EIFER

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

Elektrisches System

KIT

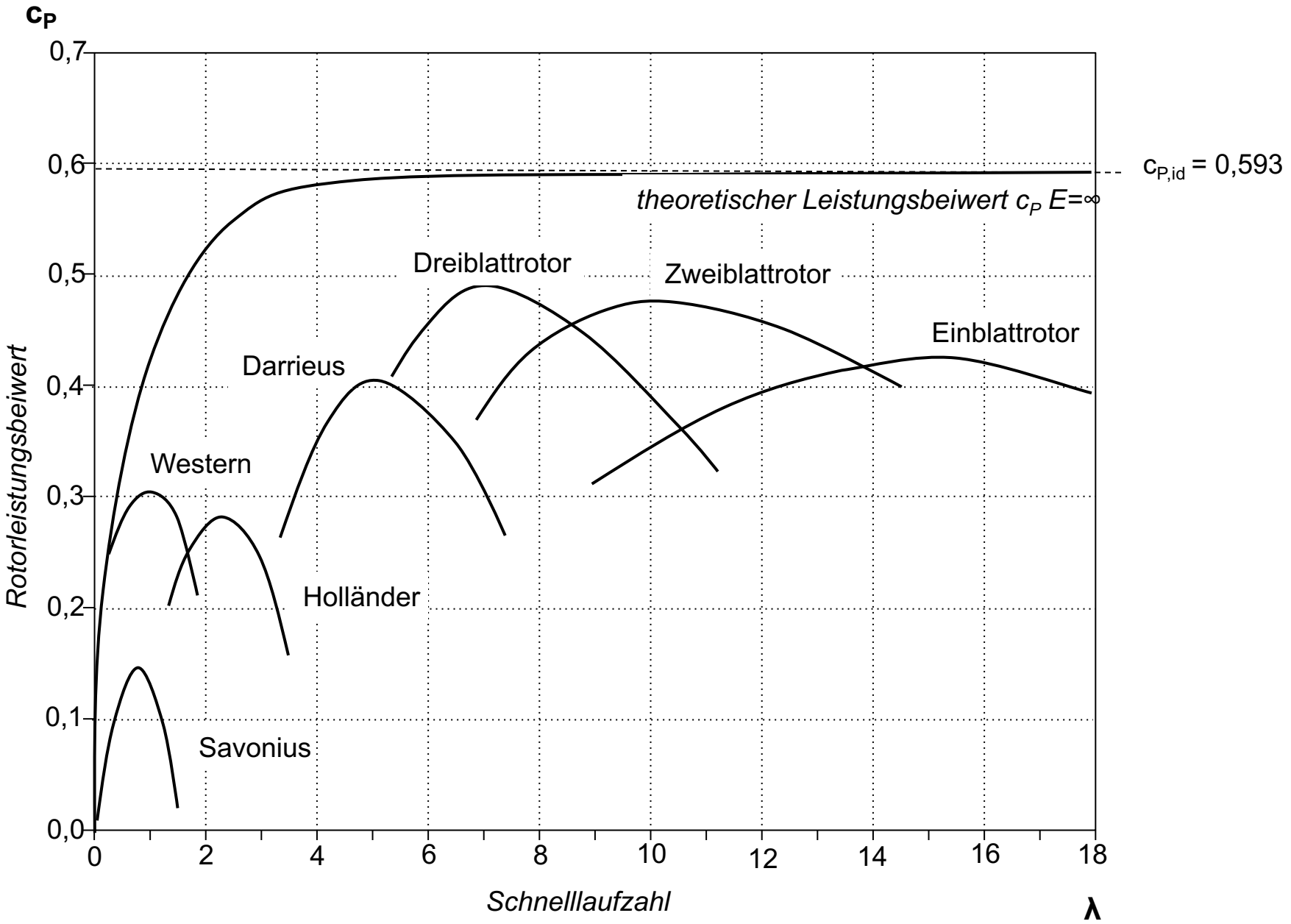
EDF

KIT

European Institute
for Energy Research
by EDF and KIT

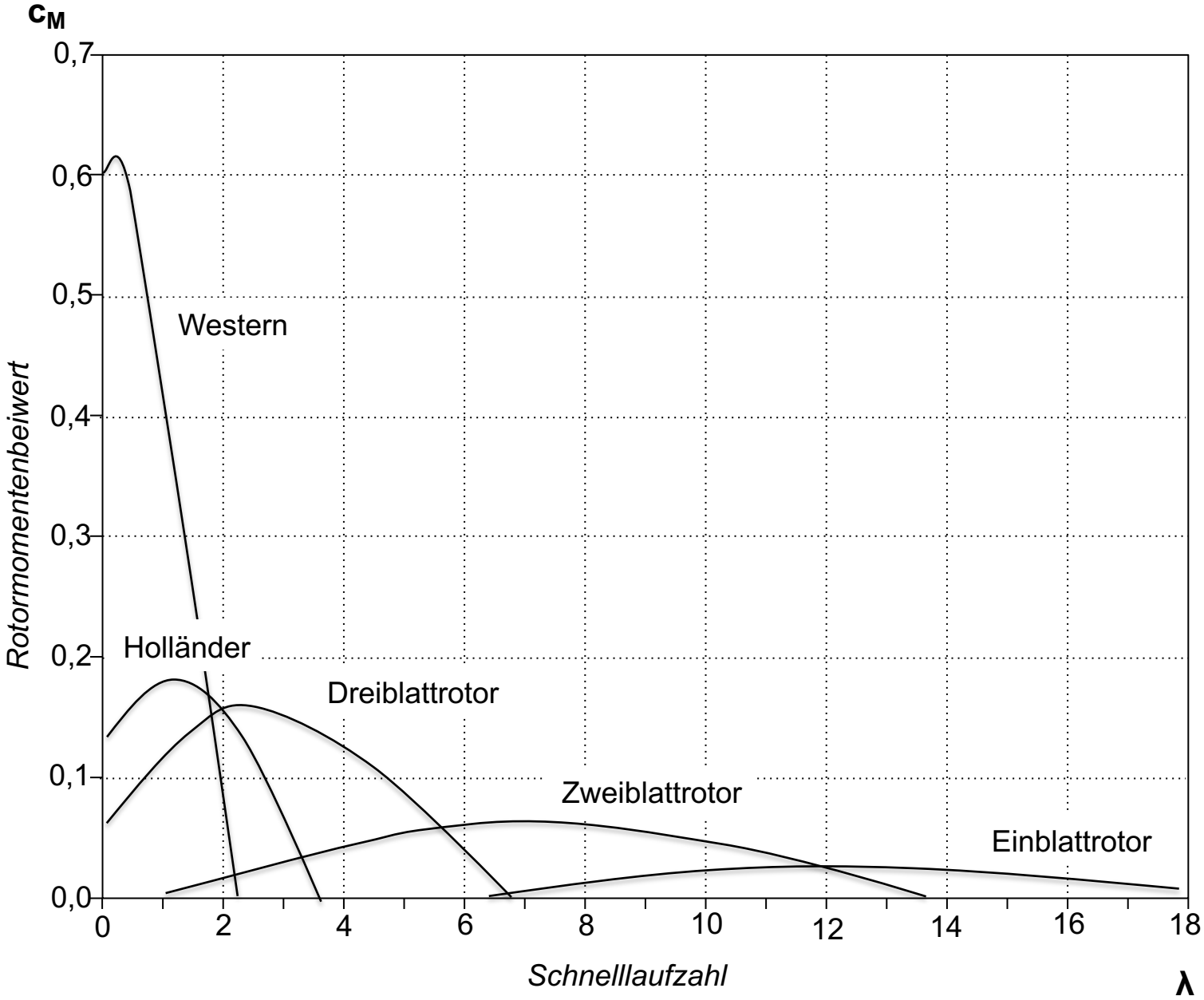
Betz

Leistungsbeiwerte / Lamda



Betz

Momentenbeiwerte



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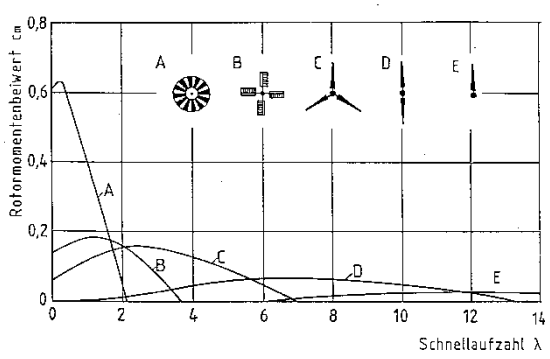
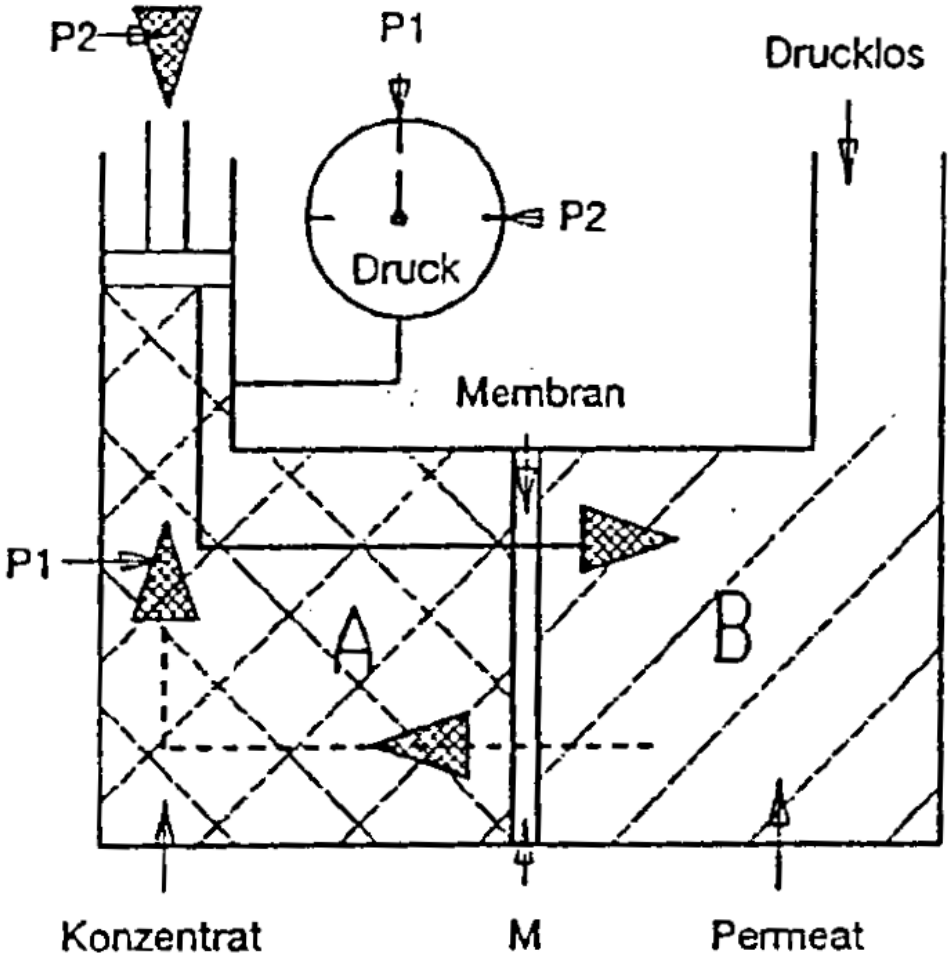
Anwendung
Pumpen



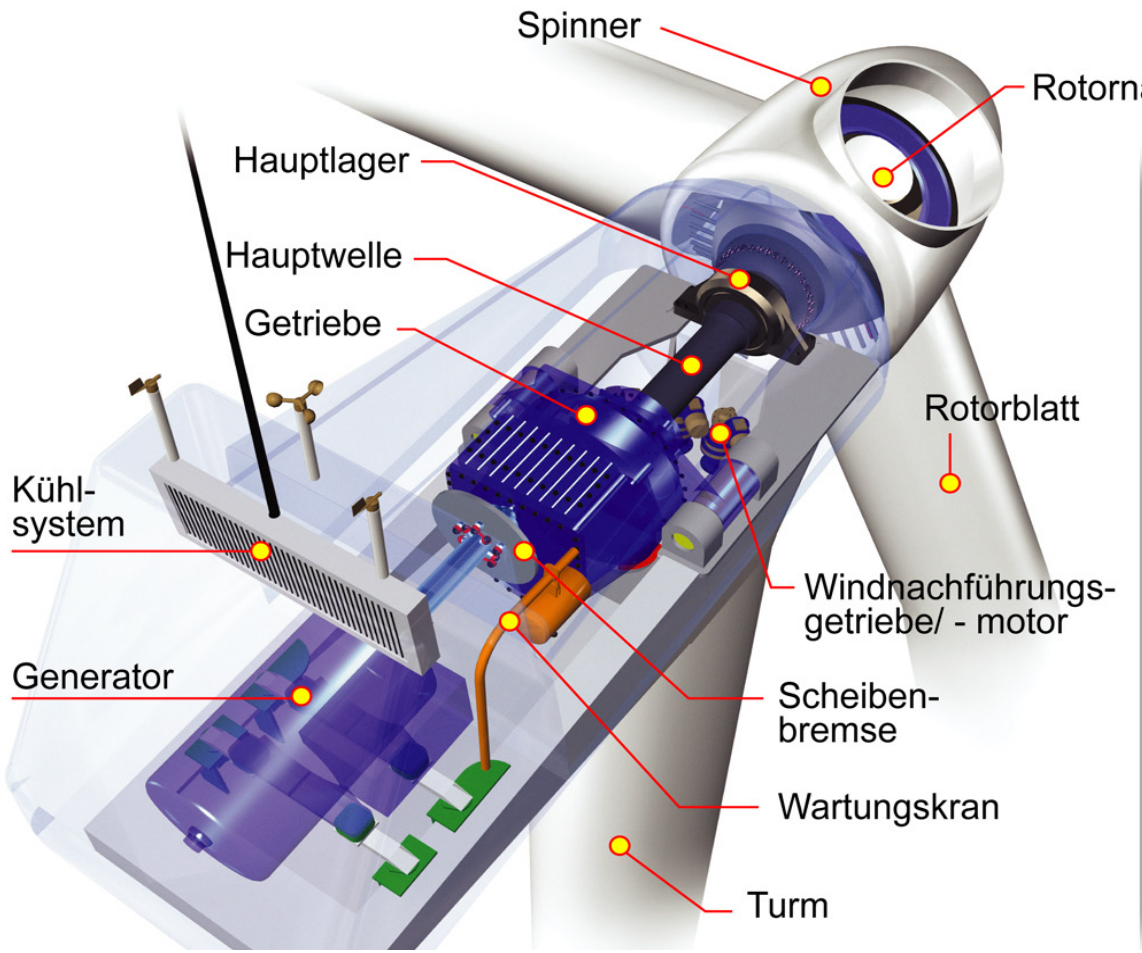
Anwendungen

Umkehrosmose



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

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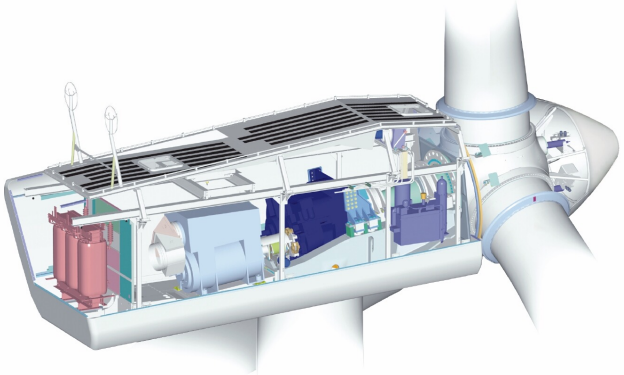
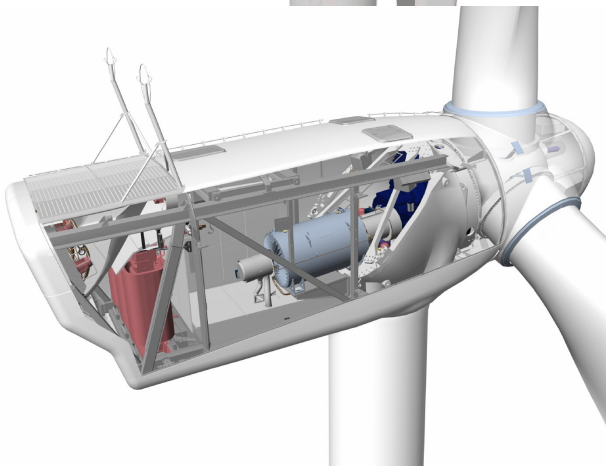
Aufbau

Triebstrang - Integration



Vestas V80 - aufgelöst

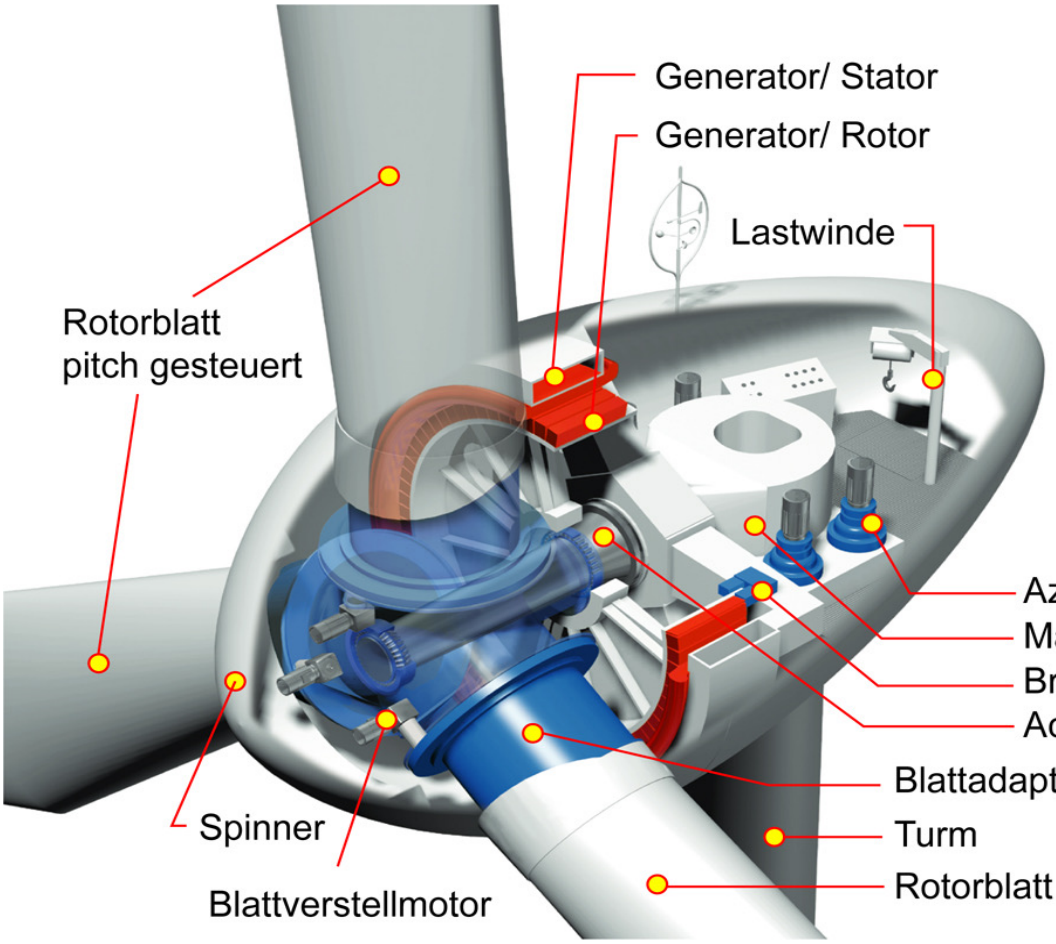
Nordex N54 - teilintegriert



Vestas V90 - integriert

Aufbau

Triebstrang - Getriebelos



Modell Enercon E-66
- technische Daten -

Technik

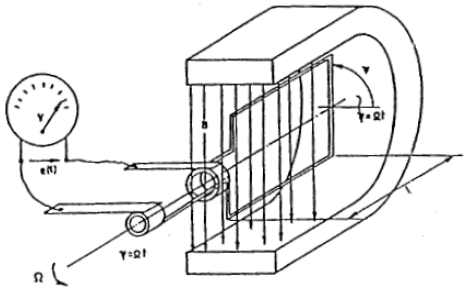
Leistung	:	1,8 MW
Nennwindgeschwindigkeit	:	12,0 m/s
Einschaltwindgeschw.	:	2,5 m/s
Rotordurchmesser	:	70,0 m
Überstrichene Fläche	:	3.848 m²
Drehzahl	:	10-22 U/min
Generator	:	synchron, Ringgenerator
Getriebe	:	ohne

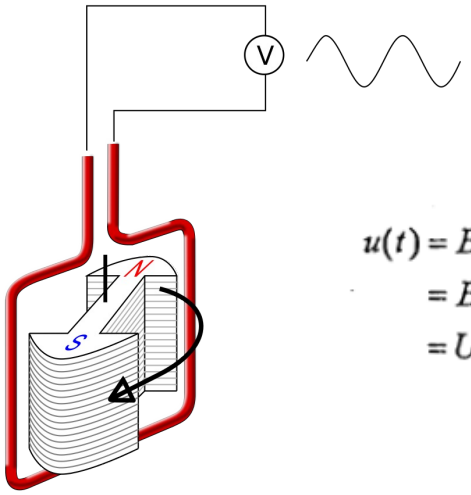
Gewicht

Gondel	:	68,8 t
Rotor (incl. Nabe)	:	31,7 t
Turm (98m, Beton)	:	861 t
Turm (86m, Stahlrohr)	:	219 t

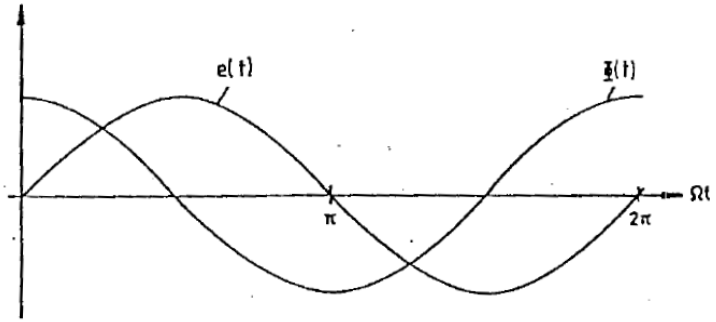
Elektrisches System

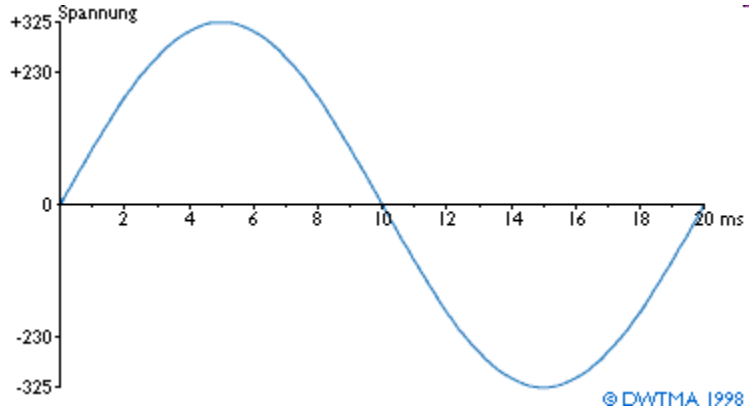
Dynamomaschine





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

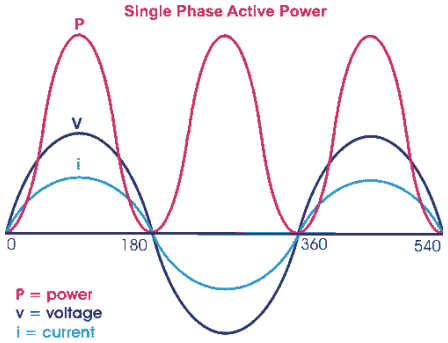


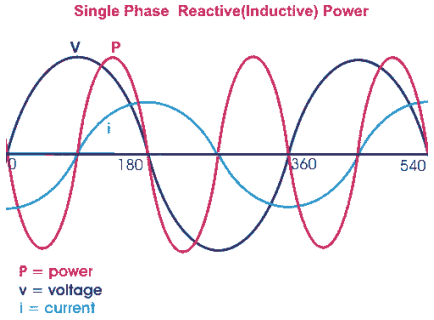


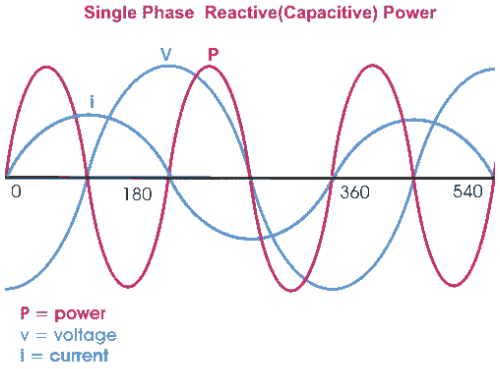
Elektrisches Systeme

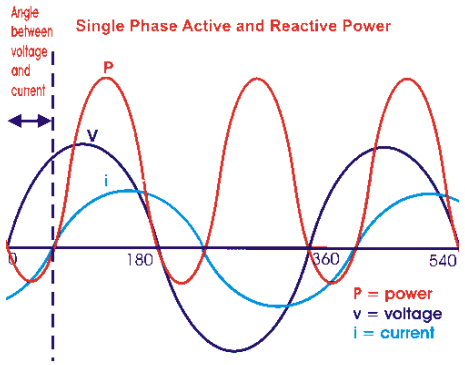
Quellspannung und magnetischer Fluss (Wirk- Blindleistung)

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



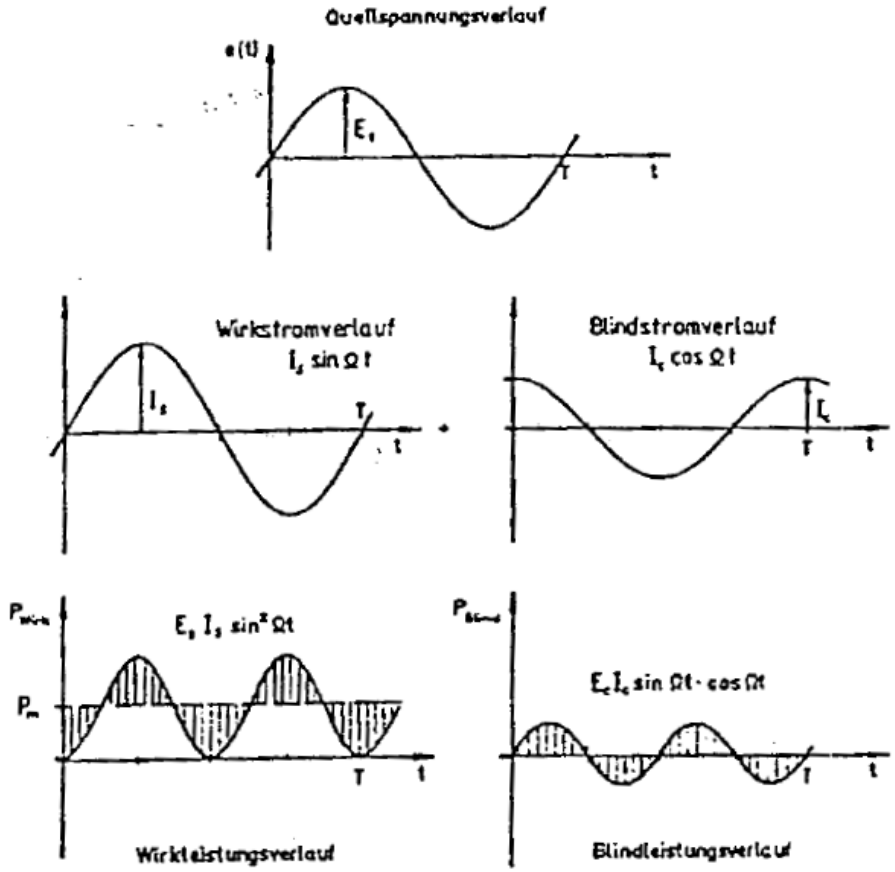






Elektrisches System

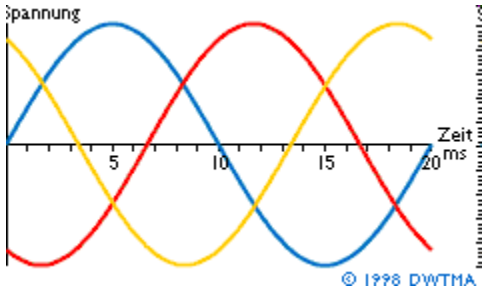
Wirk- und Blindleistung / Drehstrom



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

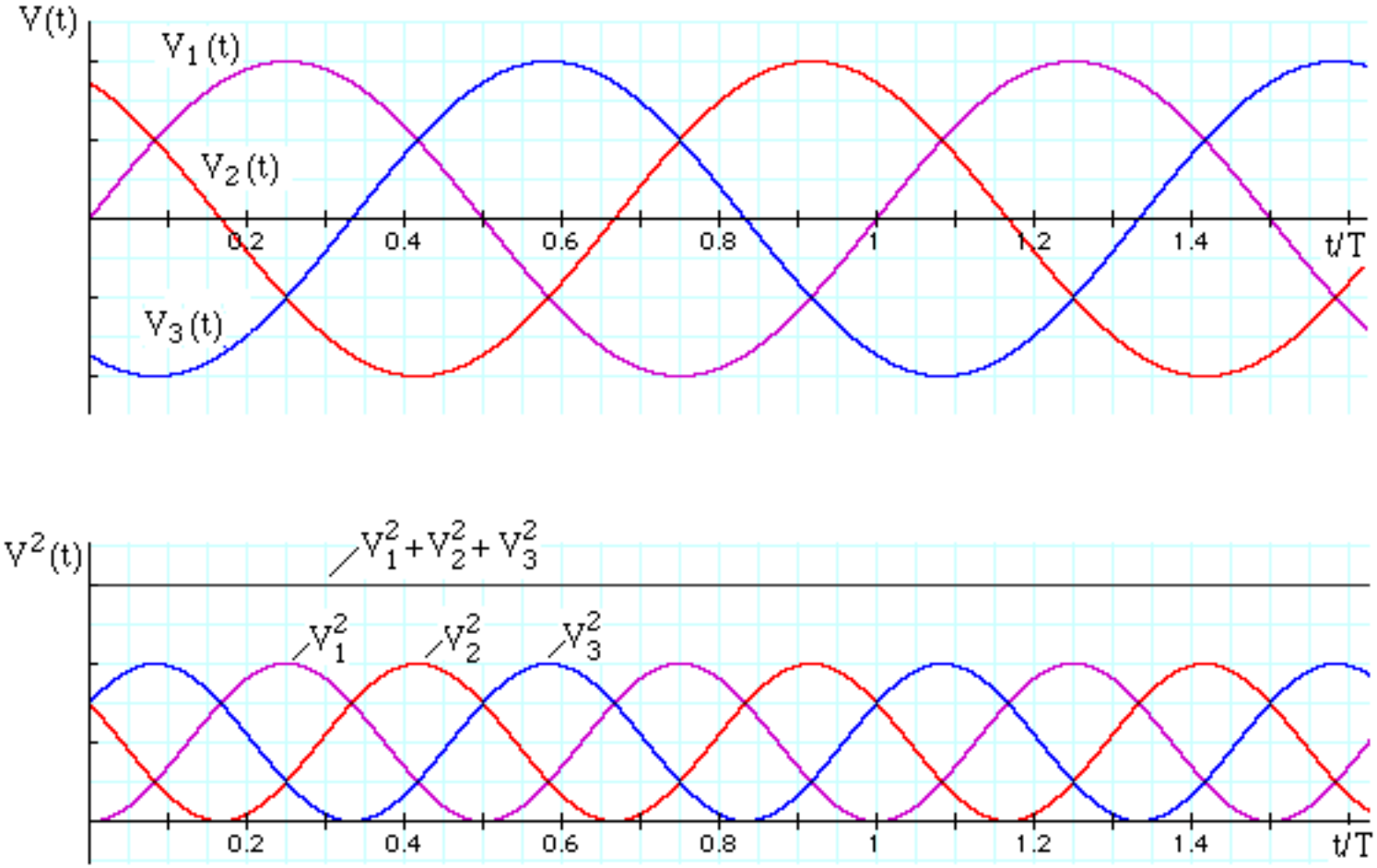
$$i(t) = I_W \cdot \sin \omega t + I_B \cdot \cos \omega t$$

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



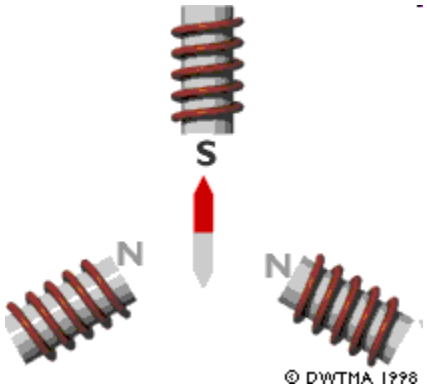
Elektrisches System

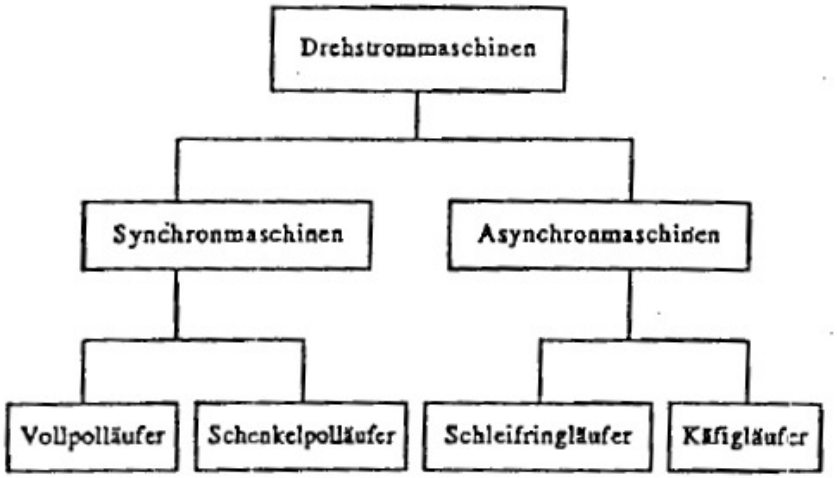
Drehstrom

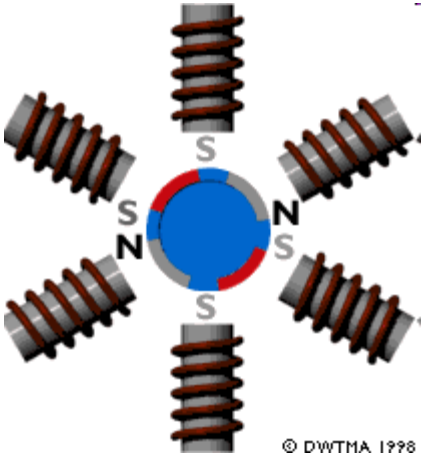


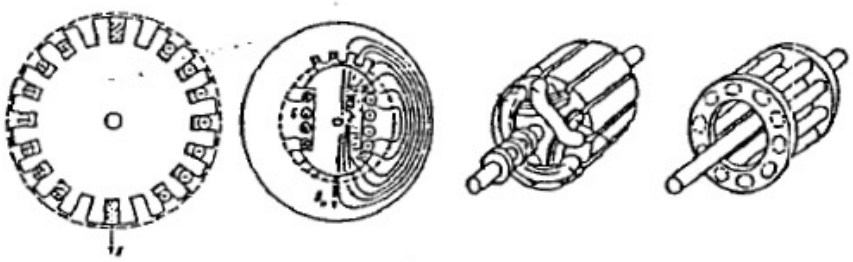
Elektrisches System

Generatortypen



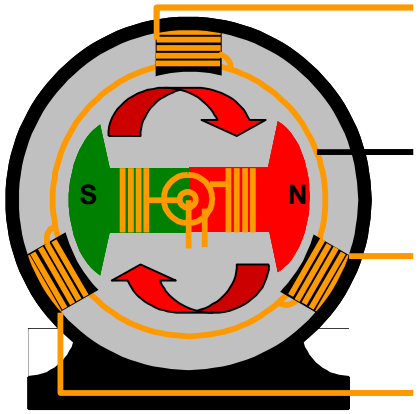




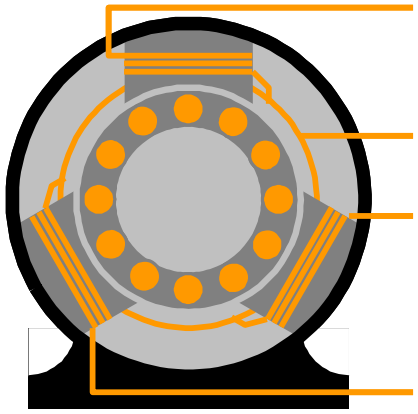


Elektrisches System

Generatoren



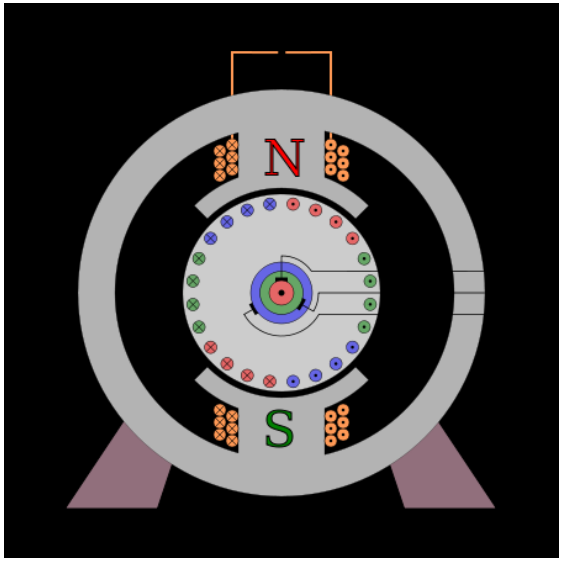
synchron



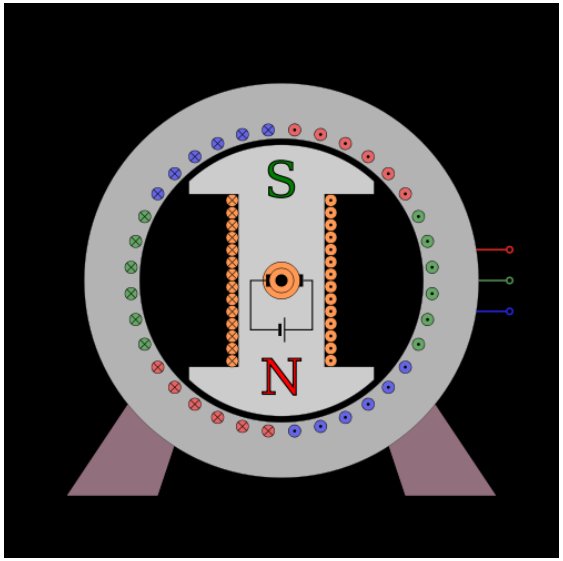
asynchron

Elektrisches System

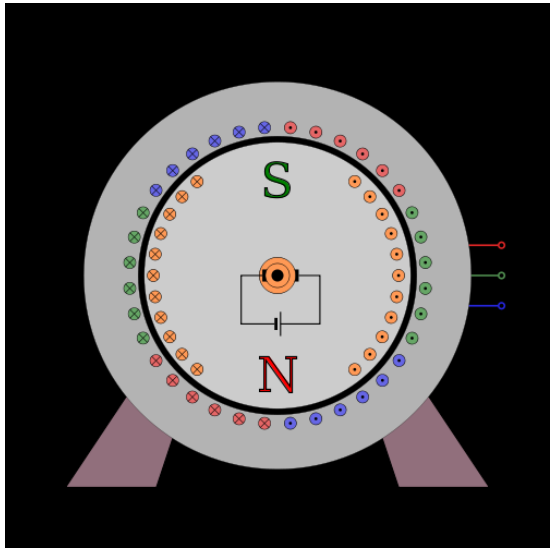
Synchrongeneratoren



Außenpolmaschine
Schenkelpol

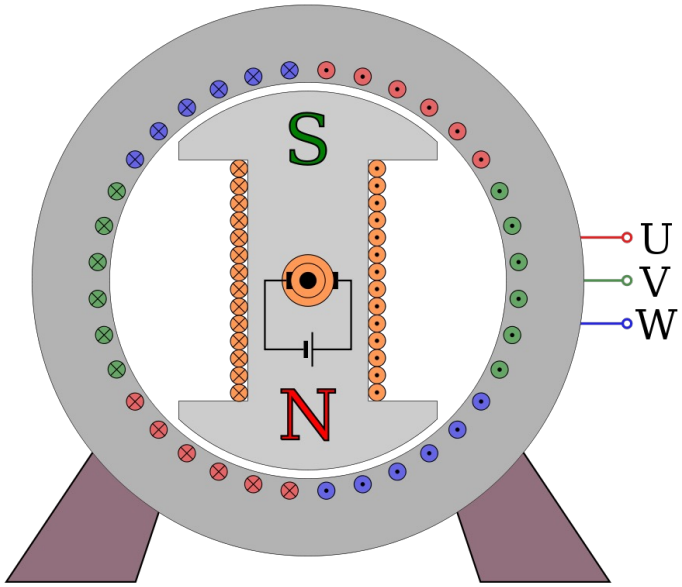


Innenpolmaschine
Schenkelpol

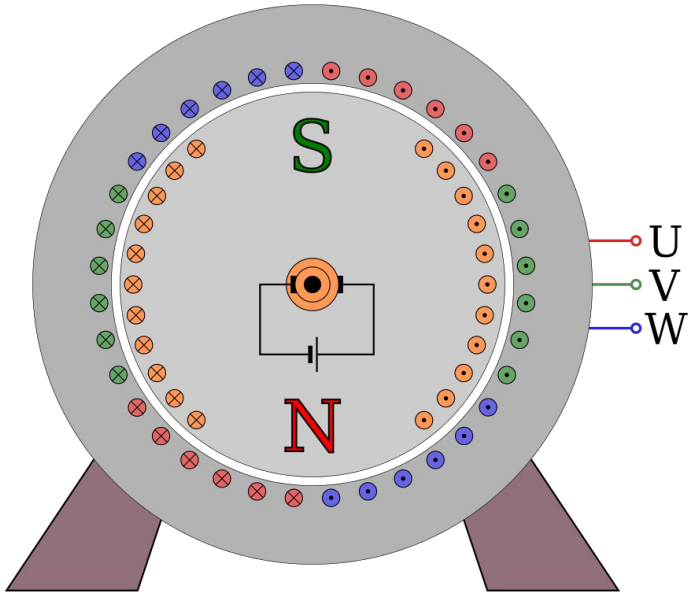


Innenpolmaschine
Vollpol

Elektrisches System
Synchrongeneratoren



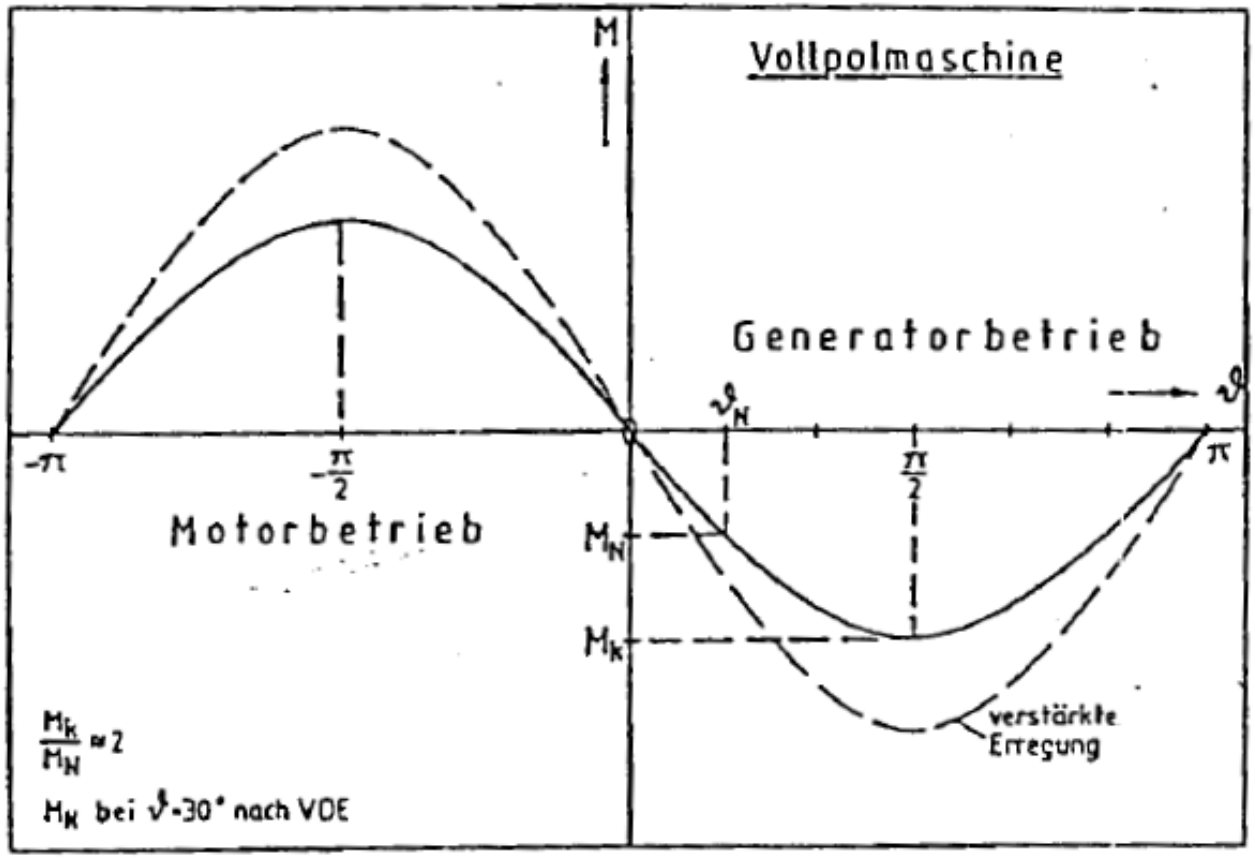
Innenpolmaschine
Schenkelpol



Innenpolmaschine
Vollpol

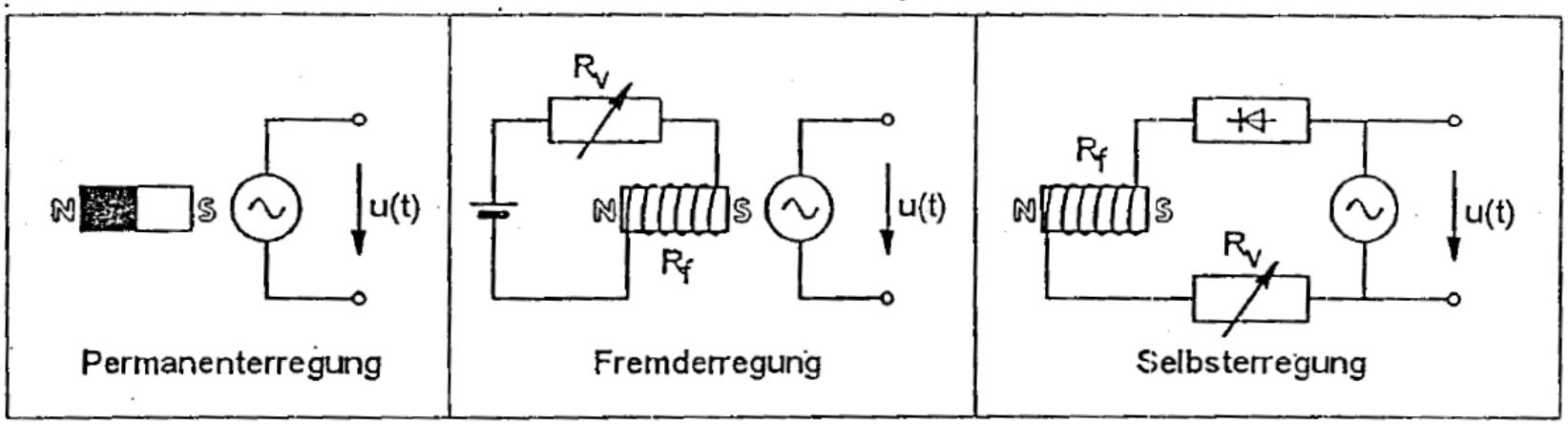
Elektrisches System

Synchronmaschine - Momentenkurve



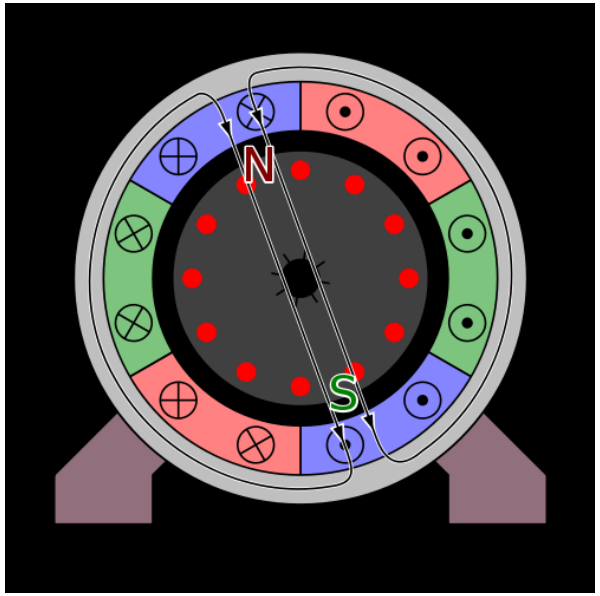
Elektrisches System

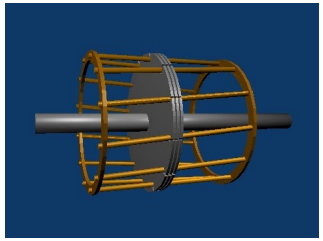
Magnetfeld

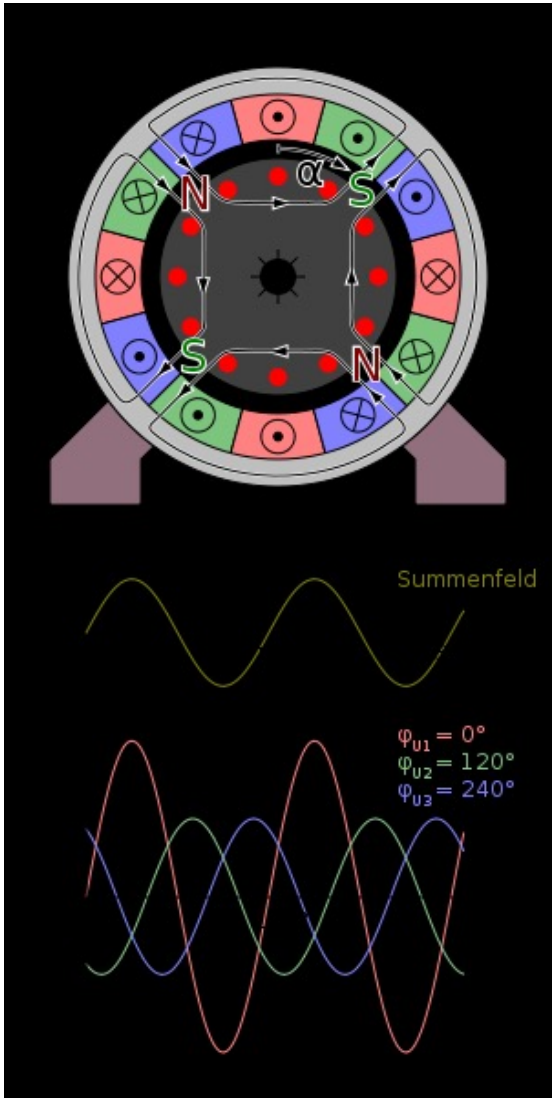


Elektrisches System

Asynchrongeneratoren

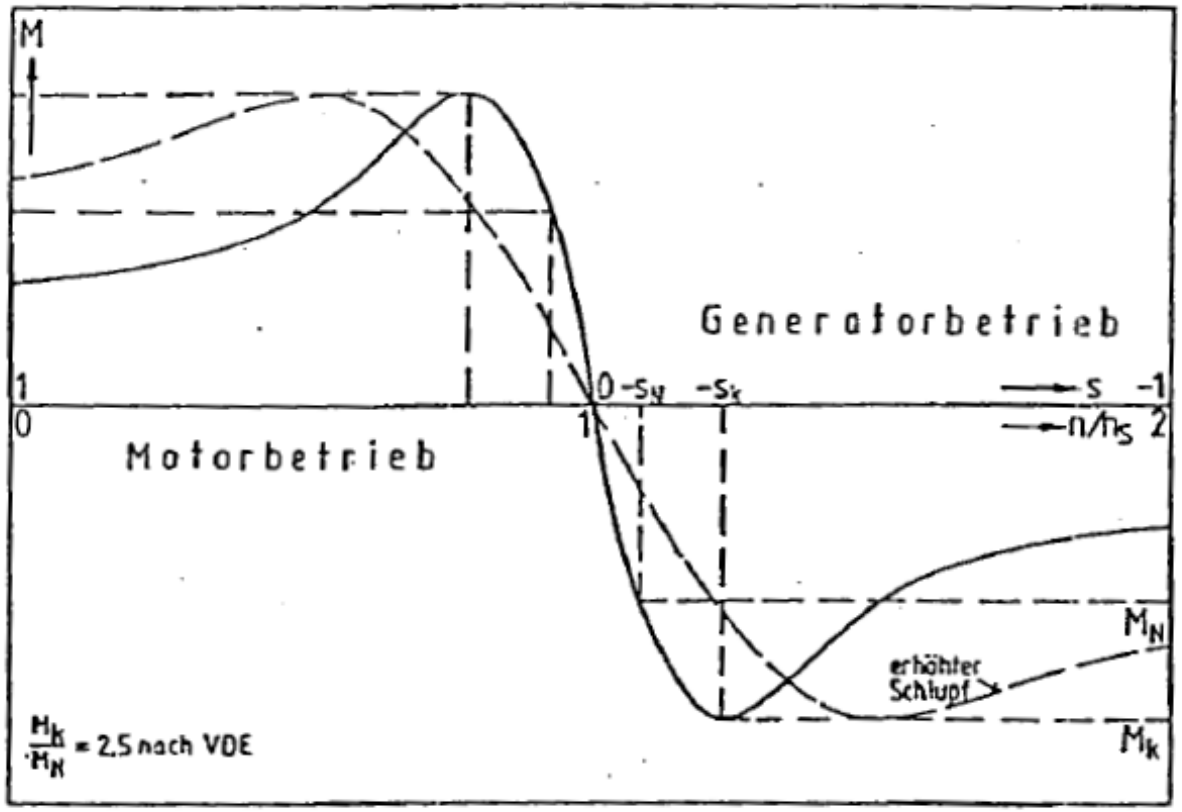






Elektrisches System

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

Frequenz

- **Getriebe ?**

$$n_s = \frac{60 \cdot f}{p}$$

n_s = Rotordrehzahl $\left[U / \min\right]$

f = Netzfrequenz $\left[\mathrm{Hz}\right]$

p = Anzahl **Polpaare**

- **Beispiele:**
  - **1 Polpaar und 50 Hz resultieren in 3.000 U/min**
  - **1 Polpaar und 60 Hz resultieren in 3.600 U/min**
- Rotorrehzahl ca. 12-35 U/min

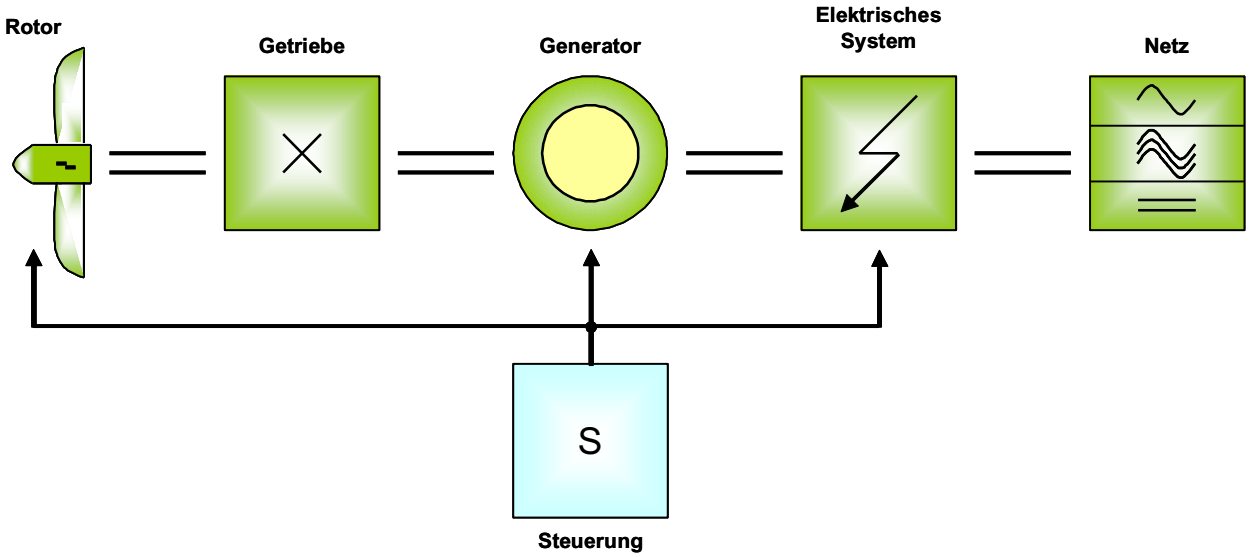
Elektrisches System
Synchron – Asynchron / Vor- Nachteile

	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.

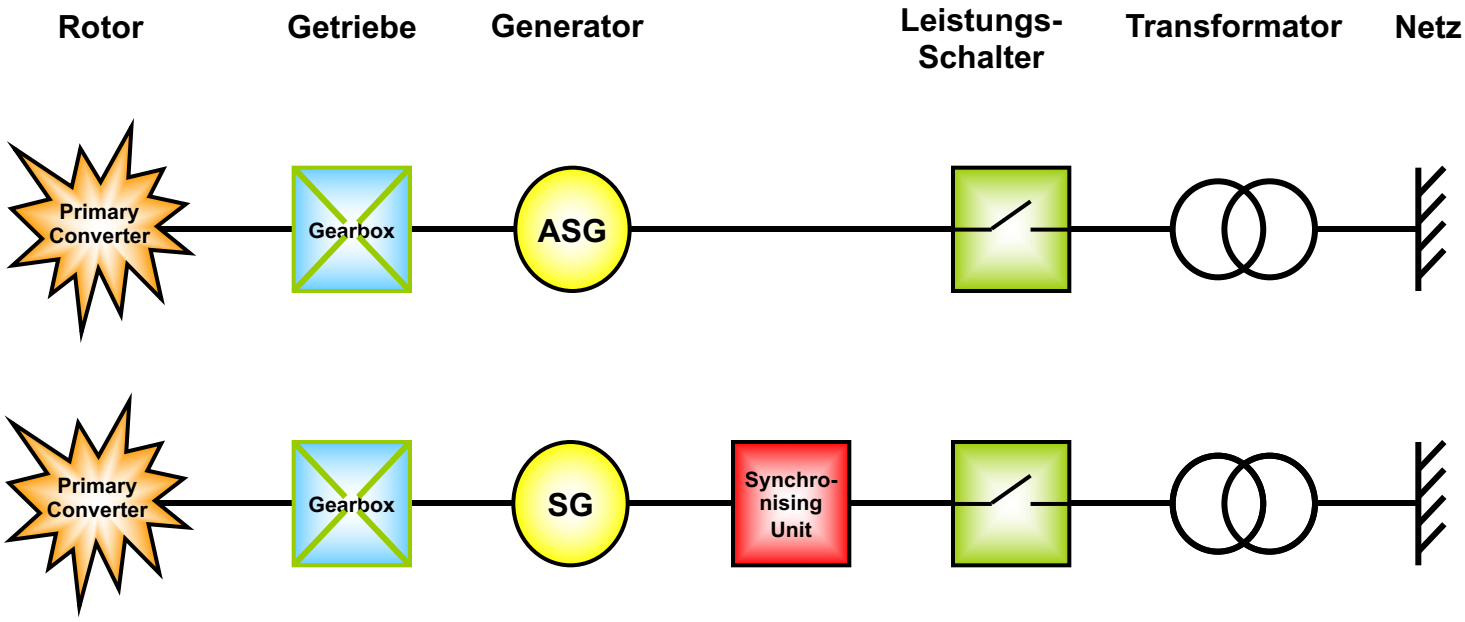
Elektrisches System

Allgemeiner Aufbau



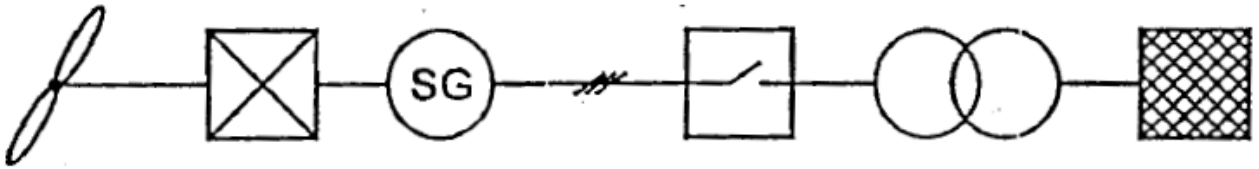
Elektrisches System

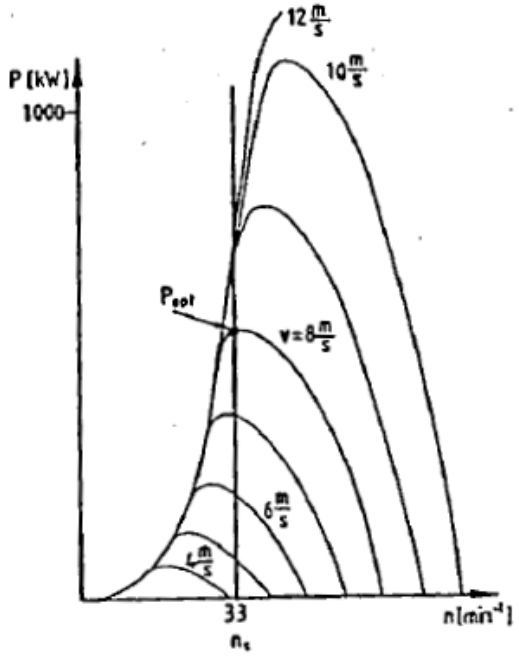
Netzanbindung



Elektrisches System

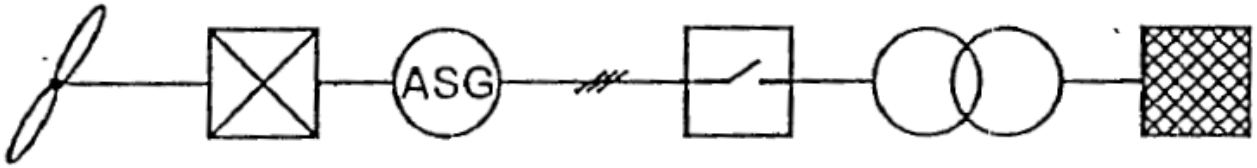
Drehzahlfeste Kopplung - Synchronmaschine

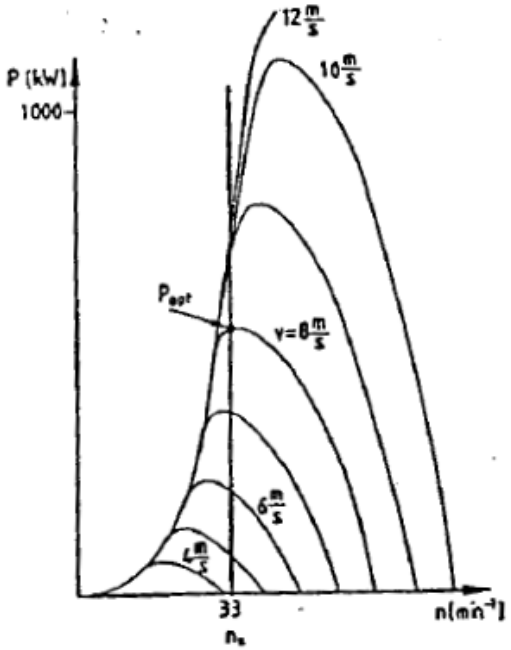




Elektrisches System

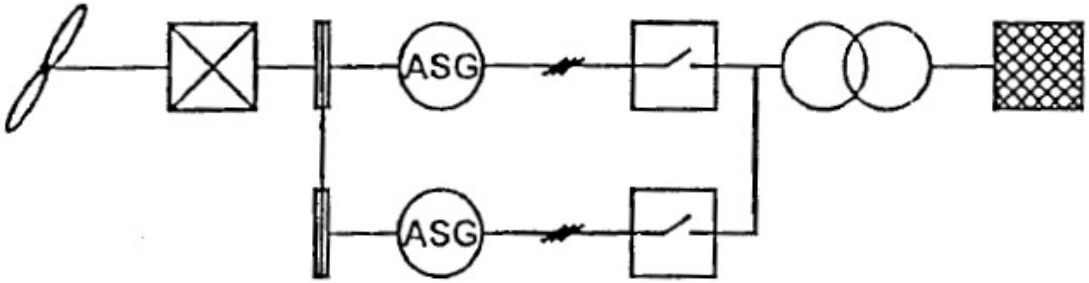
Drehzahlfeste Kopplung - Asynchronmaschine

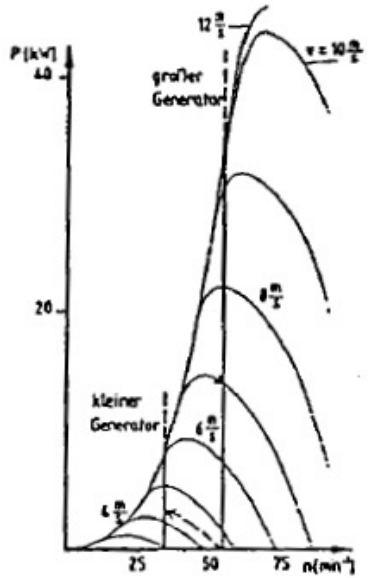




Elektrisches System

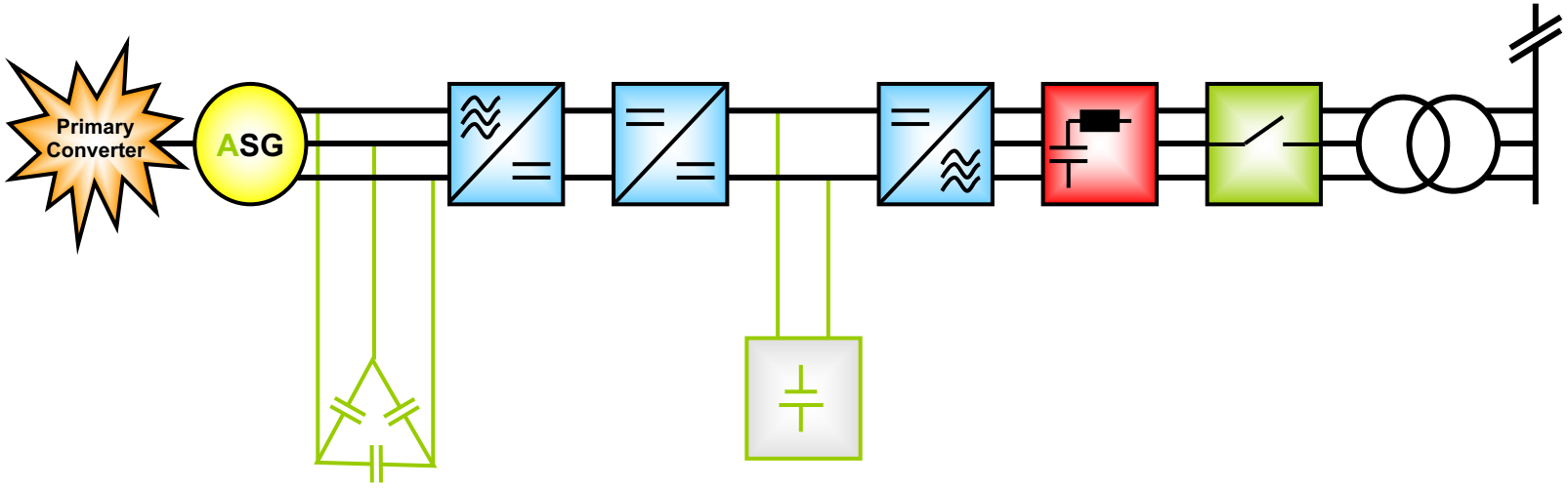
Drehzahlgestufte Kopplung – Dänisches Modell





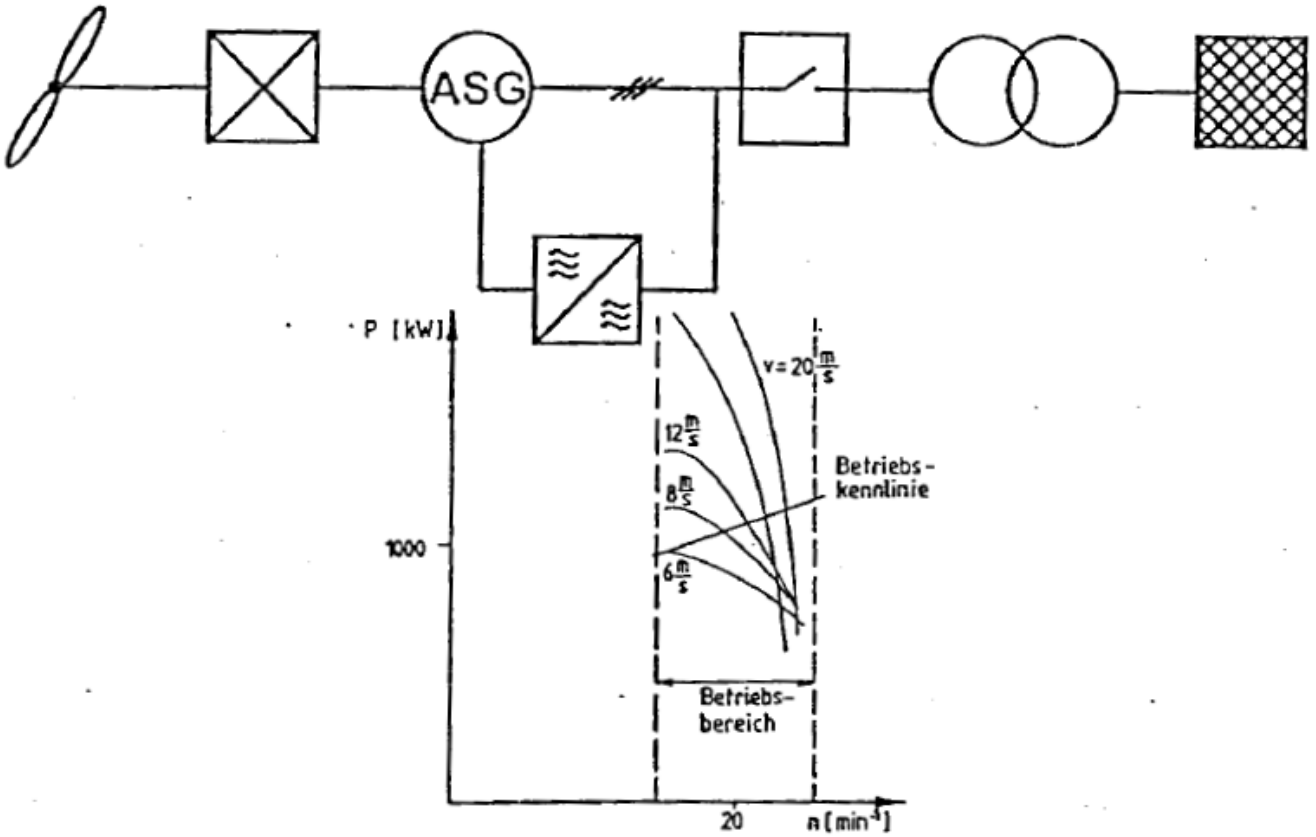
Elektrisches System

Komplexe Kopplung



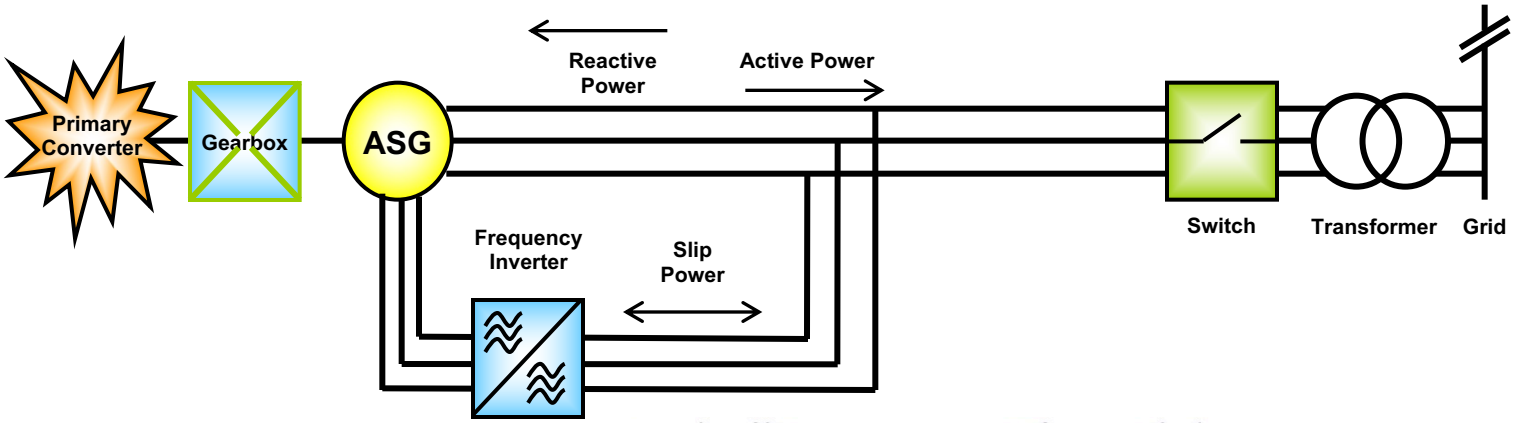
Elektrisches System

Drehzahlvariabel – Doppelt gespeister Asynchrongenerator

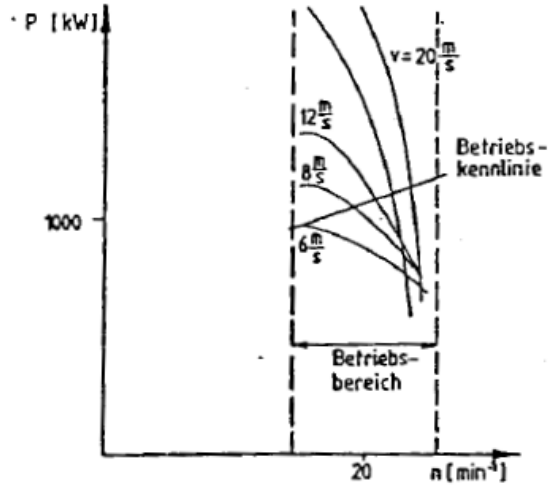


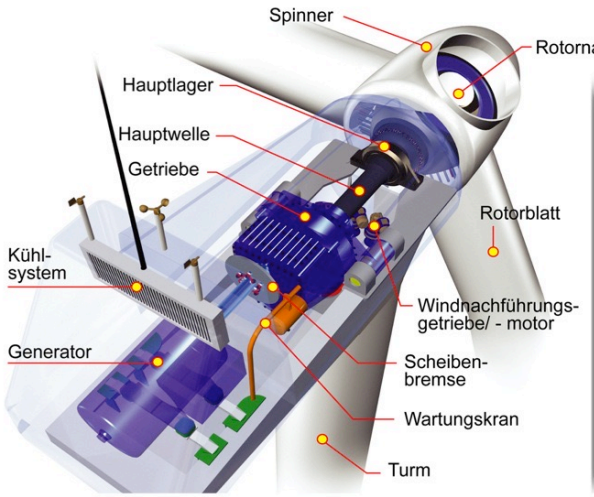
Elektrisches System

Drehzahlvariabel – Doppelt gespeister Asynchrongenerator



Aufbau einer Gondel - mit Getriebe



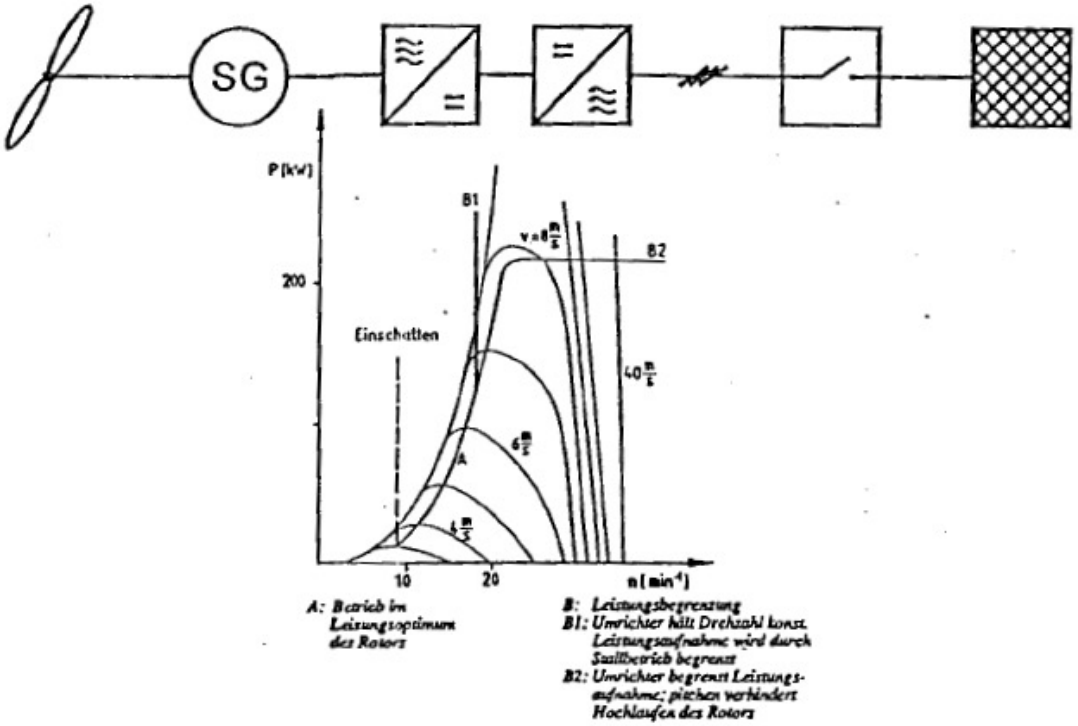


Modell NEG Micon 52/900
- technische Daten -

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

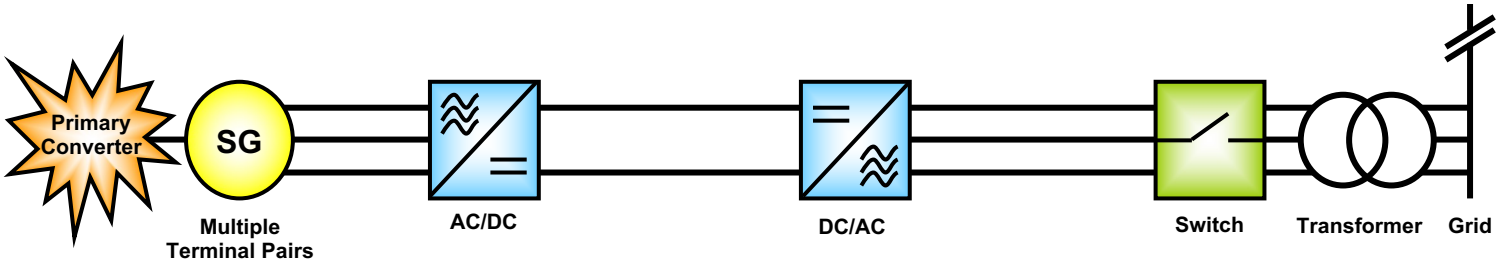
Elektrisches System

Drehzahlvariabel - Enercon



Elektrisches System

Drehzahlvariabel - Enercon



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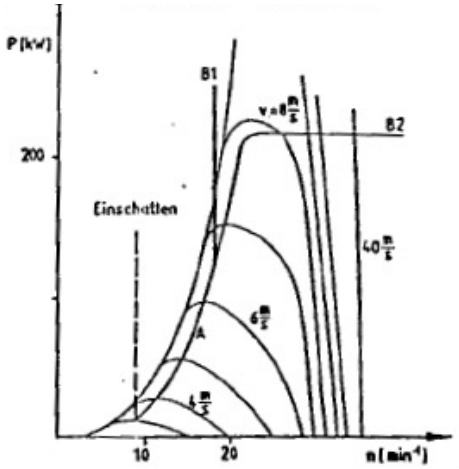
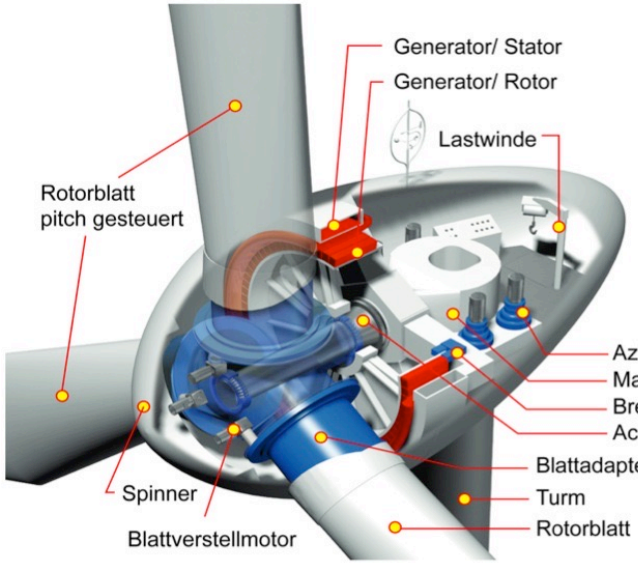
Bundesverband WindEnergie e.V.

Aufbau einer Gondel - getriebelos



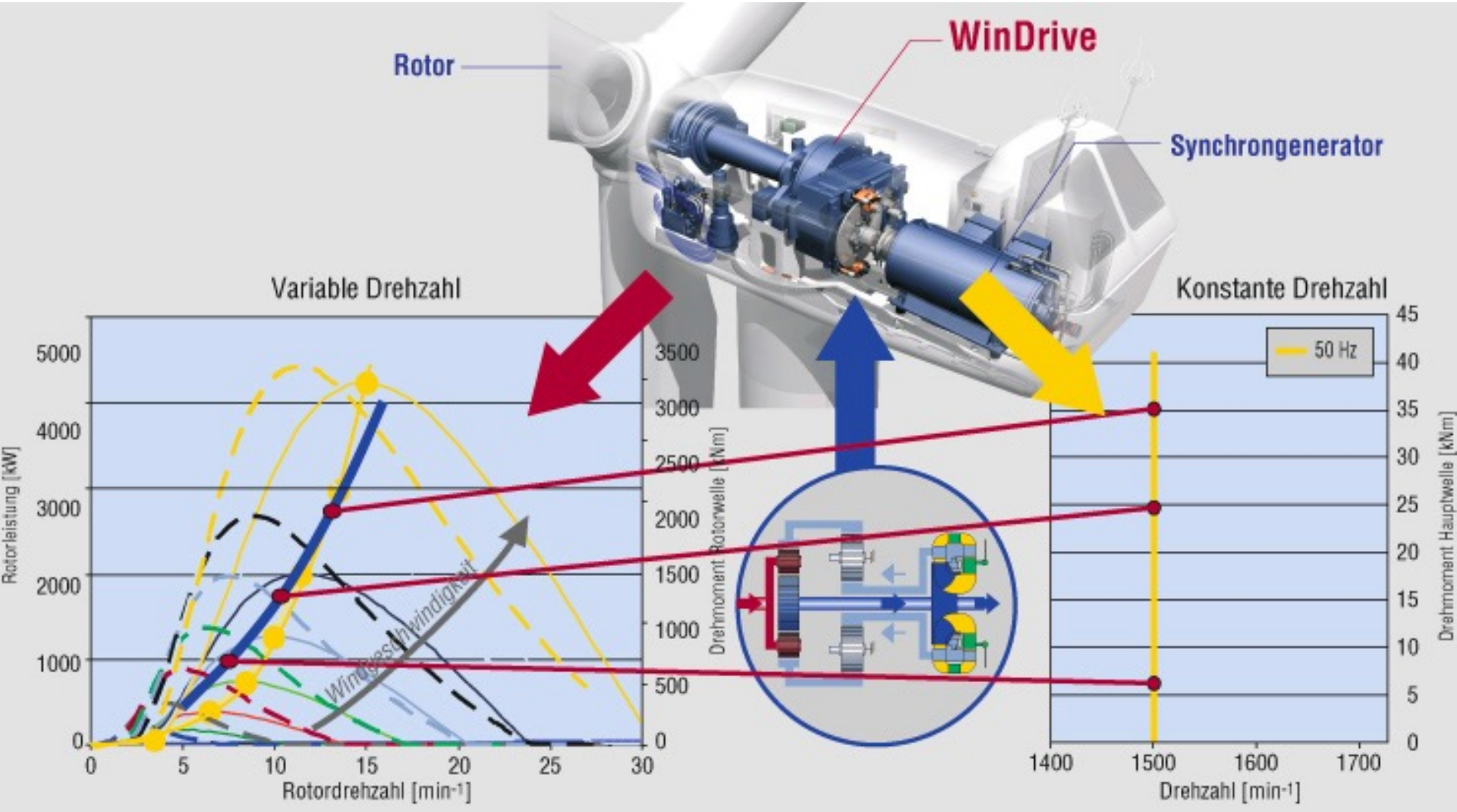


Modell Enercon E-66
- technische Daten -

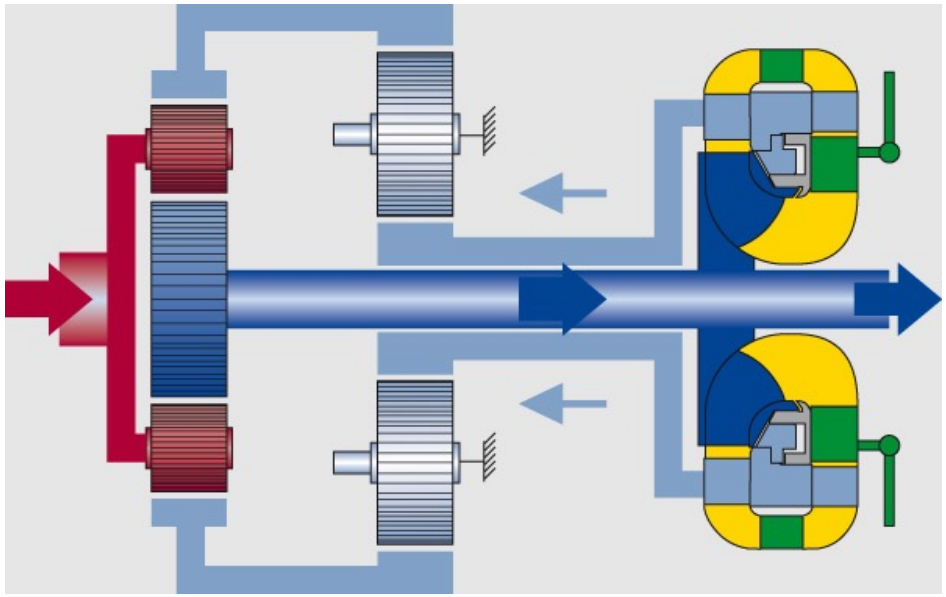
Technik		
Leistung	:	1,8 MW
Nennwindgeschwindigkeit	:	12,0 m/s
Einschaltwindgeschw.	:	2,5 m/s
Rotordurchmesser	:	70,0 m
Überstrichene Fläche	:	3.848 m²
Drehzahl	:	10-22 U/min
Generator	:	synchron, Ringgenerator
Getriebe	:	ohne
Gewicht		
Gondel	:	68,8 t
Rotor (incl. Nabe)	:	31,7 t
Turm (98m, Beton)	: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

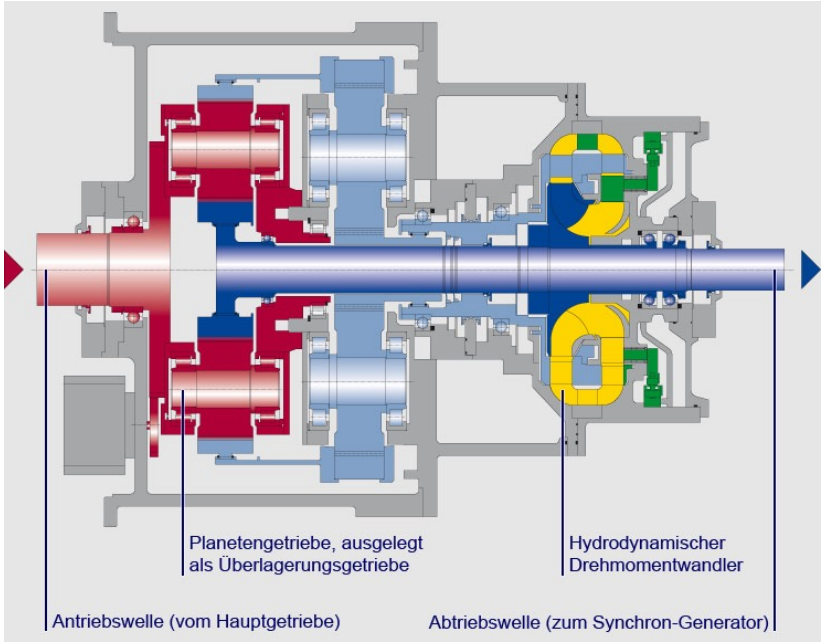
Aufbau

Voith - WinDrive



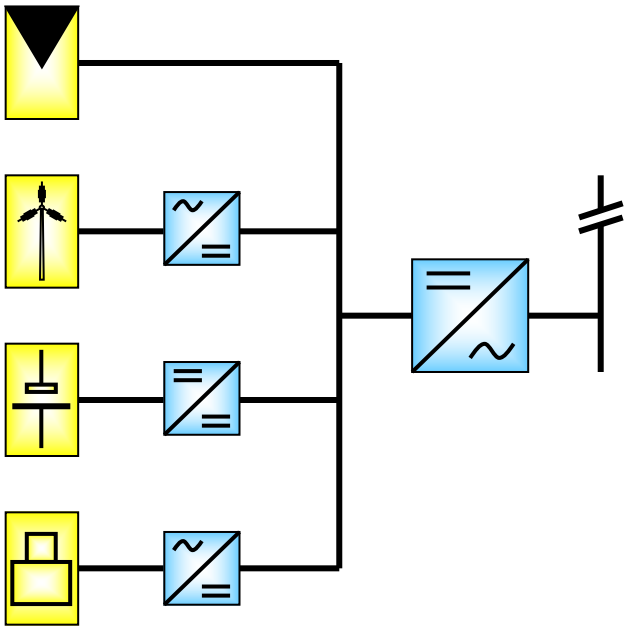
Aufbau
Voith – WinDrive - Drehmomentwandler

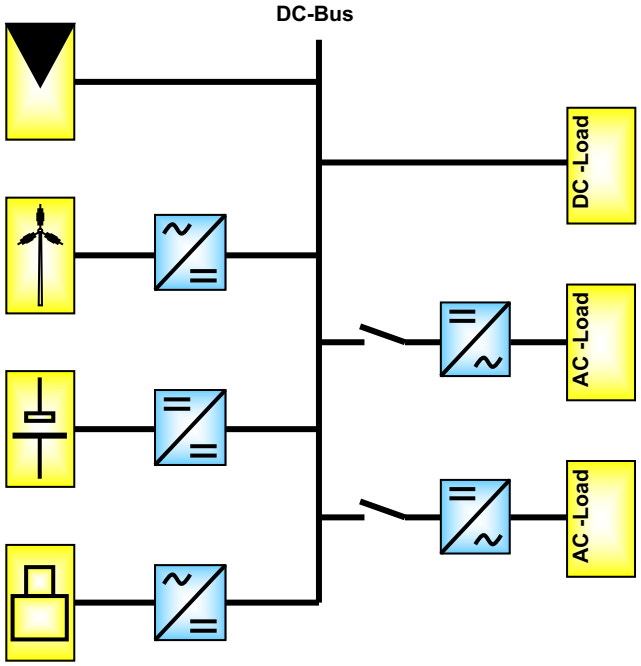




Inselsysteme

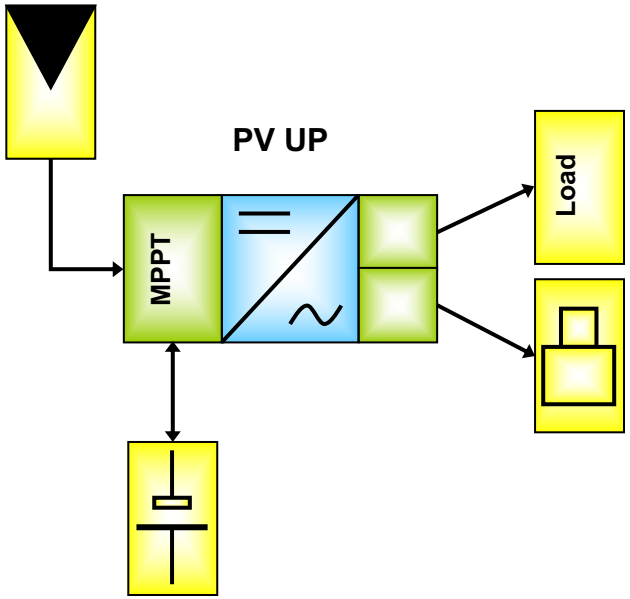
DC Kopplung





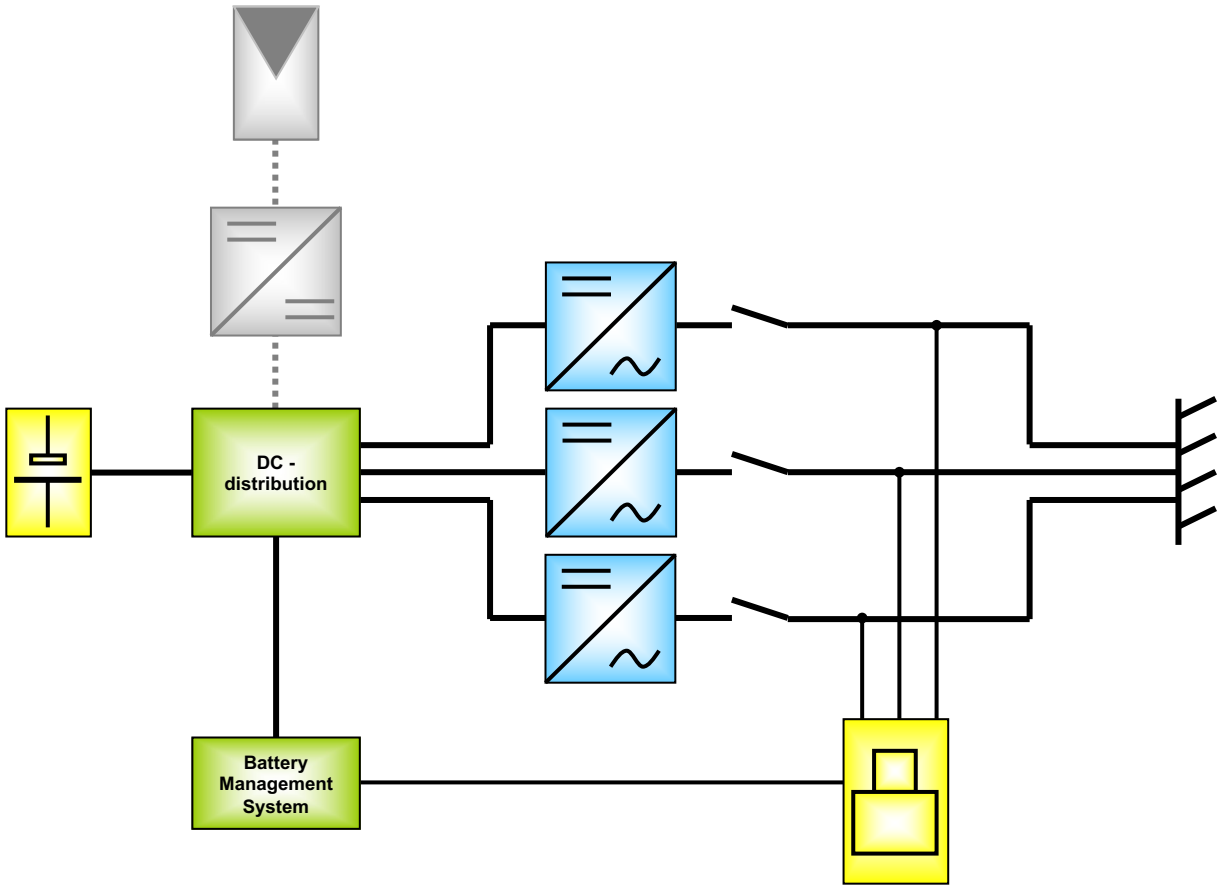
Inselsysteme

Integrierte Kopplung



Inselsysteme

Gemischte Kopplung



Inselsysteme

Wechselstromkopplung