EIFER

EUROPÄISCHES INSTITUT FÜR ENERGIEFORSCHUNG
INSTITUT EUROPEEN DE RECHERCHE SUR L'ENERGIE
EUROPEAN INSTITUTE FOR ENERGY RESEARCH

Elektrisches System

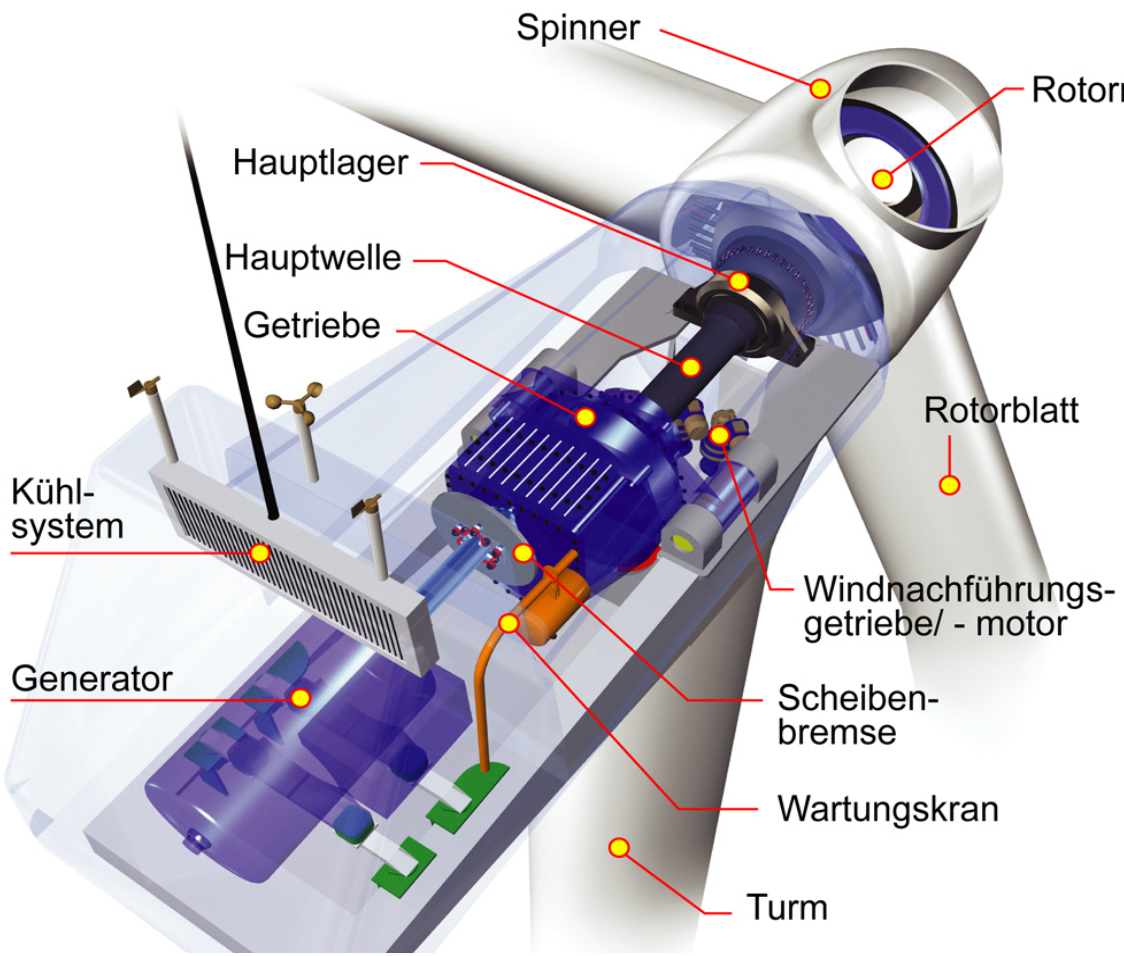
KIT

EDF

KIT

Aufbau

Triebstrang – Klassischer Aufbau



Modell NEG Micon 52/900
- technische Daten -

Technik

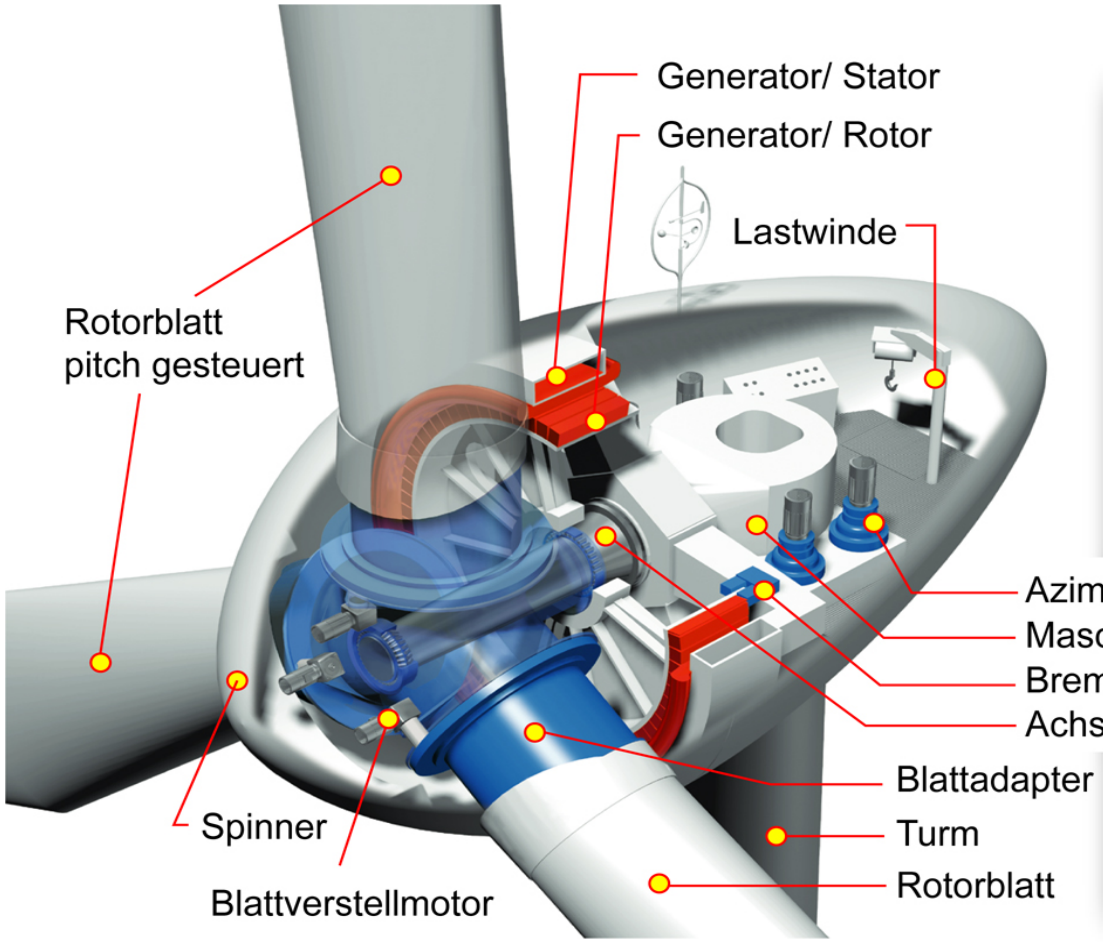
Leistung	:	900 kw
Nennwindgeschwindigkeit	:	16,0 m/s
Einschaltwindgeschw.	:	3,5 m/s
Rotordurchmesser	:	52,0 m
Überstrichene Fläche	:	2.140 m²
Drehzahl	:	15-22 U/min
Generator	:	asynchron

Gewicht

Gondel	:	26,5 t
Rotor (incl. Nabe)	:	16,5 t
Turm (74m, Stahlrohr)	:	97,0 t

Aufbau

Triebstrang - Getriebelos

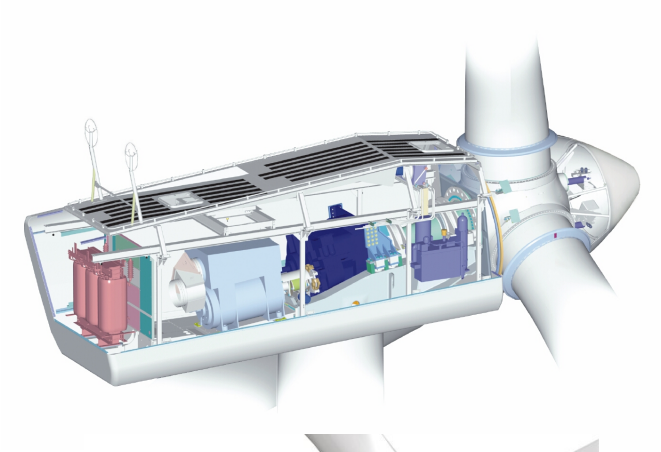


Modell Enercon E-66
- technische Daten -

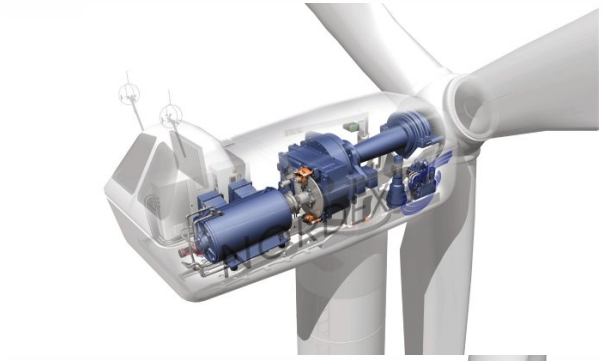
Technik		
Leistung	:	1,8 MW
Nennwindgeschwindigkeit	:	12,0 m/s
Einschaltwindgeschw.	:	2,5 m/s
Rotordurchmesser	:	70,0 m
Überstrichene Fläche	:	3.848 m²
Drehzahl	:	10-22 U/min
Generator	:	synchron, Ringgenerator
Getriebe	:	ohne
Gewicht		
Gondel	:	68,8 t
Rotor (incl. Nabe)	:	31,7 t
Turm (98m, Beton)	:	861 t
Turm (86m, Stahlrohr)	:	219 t

Aufbau

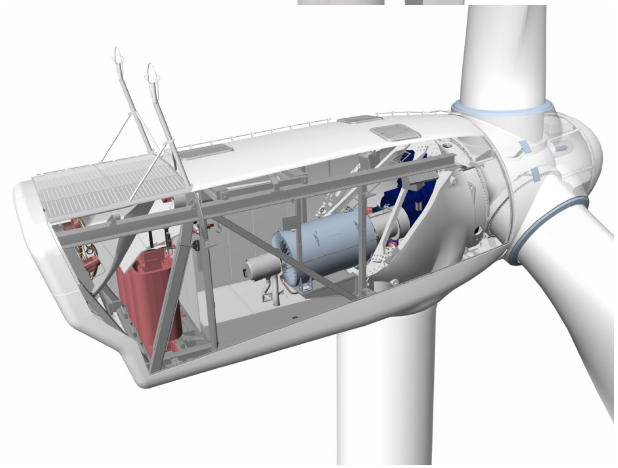
Triebstrang - Integration



Vestas V80 - aufgelöst



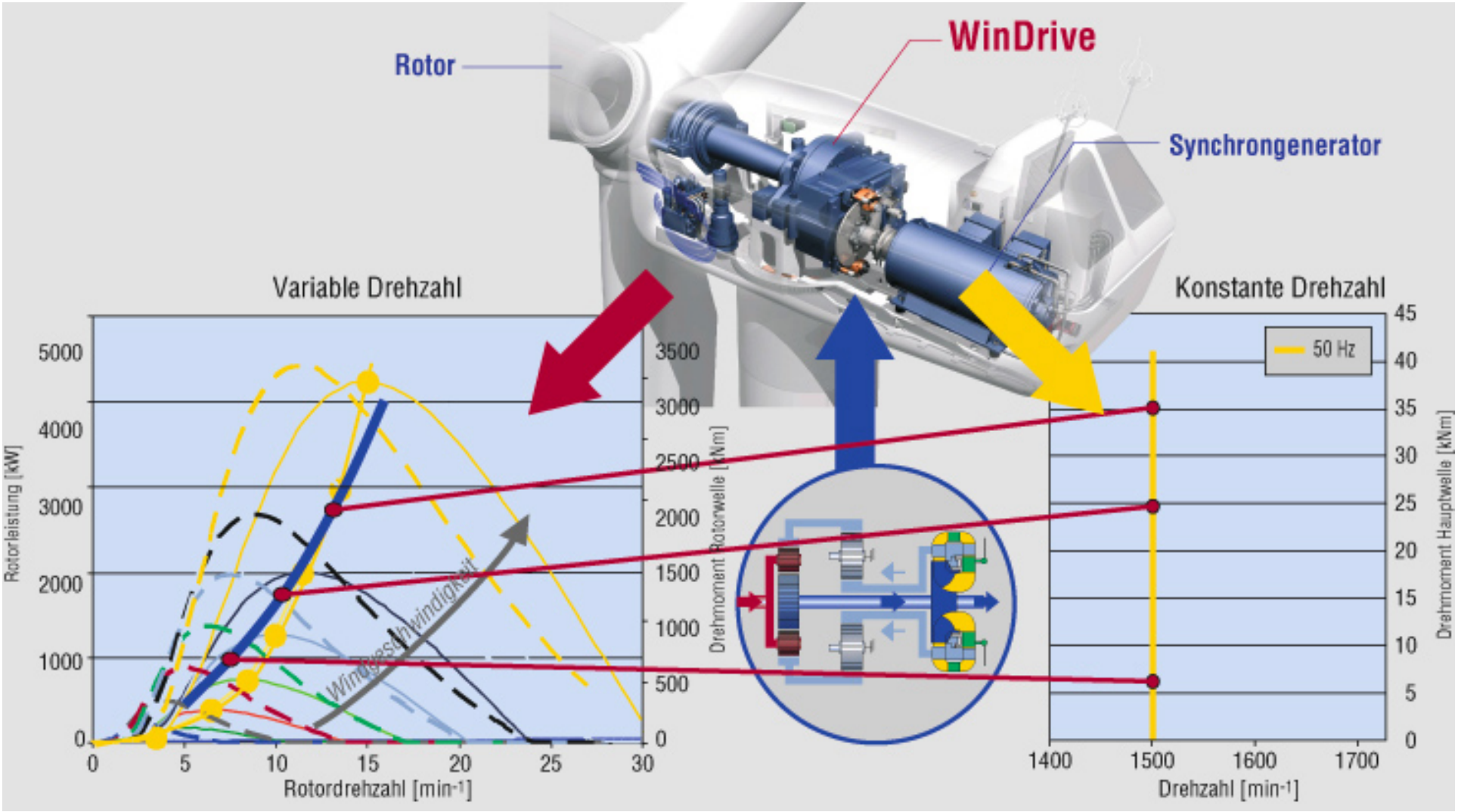
Nordex N54 - teilintegriert



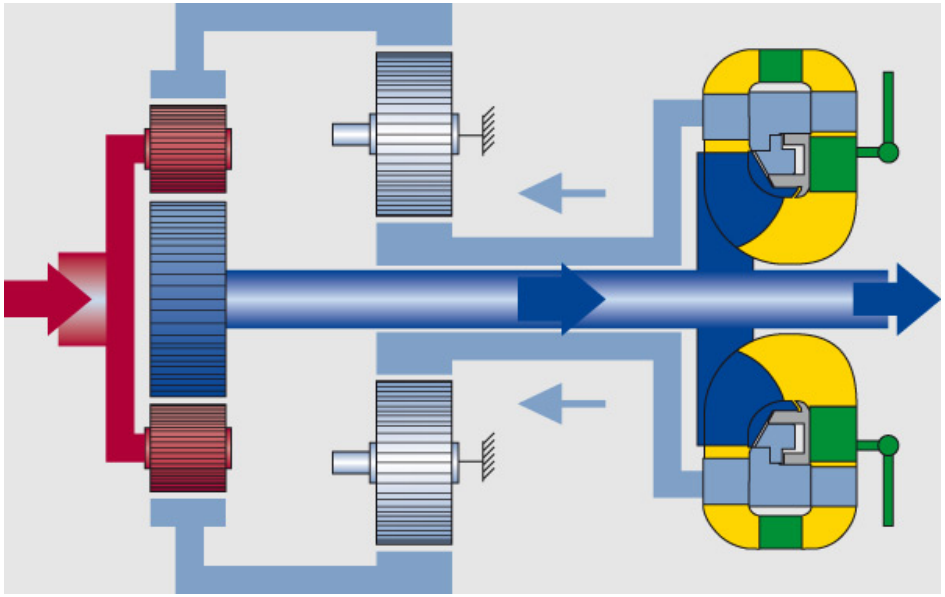
Vestas V90 - integriert

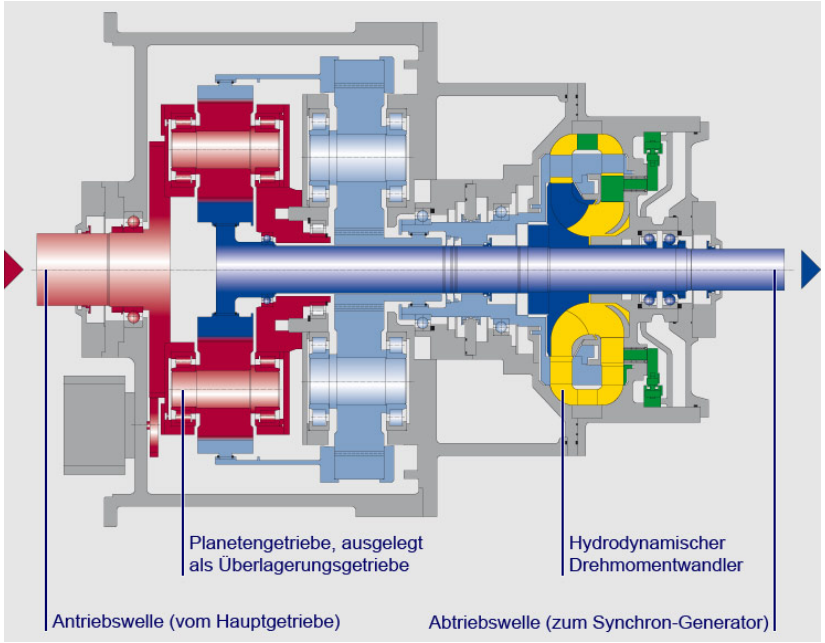
Aufbau

Voith - WinDrive

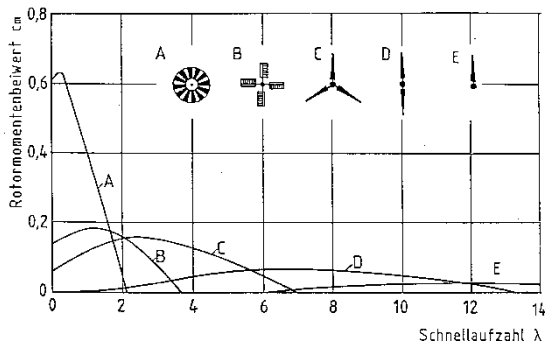


Aufbau
Voith – WinDrive - Drehmomentwandler

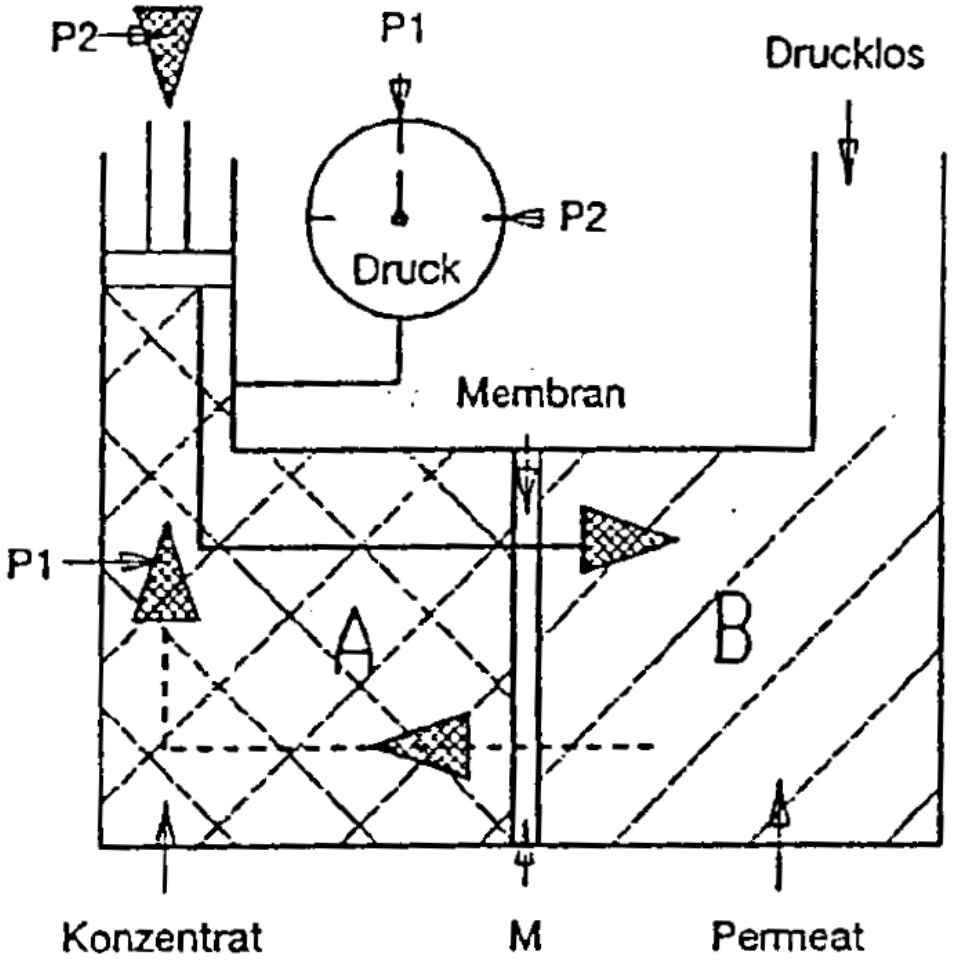




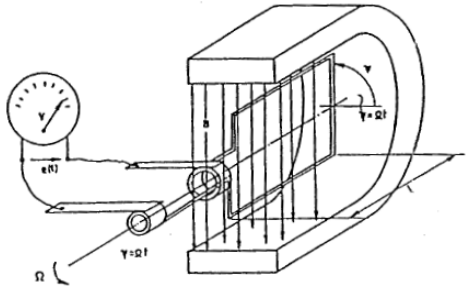
Anwendung
Pumpen

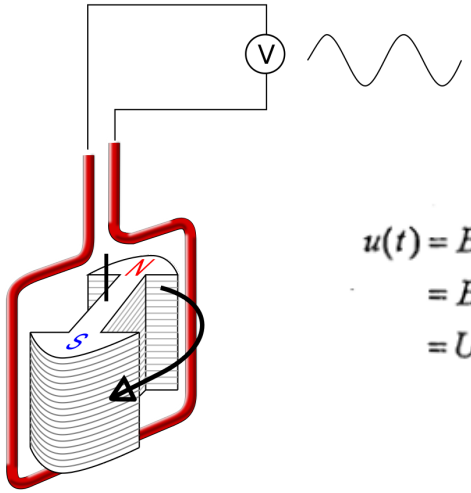


Anwendungen
Umkehrosmose

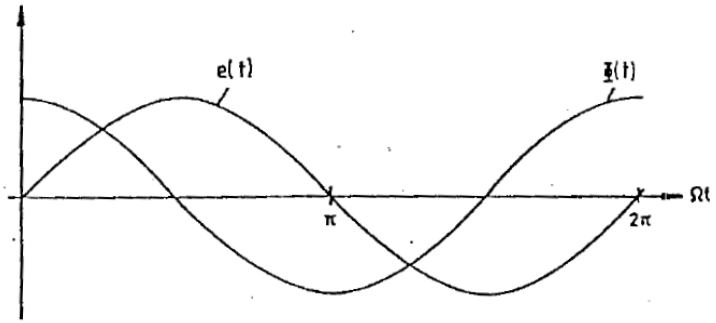


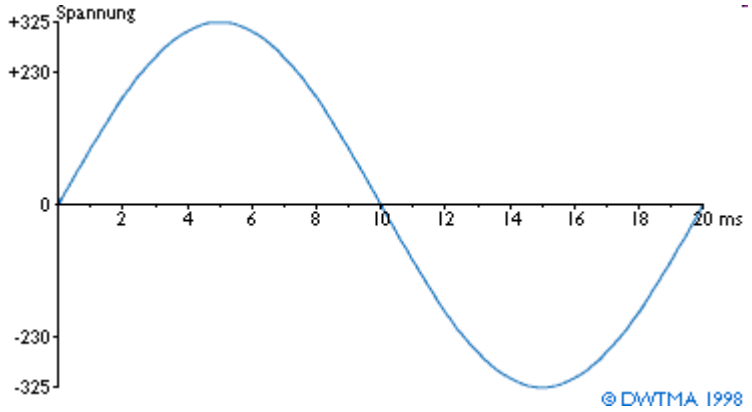
Elektrisches System
Dynamomaschine





$$u(t) = B \cdot \ell \cdot v(t)$$
$$= B \cdot 2\ell \cdot r\,\omega \cdot \sin \omega t$$
$$= U_s \cdot \sin \omega t$$

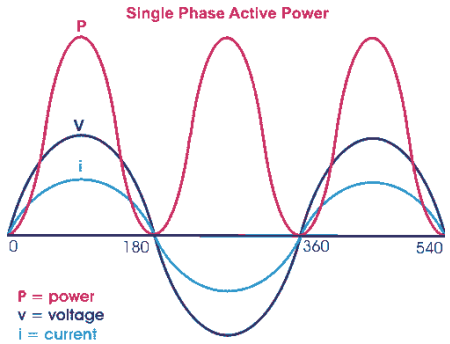


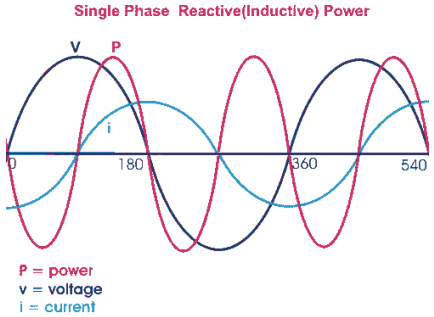


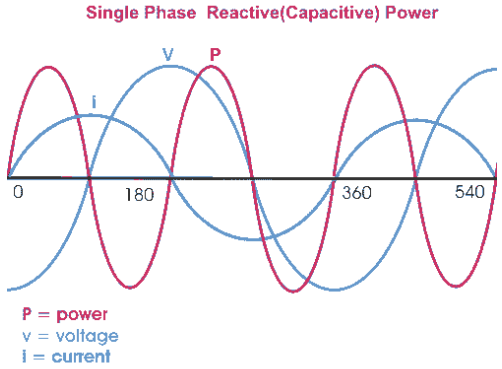
Elektrisches Systeme

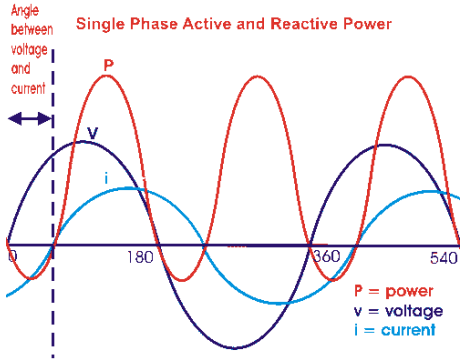
Quellspannung und magnetischer Fluss (Wirk- Blindleistung)

$$u(t) = U_S \cdot \sin \omega t$$
$$i(t) = I_W \cdot \sin \omega t + I_B \cdot \cos \omega t$$
$$P(t) = U_S \cdot I_W \cdot \sin^2 \omega t + U_S \cdot I_B \cdot \sin \omega t \cdot \cos \omega t$$



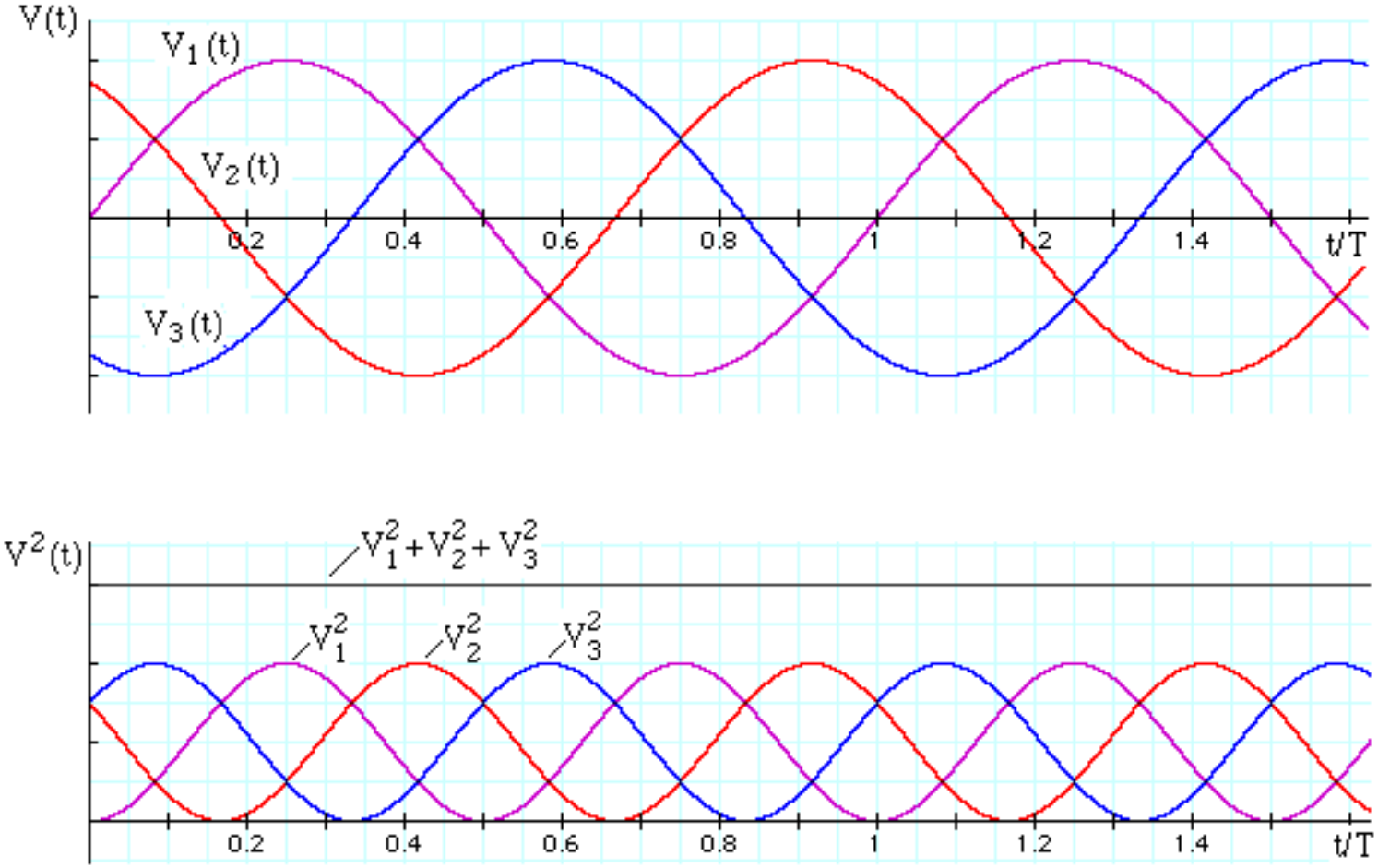






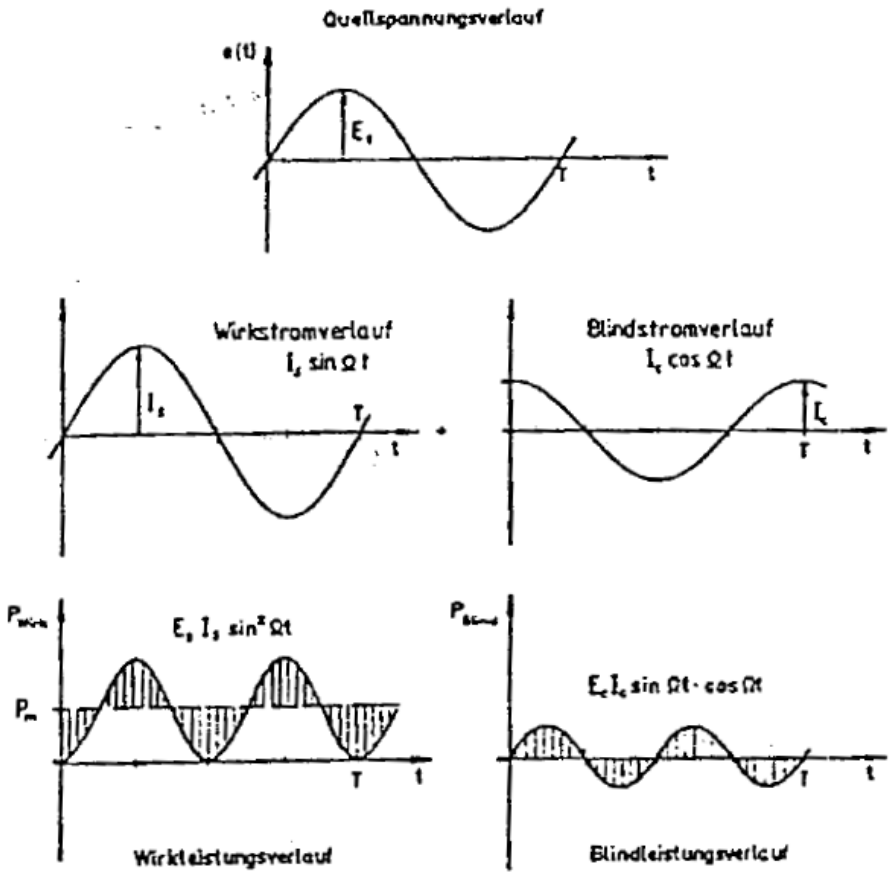
Elektrisches System

Drehstrom



Elektrisches System

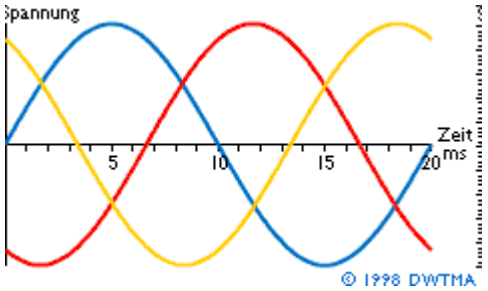
Wirk- und Blindleistung / Drehstrom



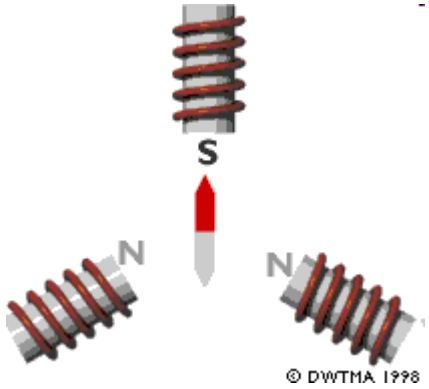
$$u(t) = U_S \cdot \sin \omega t$$

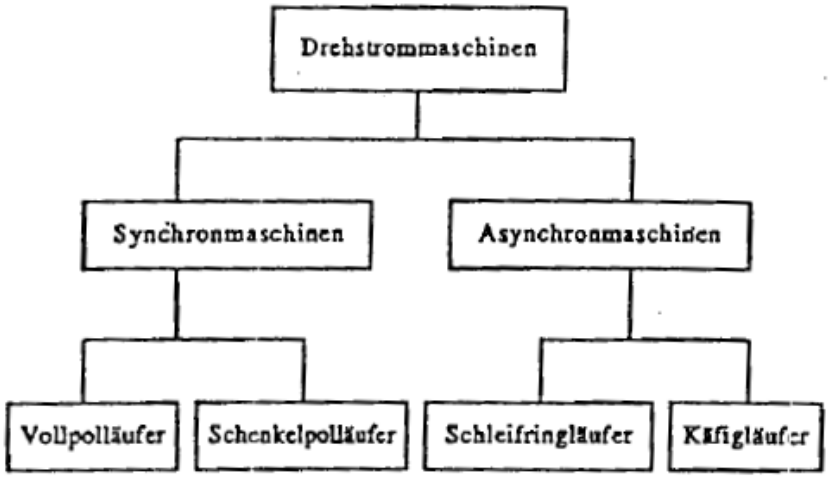
$$i(t) = I_W \cdot \sin \omega t + I_B \cdot \cos \omega t$$

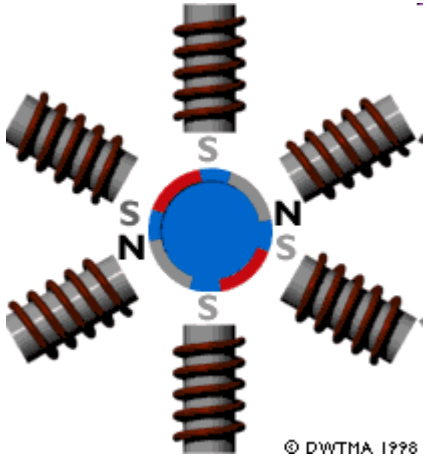
$$P(t) = U_S \cdot I_W \cdot \sin^2 \omega t + U_S \cdot I_B \cdot \sin \omega t \cdot \cos \omega t$$

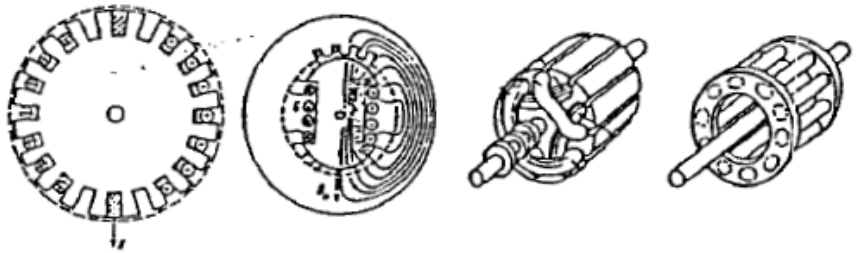


Elektrisches System
Generatortypen

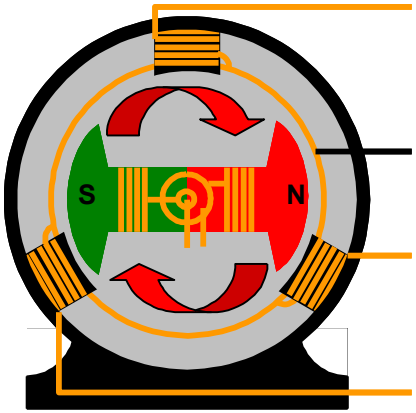




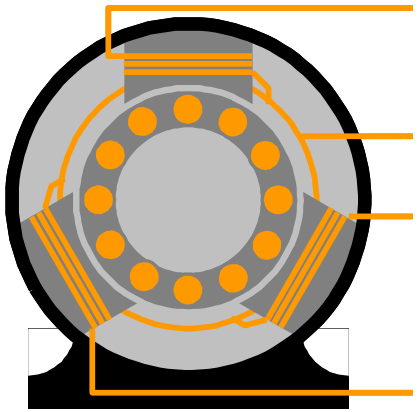




Elektrisches System
Generatoren

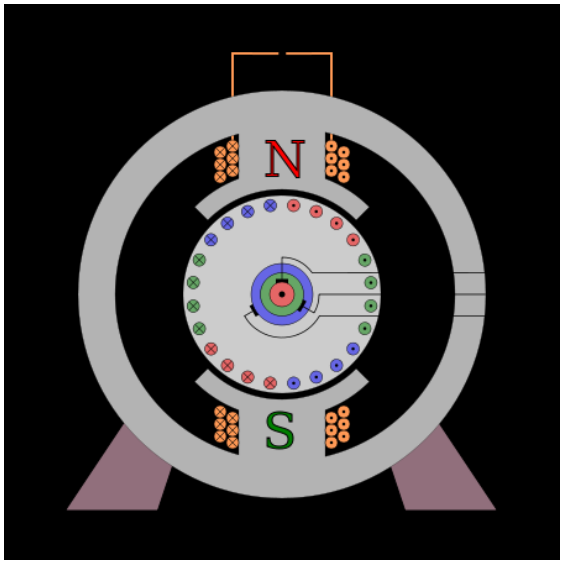


synchron

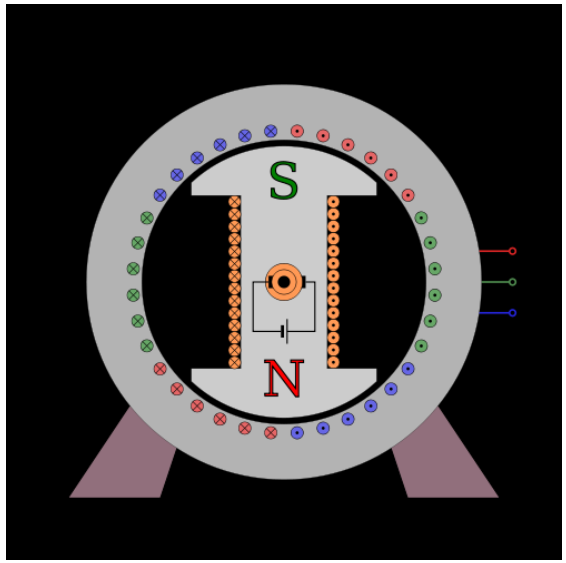


asynchron

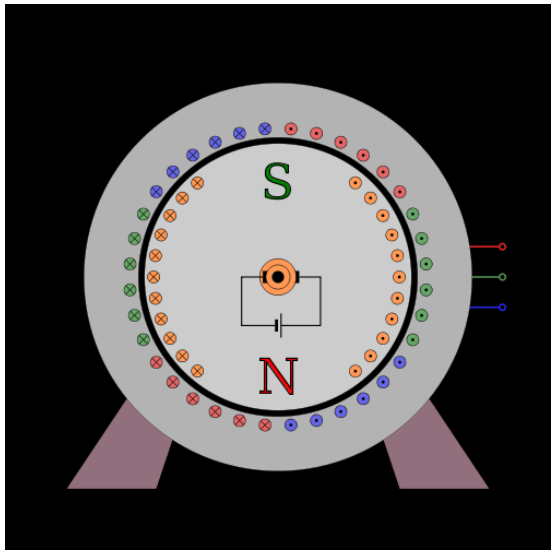
Elektrisches System
Synchrongeneratoren



Außenpolmaschine
Schenkelpol

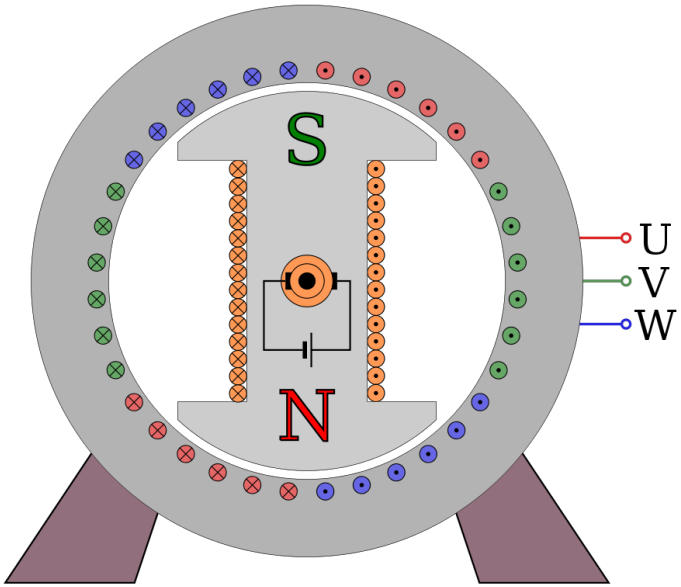


Innenpolmaschine
Schenkelpol

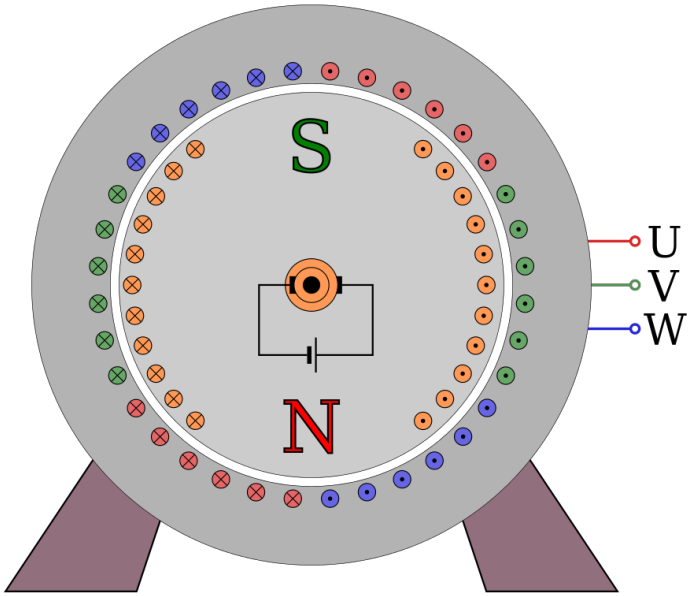


Innenpolmaschine
Vollpol

Elektrisches System
Synchrongeneratoren



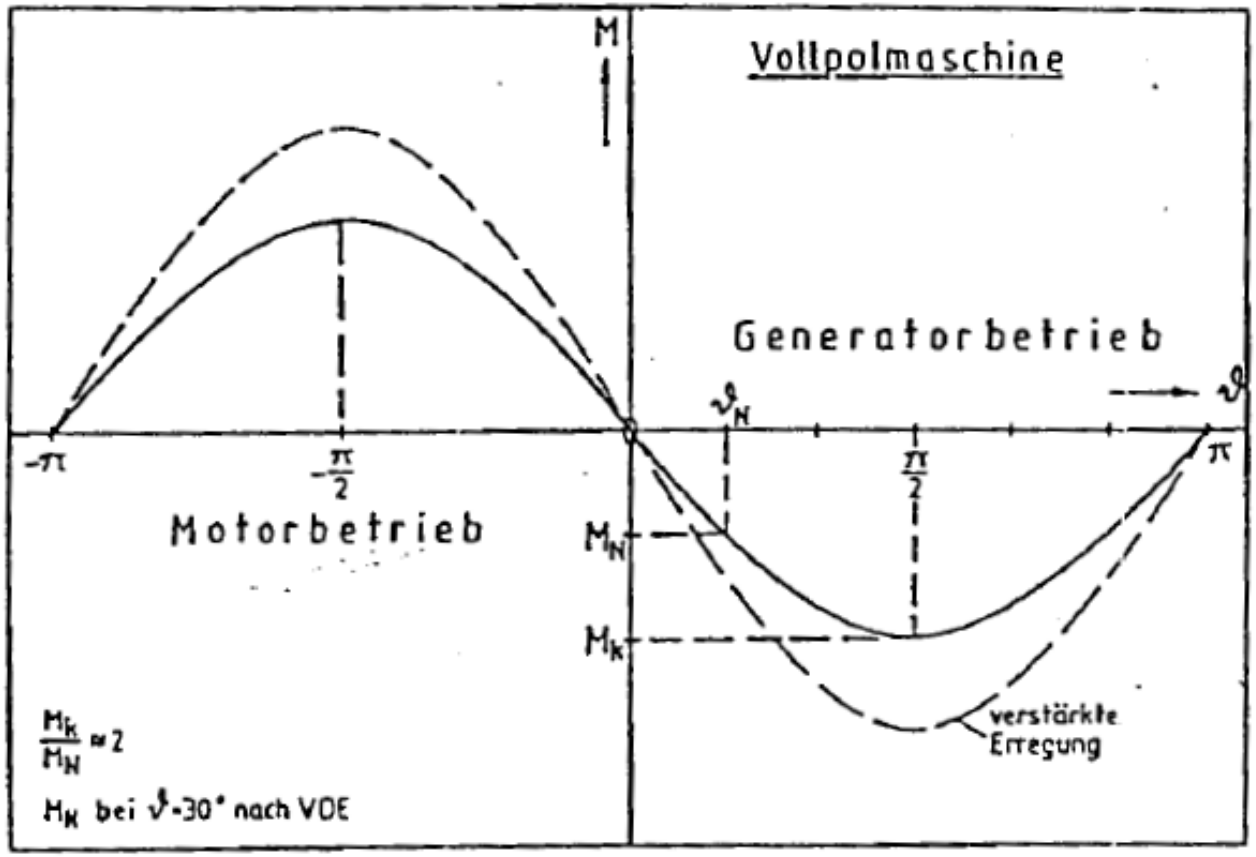
Innenpolmaschine
Schenkelpol



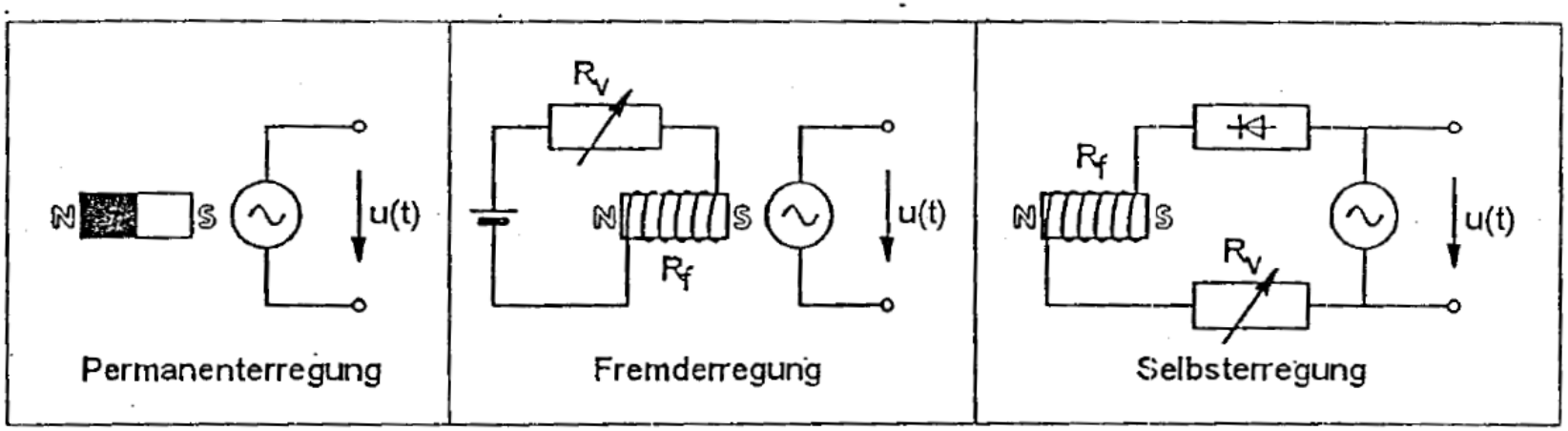
Innenpolmaschine
Vollpol

Elektrisches System

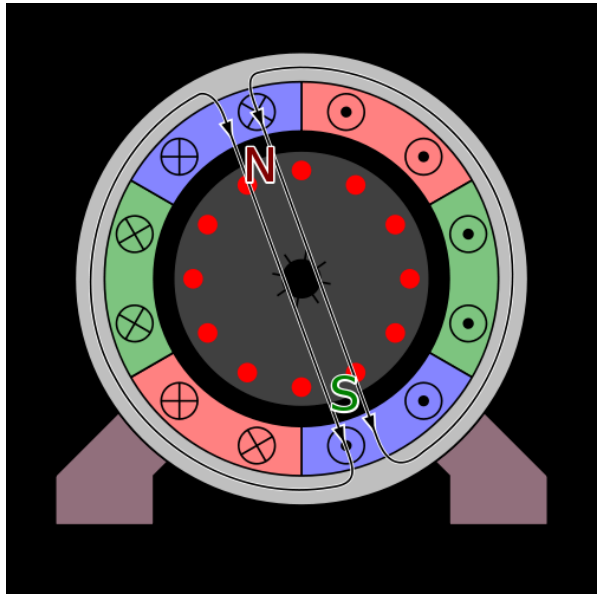
Synchronmaschine - Momentenkurve

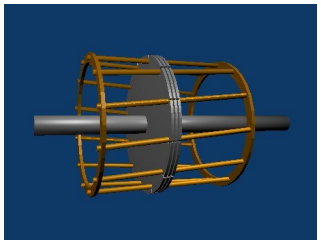


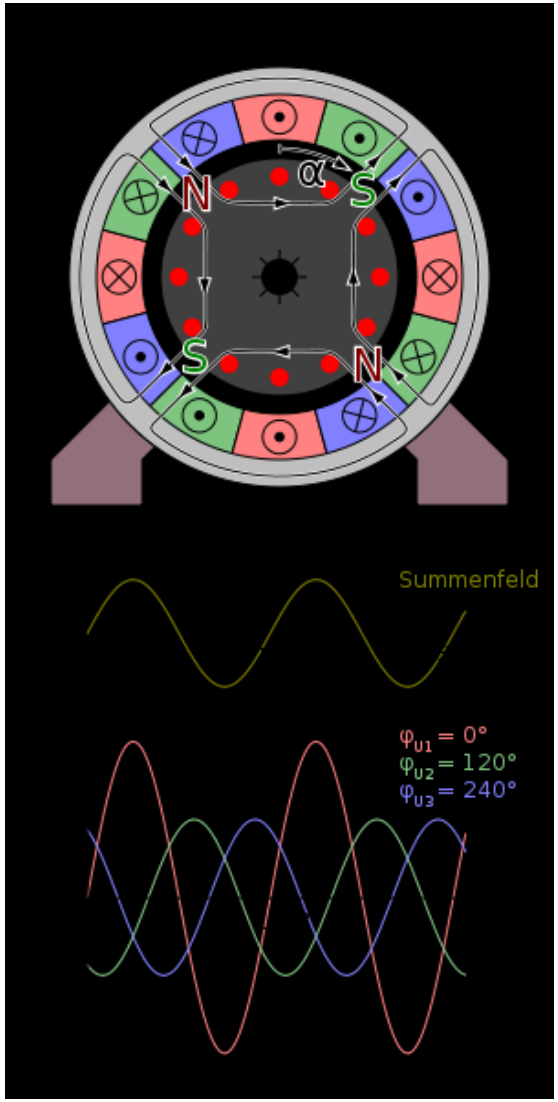
Elektrisches System
Magnetfeld



Elektrisches System
Asynchrongeneratoren

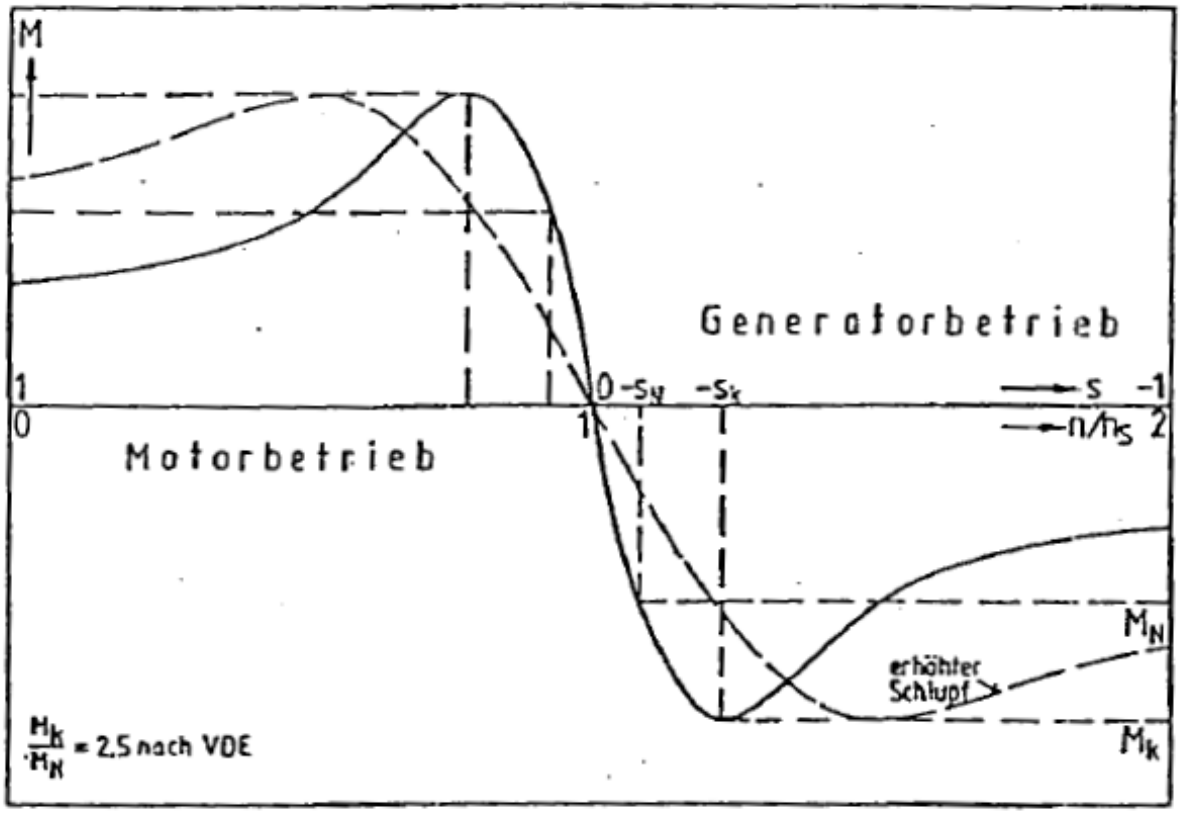






Elektrisches System

Asynchronmaschine - Momentenkurve



$$Schlupf\ s = \frac{n_s}{n_f} = \frac{n_f - n}{n_f}\ [100\%]$$

$$n_{sym} = \frac{f_{Netz}}{p} = \frac{50\,\mathrm{Hz}}{2} = 25\frac{1}{\mathrm{s}} = 1500\frac{\mathrm{U}}{\mathrm{min}}$$

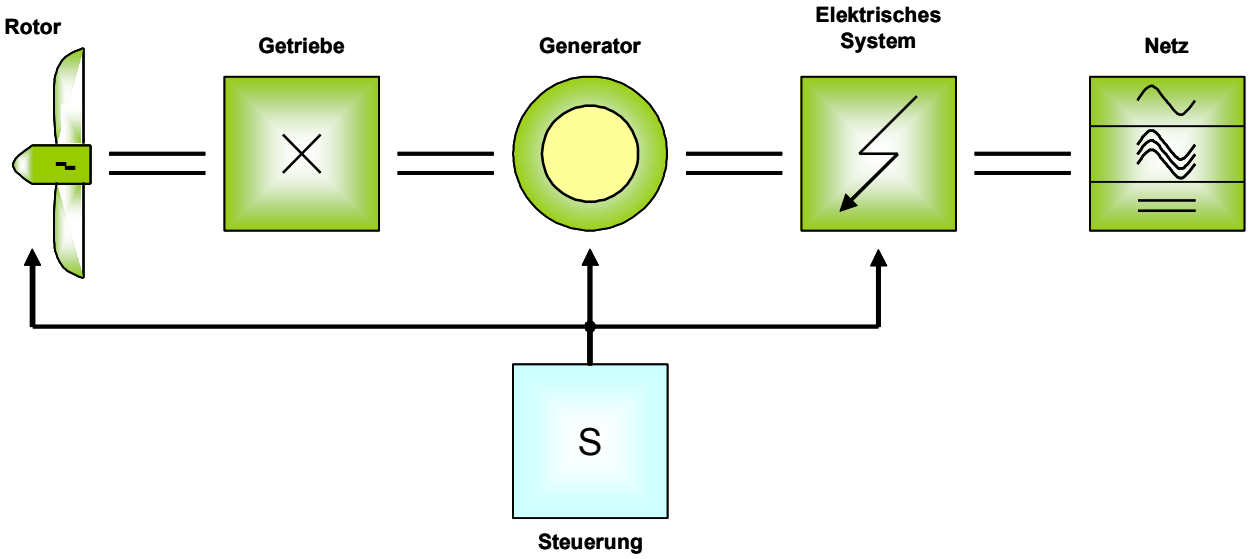
Elektrisches System
Synchron – Asynchron / Vor- Nachteile

	synchronous	*asynchronous*	*remark*
Effizienz	**++**	**+**	*ASG Schlupf*
Kosten	**+**	**++**	*ASG Massenprodukt*
Wartung	**o**	**++**	*ASG Käfigläufer*
Blindleistung	**++**	**-**	*ASG benötigt Blindleistung*
Netz Kopplung	**o**	**+**	*SG Synchronisiereinrichtung*
Netzaufbau	**++**	**-**	*SG Bereitsstellung von Blindleistung*
Leistungselektronik	**++**	**o**	*SG einfachere Leistungselektronik*

- Der Einsatz von Leistungselektronik kann die Vor- und Nachteile der einzelnen Generatortypen relativieren, wenn nicht gar aufheben.

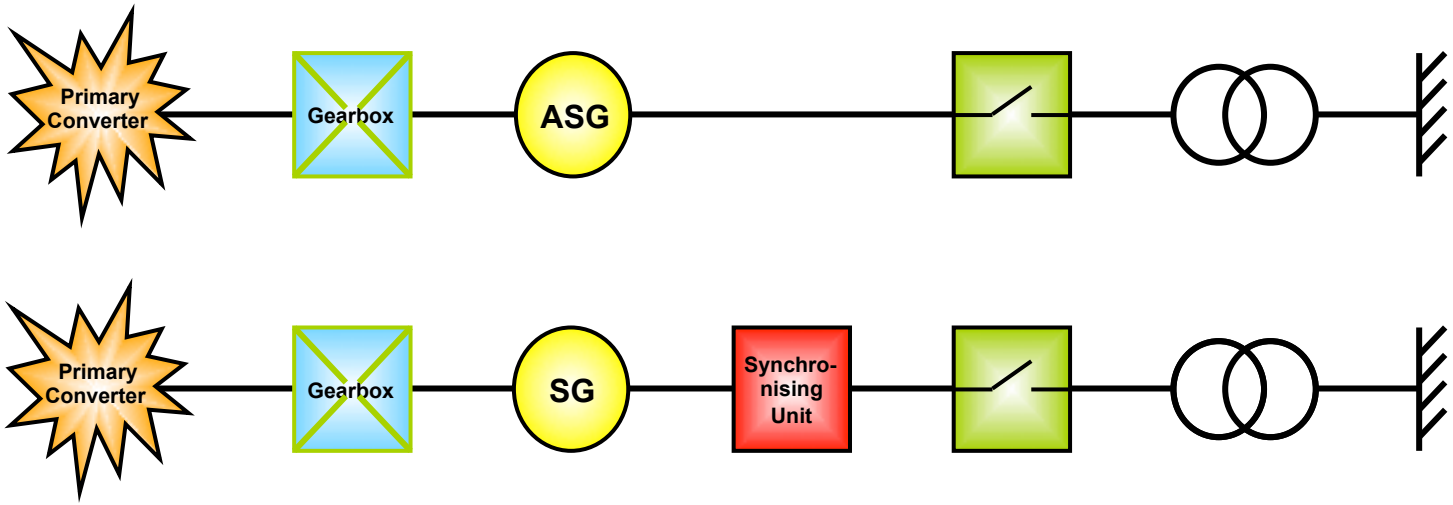
Elektrisches System
Allgemeiner Aufbau

v >= 5 m/s	*min*	*max*
Spezifische Investitionskosten	**800 €/kW**	**1300 €/kW**
Spezifische Investitionskosten (Kleinanlage)	**1100 €/kW**	**2500 €/kW**
Volllaststunden (Küste, Bergkuppe)	**2000 h**	**2500 h**
Volllaststunden (Binnenland)	**1000 h**	**1500 h**
Spezifische Energiekosten (Küste)	**0.04 €/kWh**	**0.08 €/kWh**
Spezifische Energiekosten (Binnenland)	**0.11 €/kWh**	**0.13 €/kWh**
Spezifische Energiekosten (Kleinanlage)	**0.12 €/kWh**	**0.20 €/kWh**



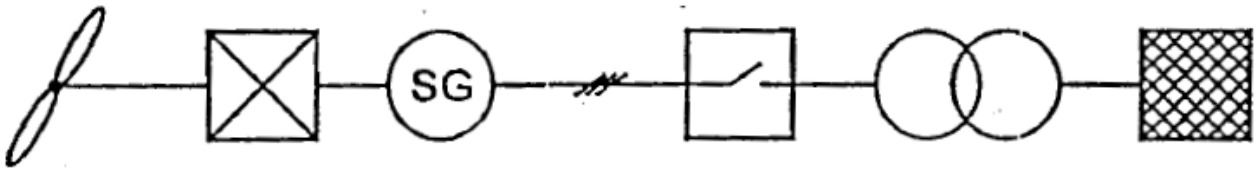
Elektrisches System

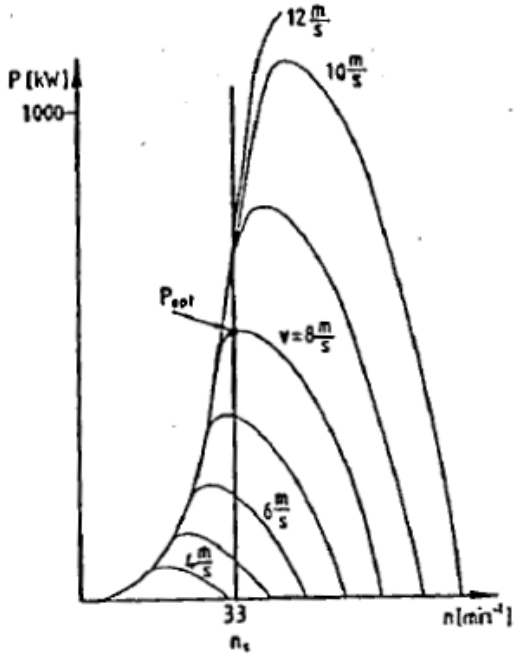
Netzanbindung



Elektrisches System

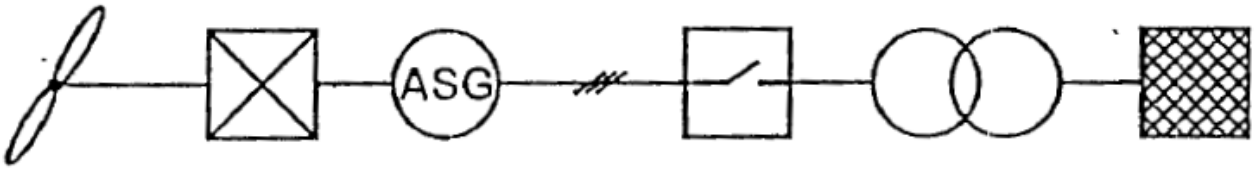
Drehzahlfeste Kopplung - Synchronmaschine

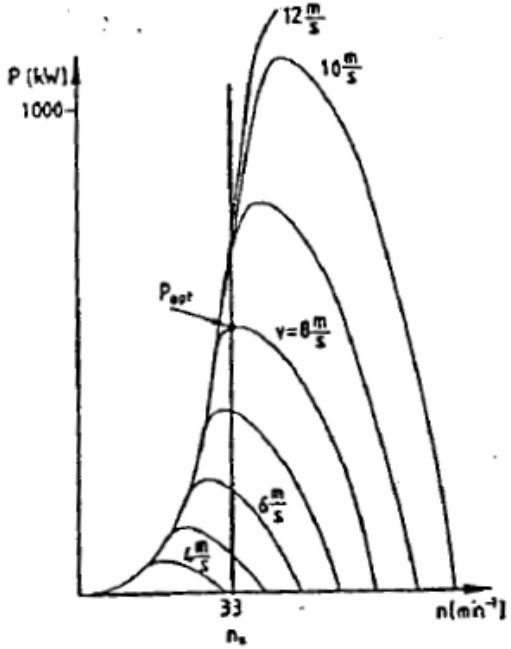




Elektrisches System

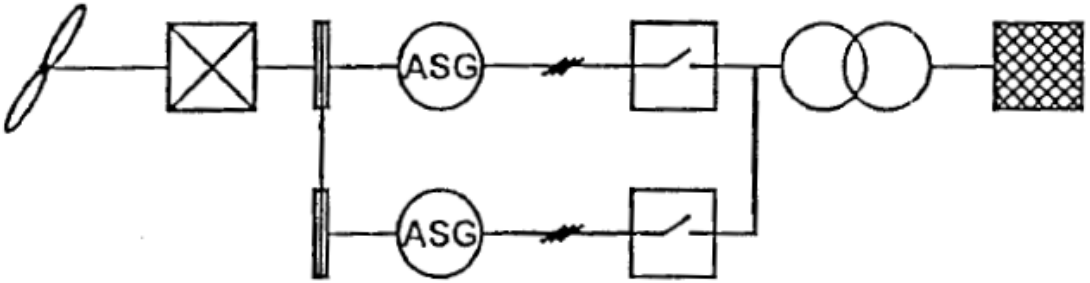
Drehzahlfeste Kopplung - Asynchronmaschine

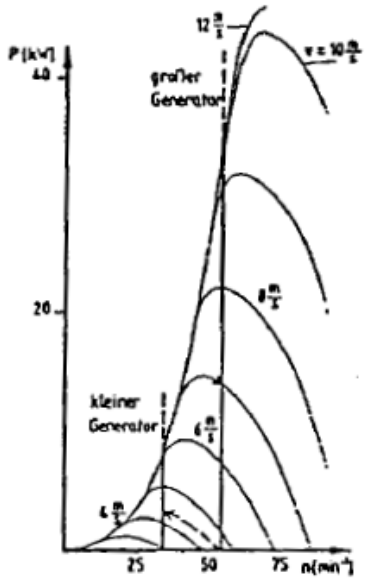




Elektrisches System

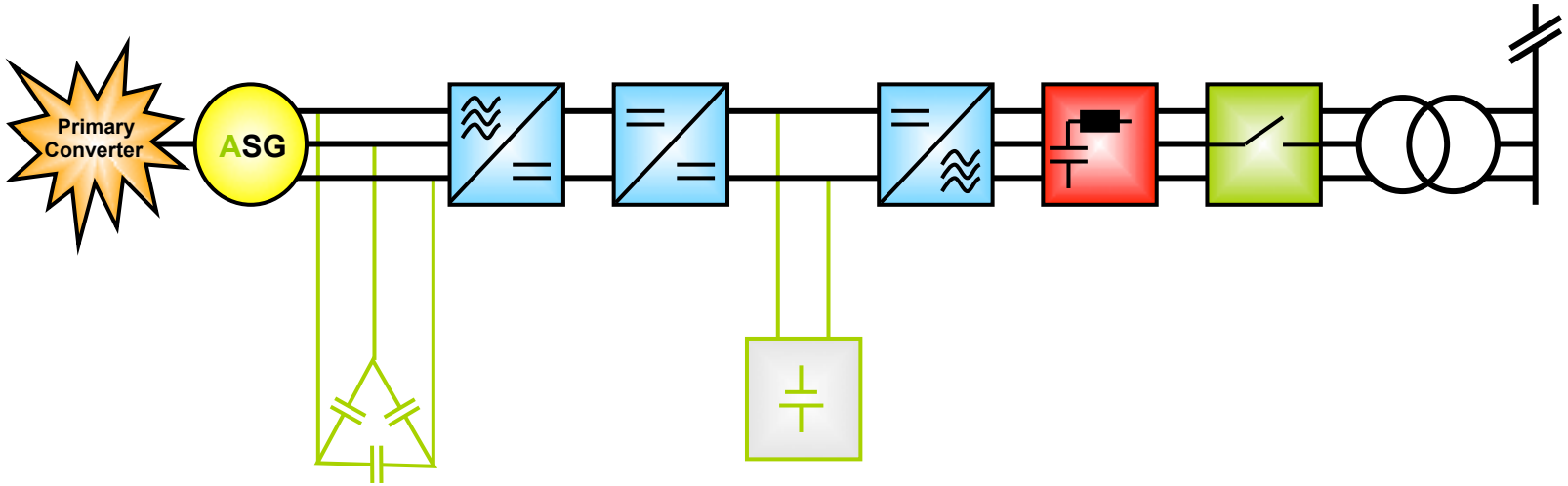
Drehzahlgestufte Kopplung – Dänisches Modell





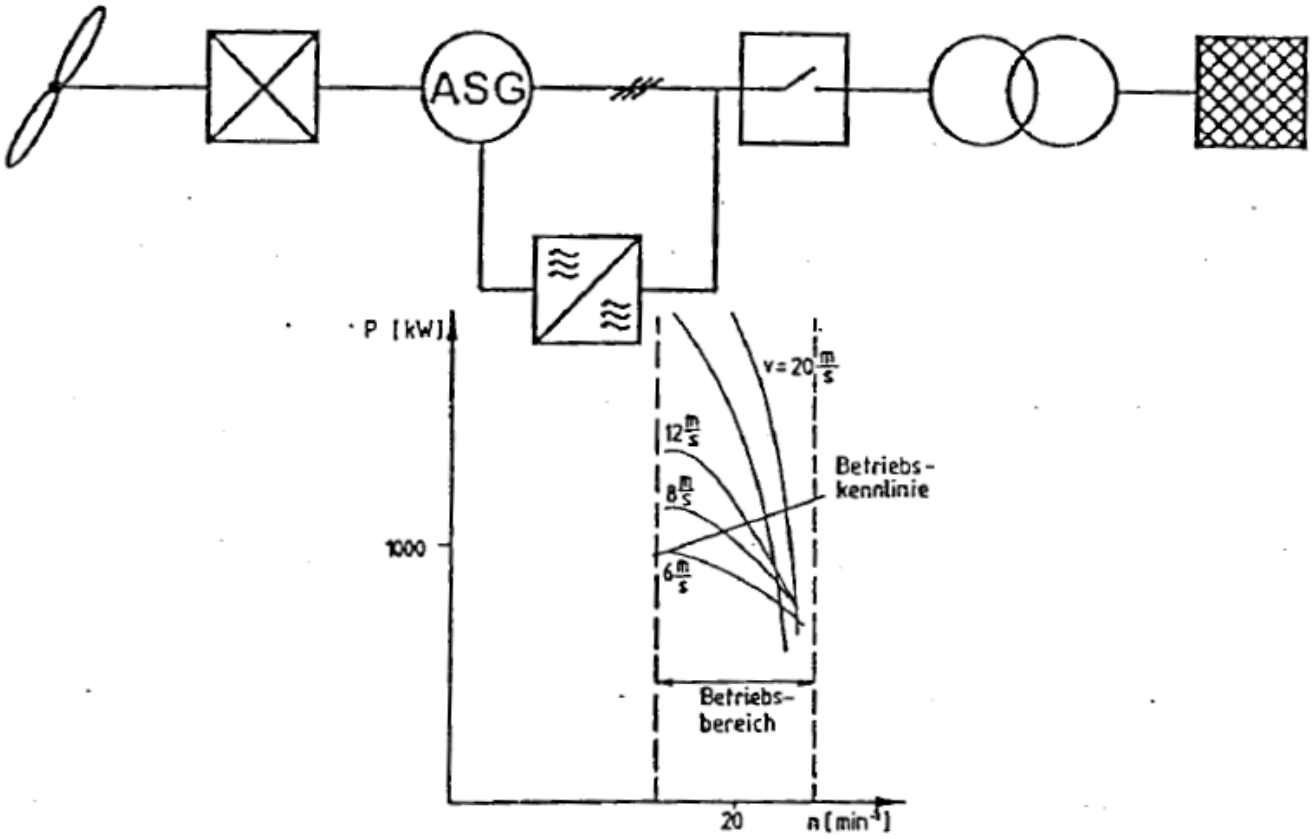
Elektrisches System

Komplexe Kopplung



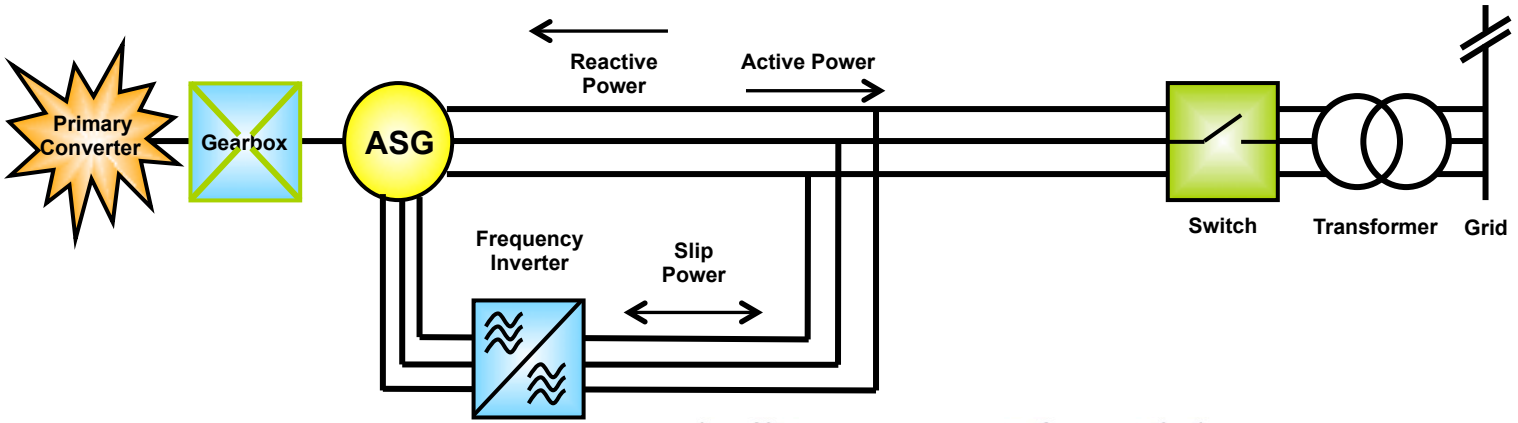
Elektrisches System

Drehzahlvariabel – Doppelt gespeister Asynchrongenerator

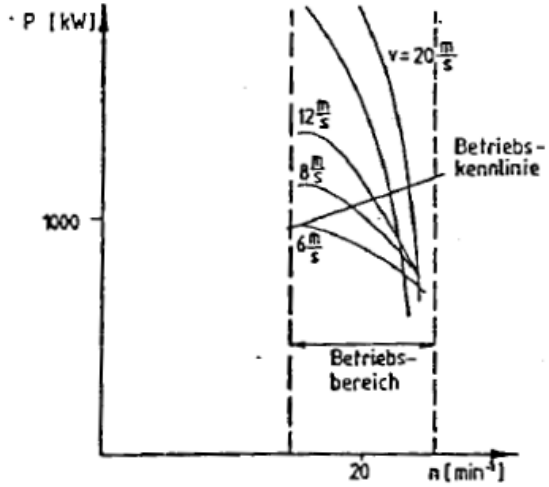


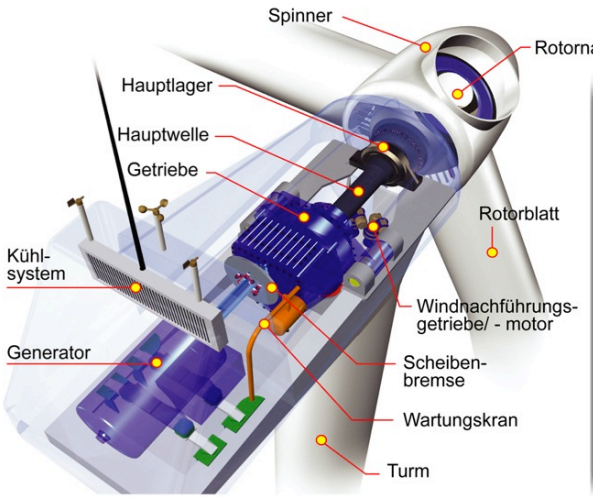
Elektrisches System

Drehzahlvariabel – Doppelt gespeister Asynchrongenerator



Aufbau einer Gondel - mit Getriebe



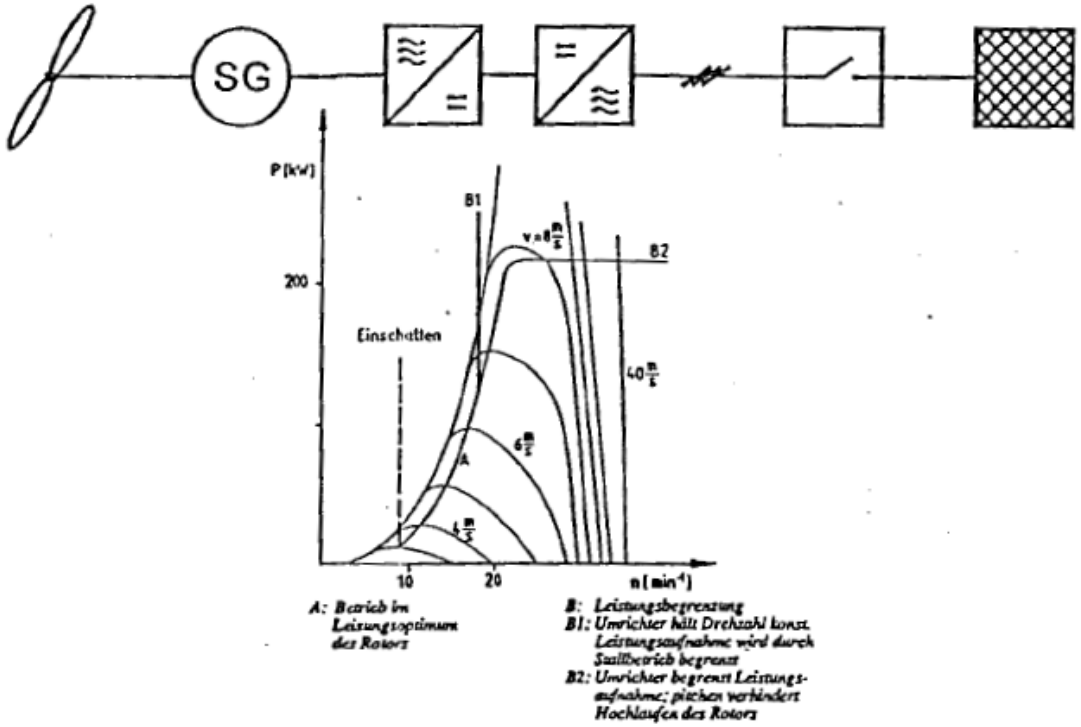


Modell NEG Micon 52/900
- technische Daten -

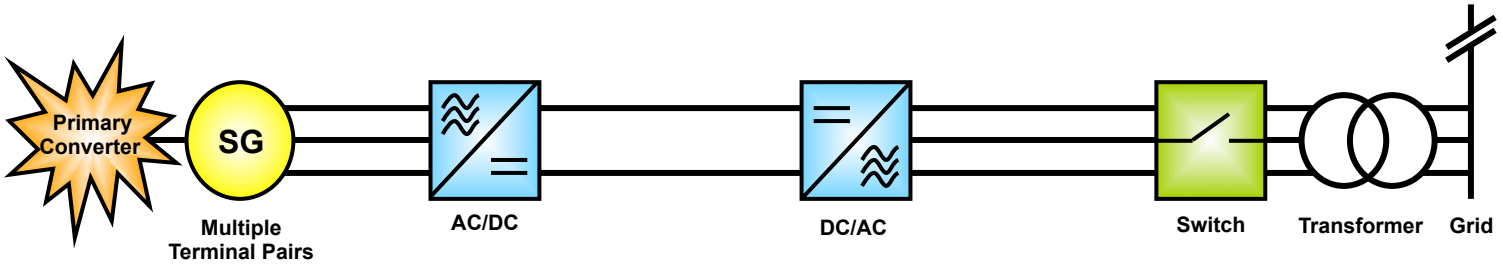
Technik		
Leistung	:	900 kw
Nennwindgeschwindigkeit	:	16,0 m/s
Einschaltwindgeschw.	:	3,5 m/s
Rotordurchmesser	:	52,0 m
Überstrichene Fläche	:	2.140 m²
Drehzahl	:	15-22 U/min
Generator	:	asynchron
Gewicht		
Gondel	:	26,5 t
Rotor (incl. Nabe)	:	16,5 t
Turm (74m, Stahlrohr)	:	97,0 t

Elektrisches System

Drehzahlvariabel - Enercon



Elektrisches System
Drehzahlvariabel - Enercon



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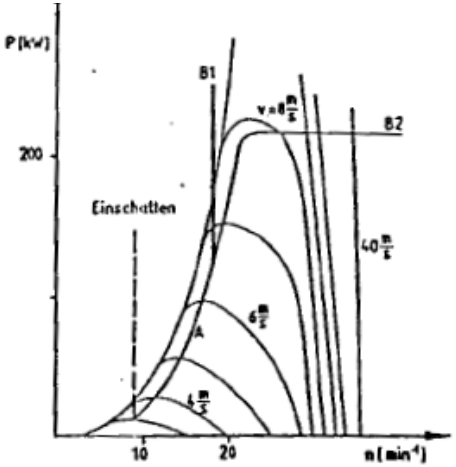
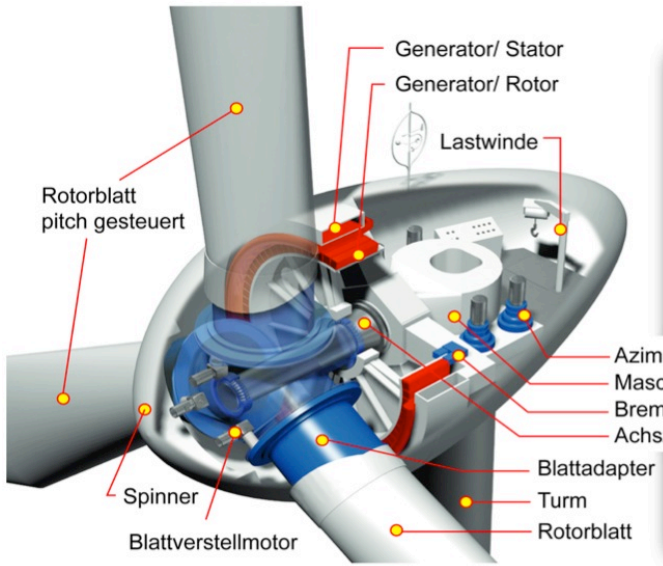
Bundesverband WindEnergie e.V.

Aufbau einer Gondel - getriebelos

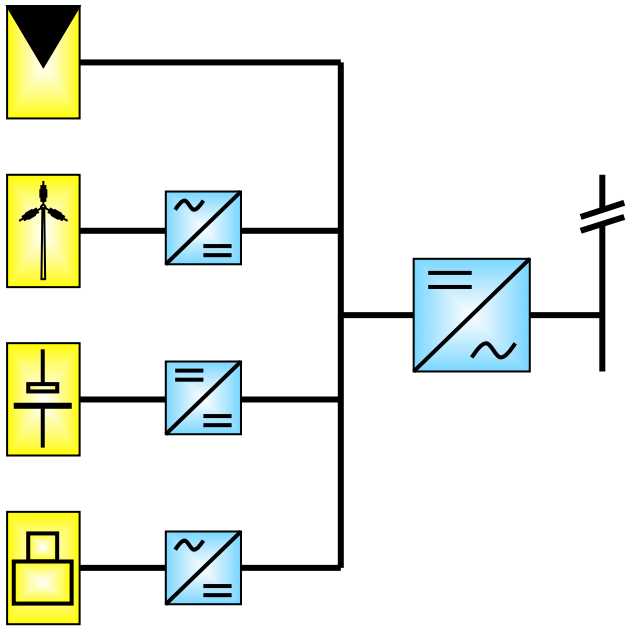


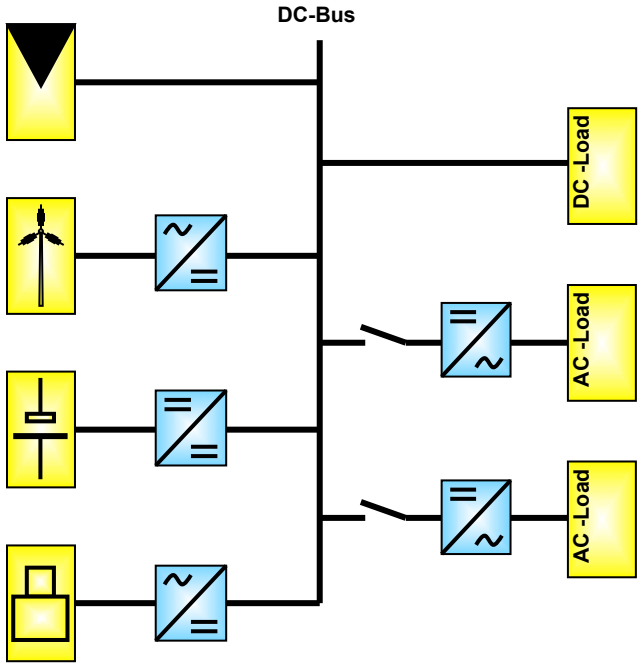


Modell Enercon E-66
- technische Daten -

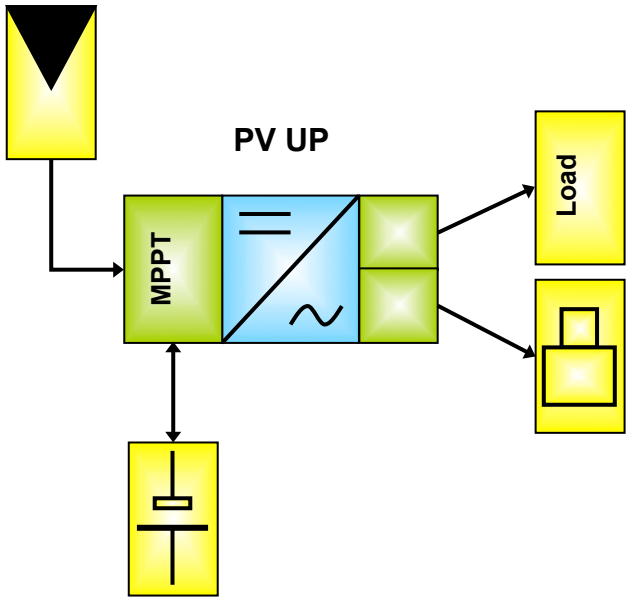
Technik		
Leistung	:	1,8 MW
Nennwindgeschwindigkeit	:	12,0 m/s
Einschaltwindgeschw.	:	2,5 m/s
Rotordurchmesser	:	70,0 m
Überstrichene Fläche	:	3.848 m²
Drehzahl	:	10-22 U/min
Generator	:	synchron, Ringgenerator
Getriebe	:	ohne
Gewicht		
Gondel	:	68,8 t
Rotor (incl. Nabe)	:	31,7 t
Turm (98m, Beton)	:	861 t
Turm (86m, Stahlrohr)	:	219 t

Inselsysteme
DC Kopplung

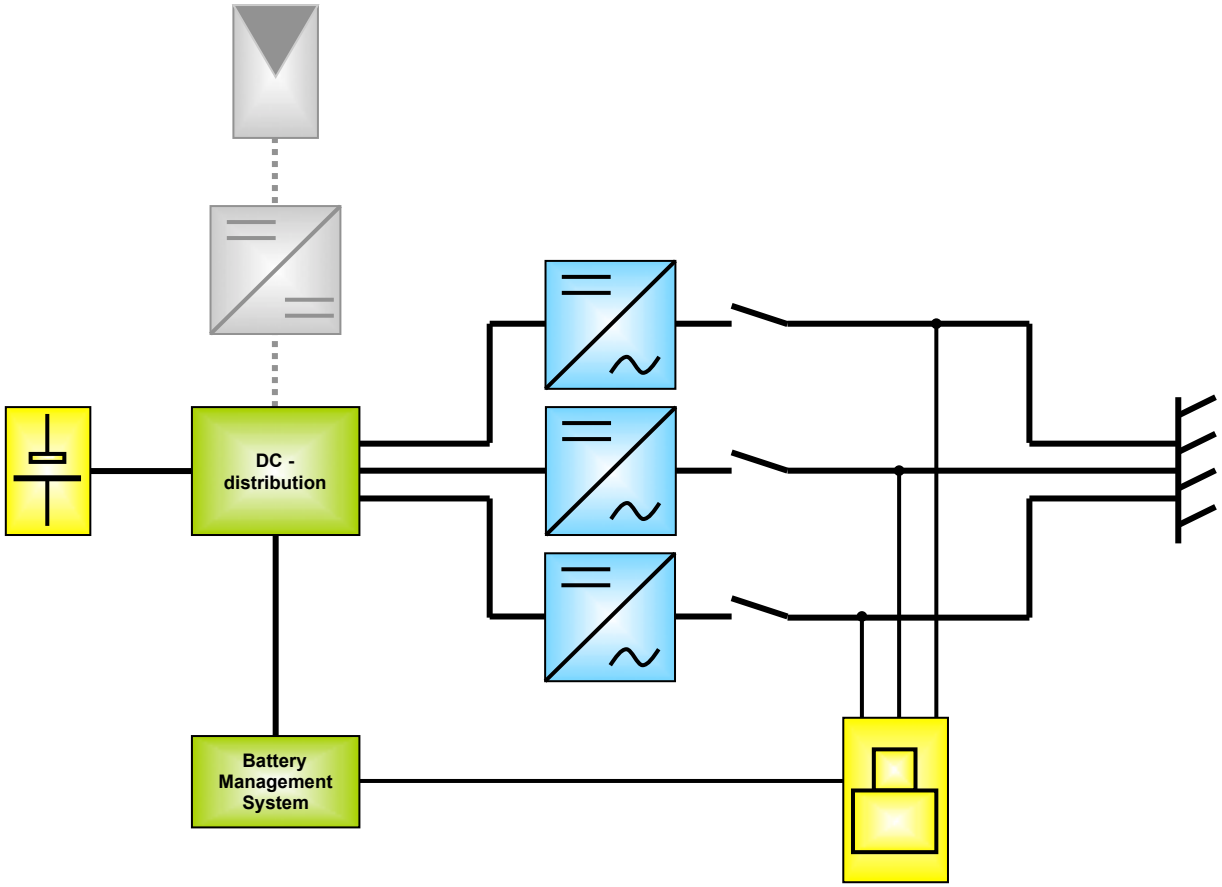




Inselsysteme
Integrierte Kopplung



Inselsysteme
Gemischte Kopplung



Inselsysteme
Wechselstromkopplung