Generator Options in Small to Medium Turbines

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Overview

• Generator options
• PM generator circuit model
• Power converter options:
  – Uncontrolled rectifier
  – Switch-mode rectifier
  – Fully controlled inverter
• Summary
Generator Options

• Induction generators
• Reluctance generators
• Permanent magnet generators
Permanent Magnet Generators

- Some form of electronic power conversion is used to process the power coming out of the generator, typically converting the variable voltage, variable frequency to dc.
PM Generator Model

- Power is maximized when the phase currents are in phase with, and of the same shape as, the back emf.
Electronic Options

• Uncontrolled rectifier: no control required, robust, least expensive

• Switched-mode rectifier: simple control, more expensive

• Fully-controlled inverter: more complicated control, still more expensive
Uncontrolled 3 Phase Rectifier

- Imposes power factor limitation on generator
Uncontrolled Rectifier

Generator Options for Small Wind
Switched-mode Rectifier

Generator Options for Small Wind
Switched-mode Rectifier

![Graph showing output power versus duty cycle for different mechanical speeds.]

- **Output Power (kW)**
  - 150 RPM
  - 250 RPM
  - 350 RPM
  - 450 RPM
  - 550 RPM
  - 650 RPM
  - 750 RPM

- **Duty Cycle for Switches**
  - 0.4
  - 0.5
  - 0.6
  - 0.7
  - 0.8
  - 0.9
  - 1

- **Mechanical Speed (rpm)**
  - 100
  - 200
  - 300
  - 400
  - 500
  - 600
  - 700
  - 800

- **Peak Output Power (kW)**
  - Uncontrolled Rectifier
  - Switched Mode Rectifier

**Generator Options for Small Wind**
Switched-mode Rectifier

**$V_{dc} = 50 \text{ V}$**

- Uncontrolled Rectifier
- Switched Mode Rectifier

**$V_{dc} = 150 \text{ V}$**

- Uncontrolled Rectifier
- Switched Mode Rectifier

Generator Options for Small Wind 11
Fully Controlled Inverter
Fully Controlled Inverter

Turbine Power Output vs Mechanical Speed

- X-axis: Mechanical Speed (RPM)
- Y-axis: Turbine Power Output (kW)

Graph showing the relationship between mechanical speed and turbine power output.
Comparison of 3 Topologies, Peak Power

Comparison of 3 Topologies, Peak Power per unit cost

Uncontrolled Rectifier
Switched Mode Rectifier
Fully Controllable
Summary

• Uncontrolled rectifiers are inexpensive, but require a larger generator to get the same output power
• Switched-mode rectifiers are simple structures that can substantially improve the energy capture relative to an uncontrolled rectifier
• Inverters extract the most power, but do not represent the best value
The value proposition is not so clear and requires careful system engineering, including consideration of the utility interactive inverter.