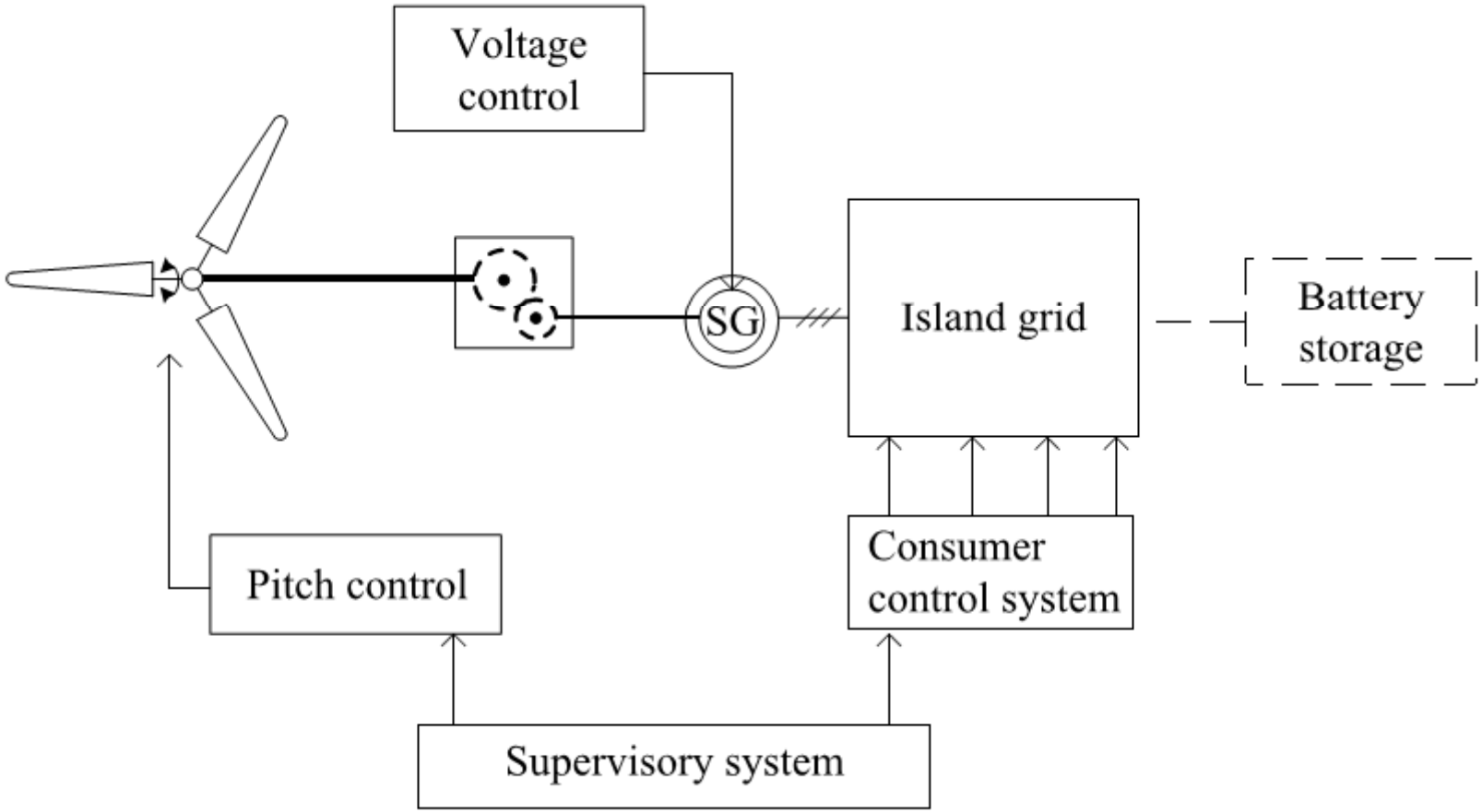
B Generator delivers voltage: pump acts as fluid friction dynamometer since the rotational speed is not sufficient to overcome the geodetic head

C Water pumping: operation of the wind pump close to optimal wind turbine power output

D Speed and power limitation: by a centrifugal pitch control


Voltage control
SG
ASM
P
ASM
P
ASM
P
submersible electrical centrifugal pumps
Pitch control
Load control
Supervisory system

# Stand-alone wind turbines for insular grids



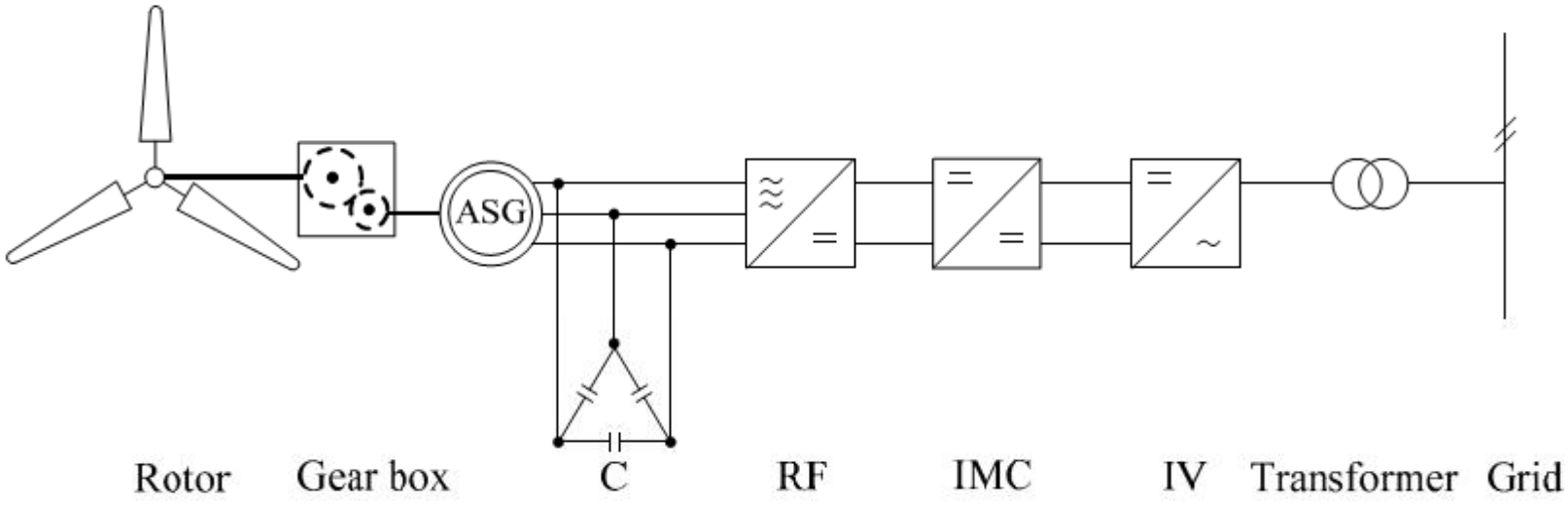



**Fig. 13-21** Variable-speed asynchronous generator with an intermediate DC circuit

# Wind turbines for hybrid systems

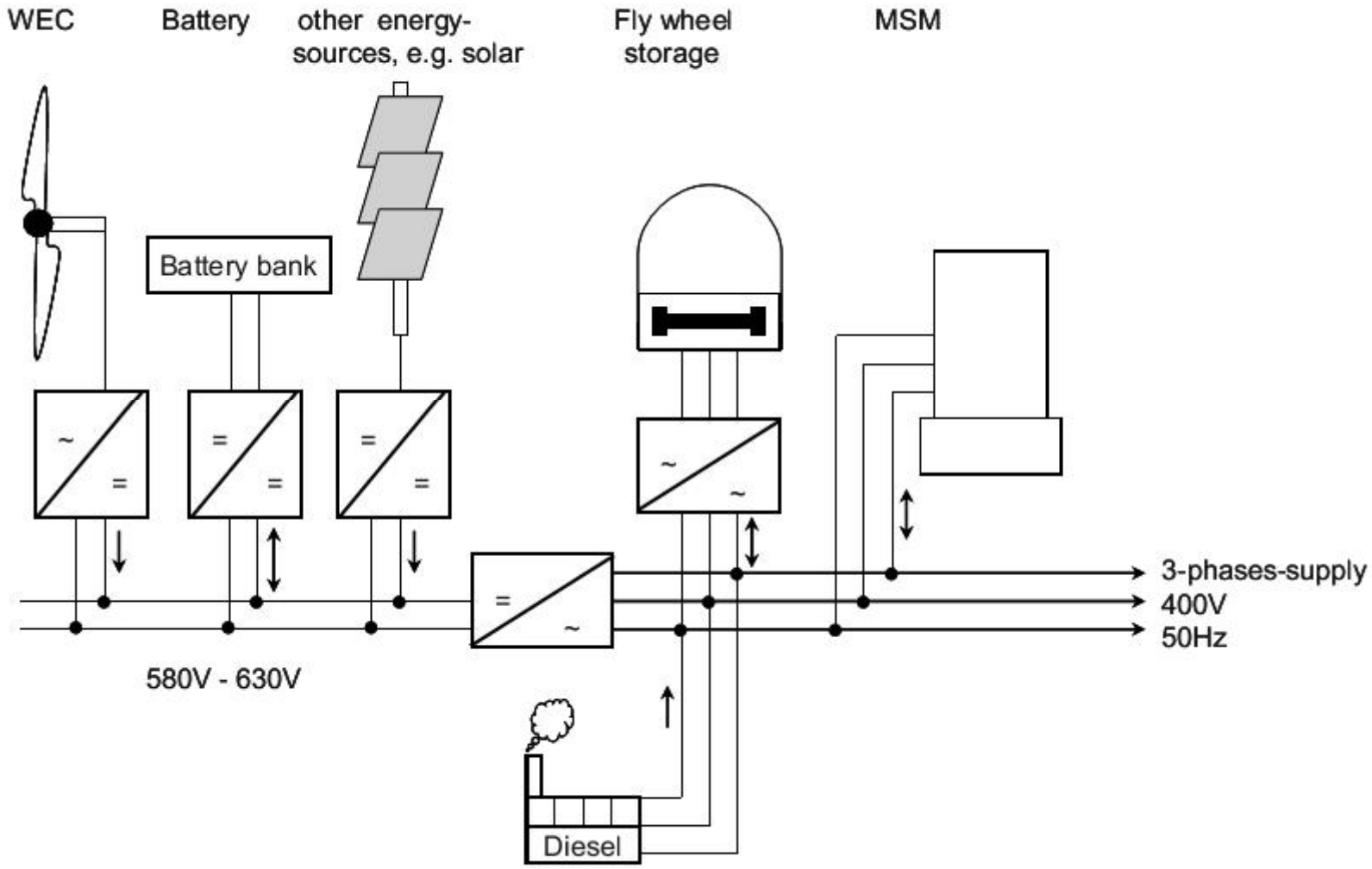



**Fig. 13-25** Stand-alone system with a master synchronous machine (MSM), acc. [13]

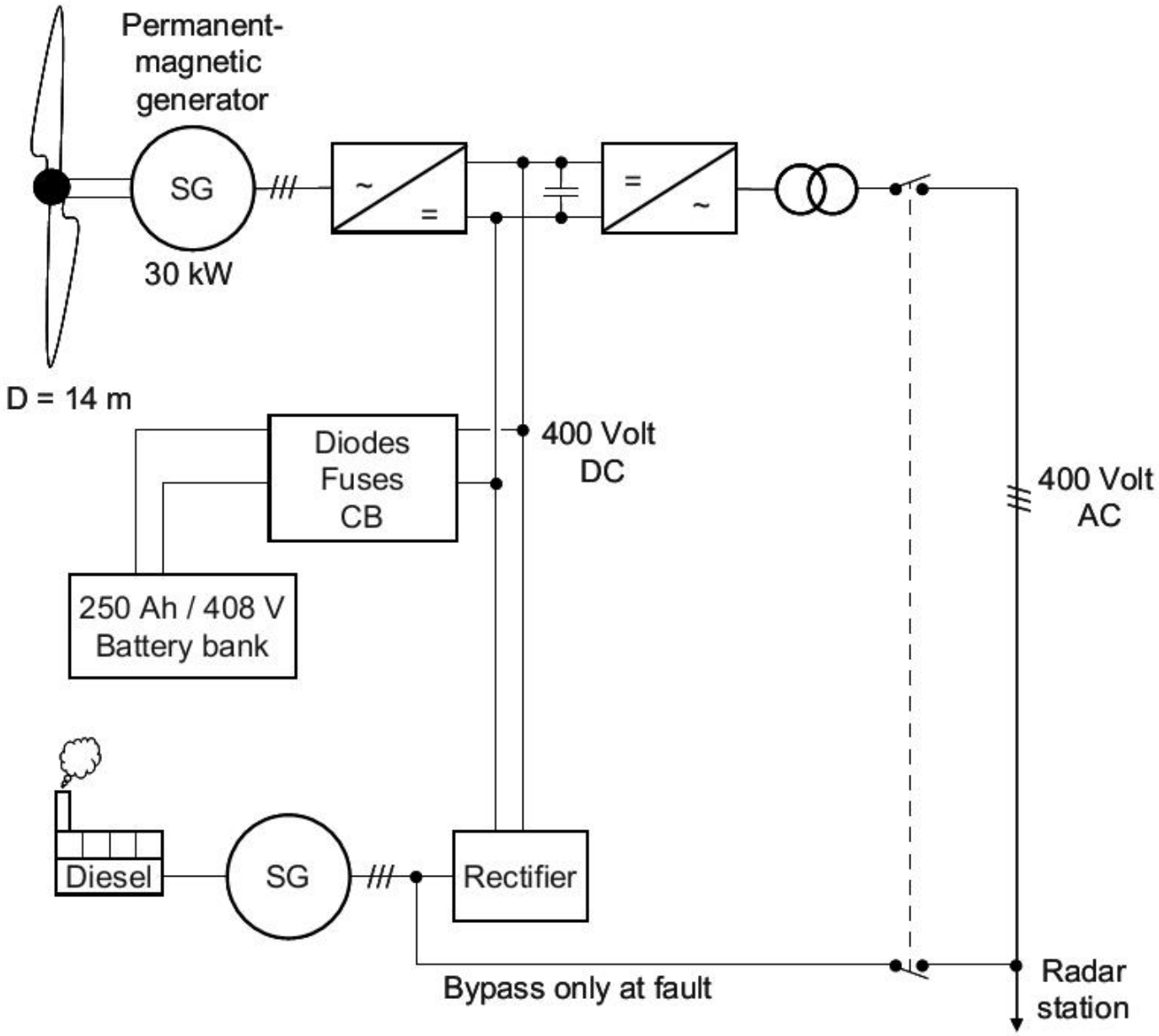



**Fig. 13-26** Wind-diesel system for the island Osmussaare (radar station) [10]

# Wind-diesel-photovoltaic system (minimal grid)

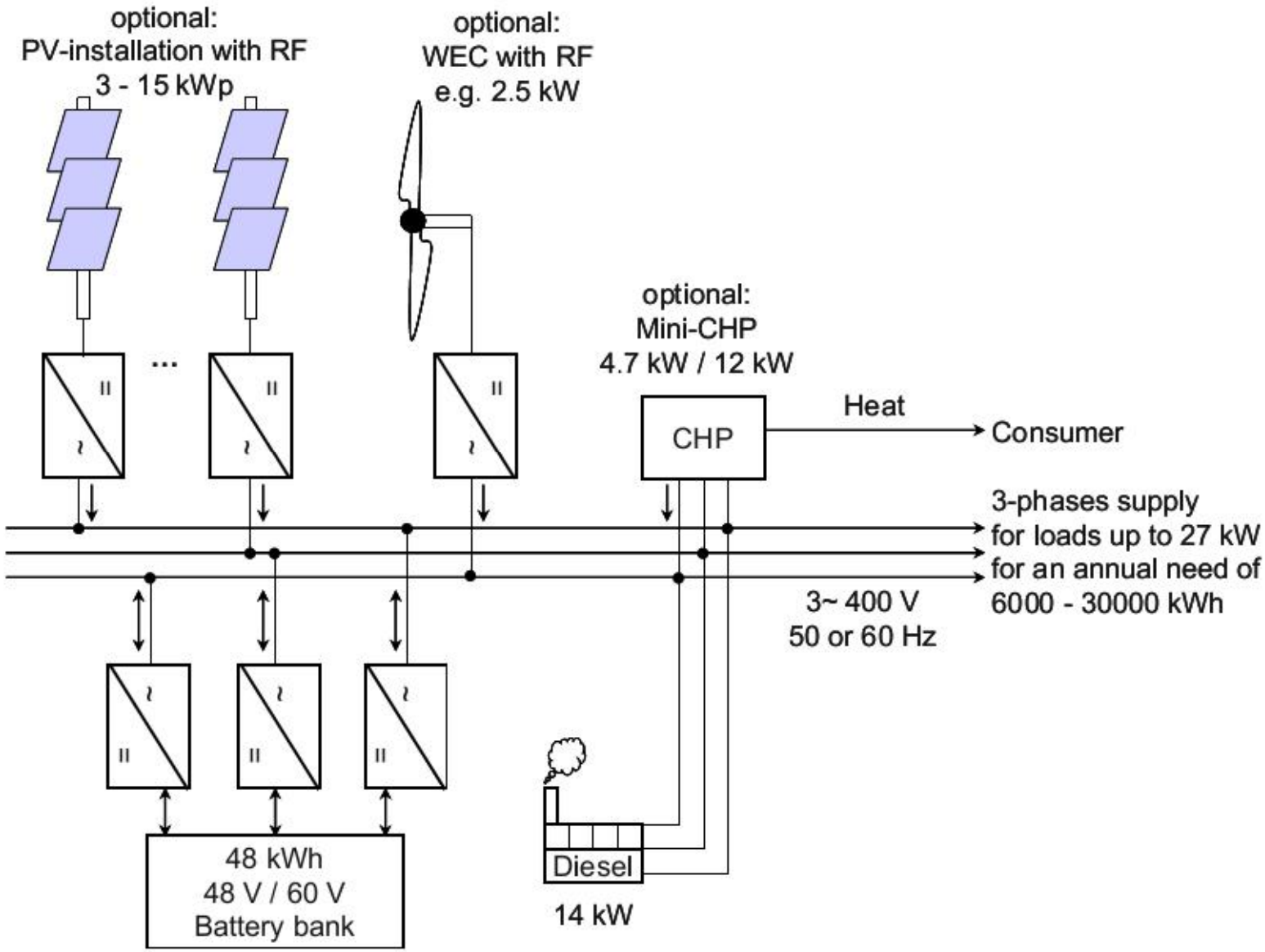



**Fig. 13-27** Hybrid system with power generation from several energy sources in a small grid [7]