High Penetration AC Bus Wind-Diesel Hybrid Power Systems

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Defining the Wind Penetration

$$\text{Energy Penetration} = \frac{\text{Wind turbine AEO}}{\text{Annual primary energy demand}}$$

$$\text{Power Penetration} = \frac{\text{Instantaneous wind power output}}{\text{Primary load}}$$

Low Penetration Systems

< 20% energy penetration
<50% peak power penetration

- Typically only found in retrofit situations
- All renewable energy output goes directly to serving primary load
- Minimal impact on diesel plant operation
- Few additional control components required
- Higher rate of return on investment possible
- Limited impact on fuel savings, diesel run time, and overall C.O.E.

High Penetration Systems

> 50% energy penetration
> 100% peak power penetration

- Larger potential impact on fuel savings, diesel run time, cost of energy.
- Usually requires energy storage to realize full benefit of wind energy component.
- Requires additional components (e.g. dump loads, synchronous condensers, power converters, etc.) to regulate system voltage and frequency.
- Typically lower rate of return on investment, due to higher per kW capital cost of system. Situation is helped by reduction in diesel maintenance cost.
- Increased system sophistication requires greater support infrastructure.

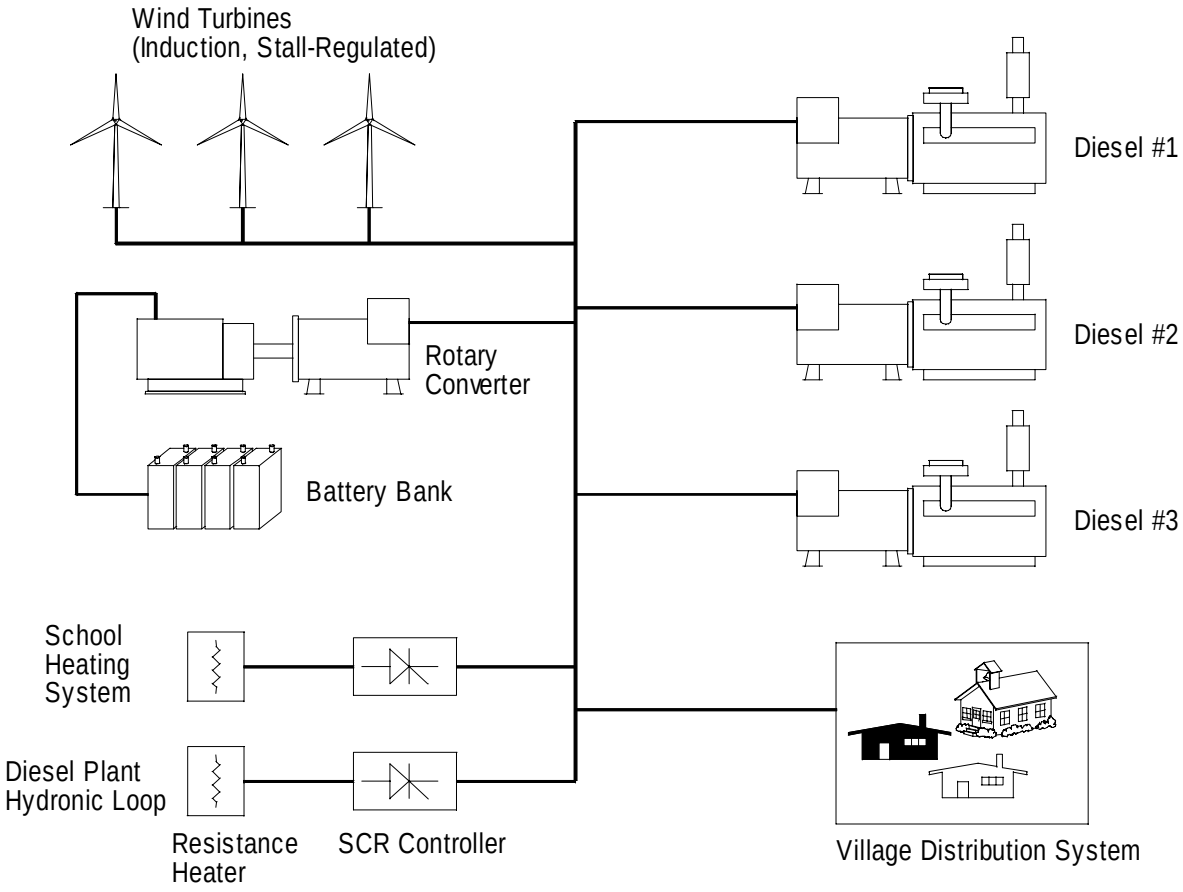
Comparison of AC and DC Bus Wind Hybrid Systems

Issue	AC Bus	DC Bus
Scale	Best suited to systems > 40 kW. Permits use of larger more cost-effective wind turbines	Best suited to small systems. Simpler architecture more easily maintained.
Renewable Energy Path	Wind turbine power can flow directly to the load, without the losses associated with power conversion.	All power must flow through a DC/AC converter (rotary or inverter)
Siting	Existing AC distribution lines can be used to connect wind turbines to power system.	Requires dedicated lines to connect turbines to power system.
Control Complexity	Active control system required to dispatch wind turbines, modulate dump load power, dispatch storage, etc.	Relatively simple system control. However, embedded inverter controls can be complex.
Cost	Often competing with existing diesel power stations. Must be competitive with diesel only.	Often offers 24 hr/day power where none existed. Higher costs are tolerated.

Principles of AC Bus Hybrid Power Systems

- Frequency is controlled by maintaining a balance of real power
  - ⇨ dump loads
  - ⇨ control power to/from energy storage
  - ⇨ diesel load following
    - > ordinary diesel
    - > variable speed diesel
  - ⇨ controllable output variable speed wind turbine
- Voltage is controlled by maintaining a balance of reactive power
  - ⇨ diesel generator voltage regulator
  - ⇨ synchronous condenser
  - ⇨ static VAR compensator

AC Bus Wind-Diesel Architecture for Wales, AK



Conclusions

- High penetration AC bus wind-diesel systems have complex control requirements. Significant engineering development effort is required.
- AC bus architecture appears to be the more cost-effective choice for larger (>100 kW) hybrid power systems
- System integration is the key. The individual components of an AC system can be as reliable as those of a DC system.