Turbine Generators

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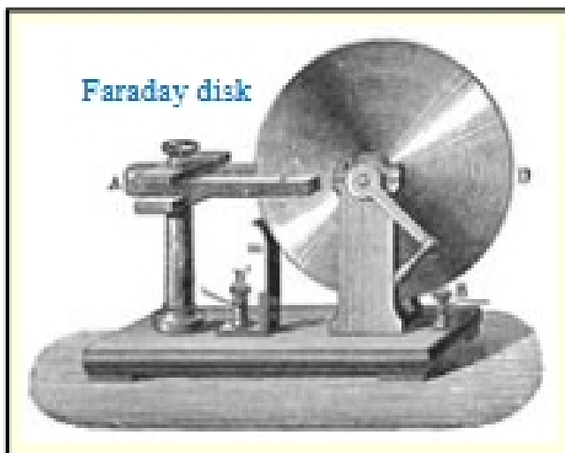
Outline

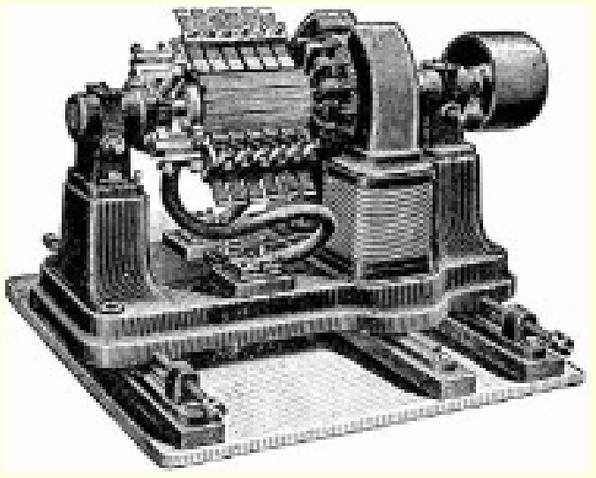
- Generators
- Synchronous machines
- Number of poles
- Asynchronous machines
- Changing number of poles
- Variable slip
- Indirect grid connection
- Gearboxes
- Controllers
- Power quality

Generator History



Michael Faraday discovered the principle of electromagnetic generators - a potential difference is generated between the ends of an electrical conductor that moves perpendicular to a magnetic field

Generator History

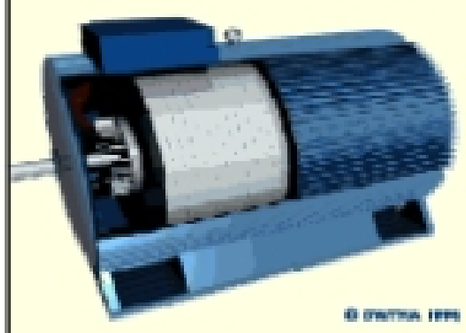


Dynamo was the first (belt driven) electrical generator capable of delivering power for industry

Turbine Generator

http://seattlepi.nwsource.com/photos/photo.asp?PhotoID=27489

Wind Turbine Generators



- ✓ The wind turbine generator converts mechanical energy (torque) into electrical energy
- ✓ Wind turbine generators differ from ordinary generating units found in an electrical grid

- ✓ The main reason is that the generator works with a power source (the wind turbine rotor) supplying highly fluctuating mechanical power (torque)

Turbine Classification

Based on the rotor-generator systems, turbines are classified into four types:

- ✓ Type A: Fixed speed
- ✓ Type B: Limited variable speed
- ✓ Type C: Variable speed with partial scale energy converter
- ✓ Type D: Variable speed with full scale energy converter

Turbine Classification

Speed control		Power control		
		Stall	Pitch	Active stall
Fixed speed	Type A	Type A0	Type A1	Type A2
Variable speed	Type B	Type B0	Type B1	Type B2
	Type C	Type C0	Type C1	Type C2
	Type D	Type D0	Type D1	Type D2

Note: The grey zones indicate combinations that are not in use in the wind turbine industry today.

- ✓ Examples: GE 1.5 MW turbine is type C1, 3.2 MW is type C1
  Gemesa 2 MW turbine is type C1
  Vestas 1.8 MW turbine is type B1, 2MW is type C1

Turbine Classification

Generator-rotor

Speed control		Power control		
		Stall	Pitch	Active stall
Fixed speed	Type A	Type A0	Type A1	Type A2
Variable speed	Type B	Type B0	Type B1	Type B2
	Type C	Type C0	Type C1	Type C2
	Type D	Type D0	Type D1	Type D2

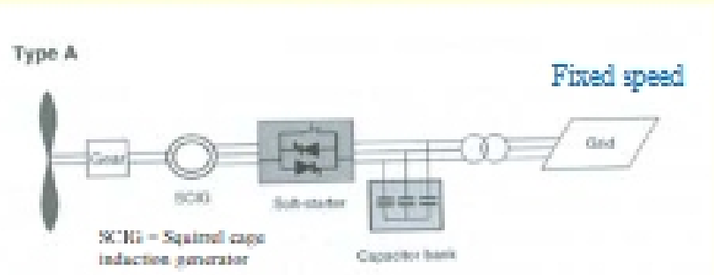
Note: The grey zones indicate combinations that are not in use in the wind turbine industry today.

Turbine-wind parameters

IFT Classes	I	II	III	IV	S
v_{ave} (m/s)	10	8.5	7.5	6	
I_{ref} (-)	0.1	0.1	0.1	0.1	
v_{ref} = 1.4v_{ave}	70	59.5	52.5	42	values for the
v_{ref} (m/s)	52.5	44.6	39.4	31.5	cyclonically
A I_{15}	0.18	0.18	0.18	0.18	the dot proc
a	2	2	2	2	
B I_{15}	0.16	0.16	0.16	0.16	
a	3	3	3	3	

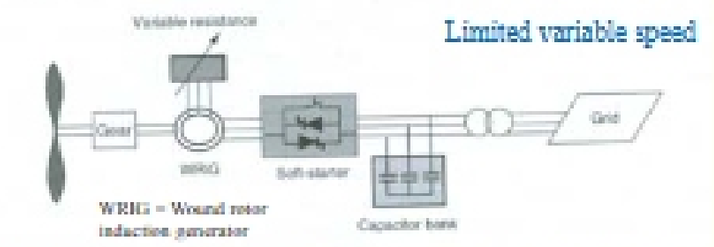
Turbine Classification

Type A — Fixed speed



SCIG = Squirrel cage induction generator

Type B — Limited variable speed



WRIG = Wound rotor induction generator

Turbine Classification

Type C — Variable speed with partial scale energy converter

WRIG = Wound rotor induction generator

Type D — Variable speed with full scale energy converter

PMSG (Permanent magnet squirrel generator)
WRSG (Wound rotor synchronous generator)
WRIG (Wound rotor induction generator)

Type A: Fixed Speed

- ✓ SCIG (Squirrel cage induction generator) directly connected to the grid via a transformer
- ✓ SCIG draws reactive power from the grid that is compensated by the capacitor bank (in the absence of the capacitor bank voltage fluctuations and power line losses are inevitable)
- ✓ Wind speed variability imposes high stresses on the turbine structure