# Wind/Diesel Power Systems Basics and Examples

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# Remote Power Systems

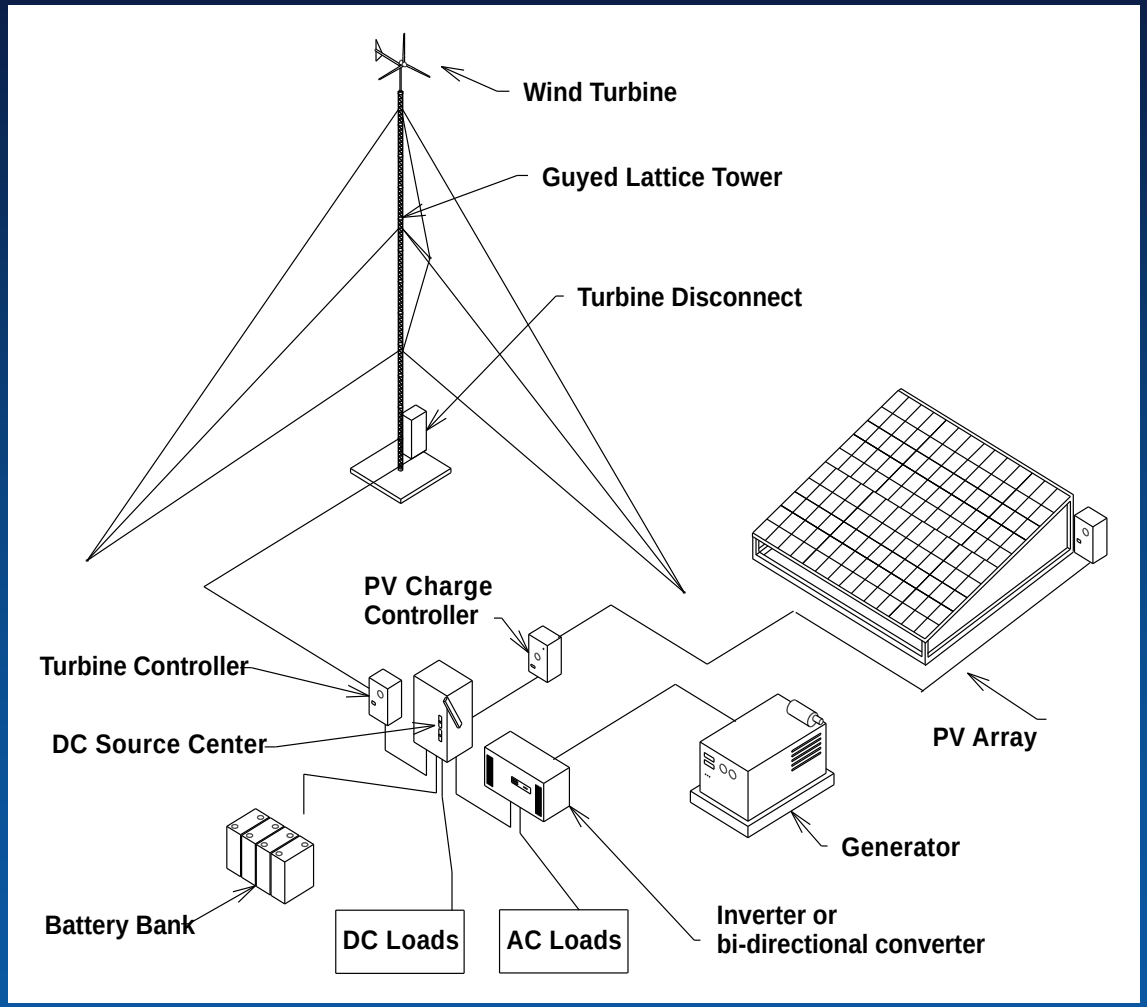
Renewable based power system can be used to supply a wide range of energy needs including:

- **Dedicated use:** Water pumping/ice making.
- **House systems:** Power systems for individual homes, buildings, and load centers.
- **Community Power Systems:** Power systems for a whole community and can include conventional generation, renewable technologies and storage technologies.
  - Community hybrid systems
  - Wind/Diesel systems

# Community Scale Hybrid Systems

- Takes advantage of local renewable resources when available in place of diesel produced energy
- Centrally located power plants that distribute AC power to the connected homes.
- Components of wind, PV, biomass, batteries and conventional generators
- Use of batteries when appropriate to store renewable energy for use at night or low renewable times
- Generator used as backup or secondary power supply
- Incorporate larger or multiple generation units to improve operation performance and benefit from quantities of scale benefits
- Relatively mature market, understood technology

# Hybrid (Wind, PV, Diesel, Storage) Community System



# Lime Village, Alaska

Small community in central Alaska using a solar – diesel hybrid power system as part of an AEA / Sandia National Laboratory PV technology demonstration project

- Average daily load peak of about 15 kW
- Successful technology demonstration
- Currently under monitoring to assess economics and operational characteristics

- 12 kW Solar Array (Siemens & BP)
- 24 kW power converter
- 530 Ahr lead Acid battery bank
- 2 diesel engines

# Wind-Diesel Power Systems

- Designed to reduce the consumption of diesel
  - Pits cost of wind power against cost of diesel power
  - Reduces diesel storage needs
  - Reduced environmental impact; fuel transport & emissions
- Used for larger systems with demands over ~ 100 kW peak load up to many MW
- Based on an AC bus configurations using wind turbines and diesel engines
- Batteries, if used, store power to cover short lulls in wind power
- Large potential, varying degrees of maturity with fewer examples
- Obviously requires a good wind resource to be “economical”

# What's the Challenge Behind Wind Diesel Power Systems?

By their nature renewable energy is stochastic (uncontrolled) and it varies with the resource.

We like our power very constant and controlled - 60 Hz, 120 V – for our TV's, lights, computers

Turning the variable energy in the wind into constant, consistent energy we can use can be a difficult task – the more energy from the wind, the more complex the task

# Wind-Diesel Penetration

One of the critical design factors is how much energy is coming from the wind – called wind penetration – as this helps determine the level of system complexity

$$\text{Instantaneous Penetration} = \frac{\text{Wind Power Output (kW)}}{\text{Primary Electrical Load (kW)}}$$

- Used to understand control requirements
- Reactive power needs, voltage and frequency regulation

$$\text{Average Penetration} = \frac{\text{Wind Energy Produced (kWh)}}{\text{Primary Energy Demand (kWh)}}$$

- Generally calculated on monthly or annual basis
- Total energy savings
- Loading on the diesel engines
- Spinning reserve losses/efficiencies

# AC Based Hybrid System

- **Low penetration systems -** Wind acts as a negative load, very little control or integration of wind turbines into the power system is needed .
- **Mid penetration systems -** Wind becomes a major part of the power system but diesel engines still provide much of the system power control. Additional components and limited supervisory control required to assist diesels in maintaining power quality.
- **High penetration systems -** Completely integrated power system with advanced control. Diesel generators shut off when not needed. Limited operational control of system by plant staff.

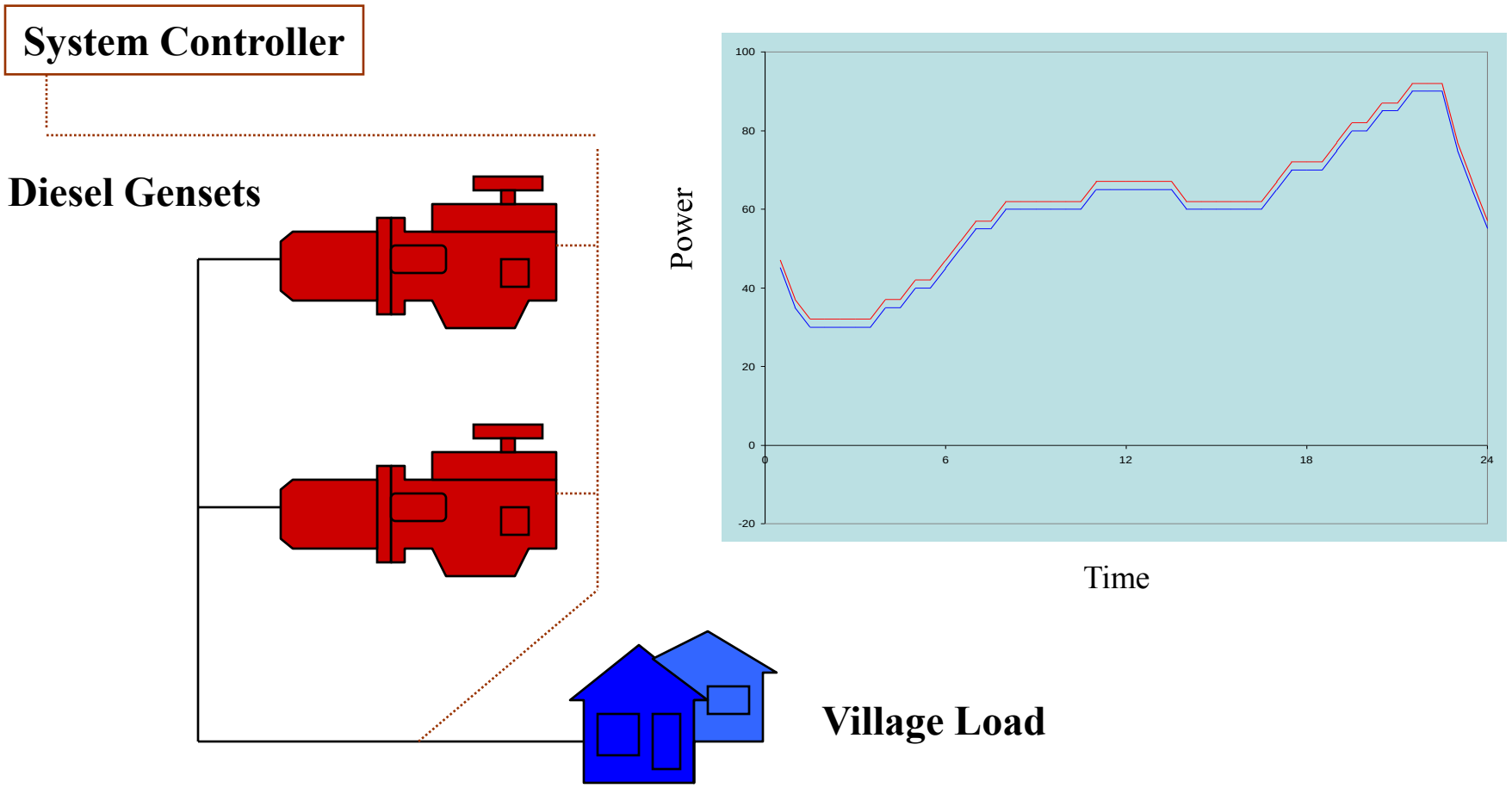
# System Penetration

| Penetration Class | Operating Characteristics | Penetration | |
|---|---|---|---|
| | | Peak Instantaneous | Annual Average |
| Low | ▪ Diesel(s) run full-time<br>▪ Wind power reduces net load on diesel<br>▪ All wind energy goes to primary load<br>▪ No supervisory control system | < 50% | < 20% |
| Medium | ▪ Diesel(s) run full-time<br>▪ At high wind power levels, secondary loads dispatched to ensure sufficient diesel loading or wind generation is curtailed<br>▪ Requires relatively simple control system | 50% – 100% | 20% – 50% |
| High | ▪ Diesel(s) may be shut down during high wind availability<br>▪ Auxiliary components required to regulate voltage and frequency<br>▪ Requires sophisticated control system | 100% - 400% | 50% – 150% |

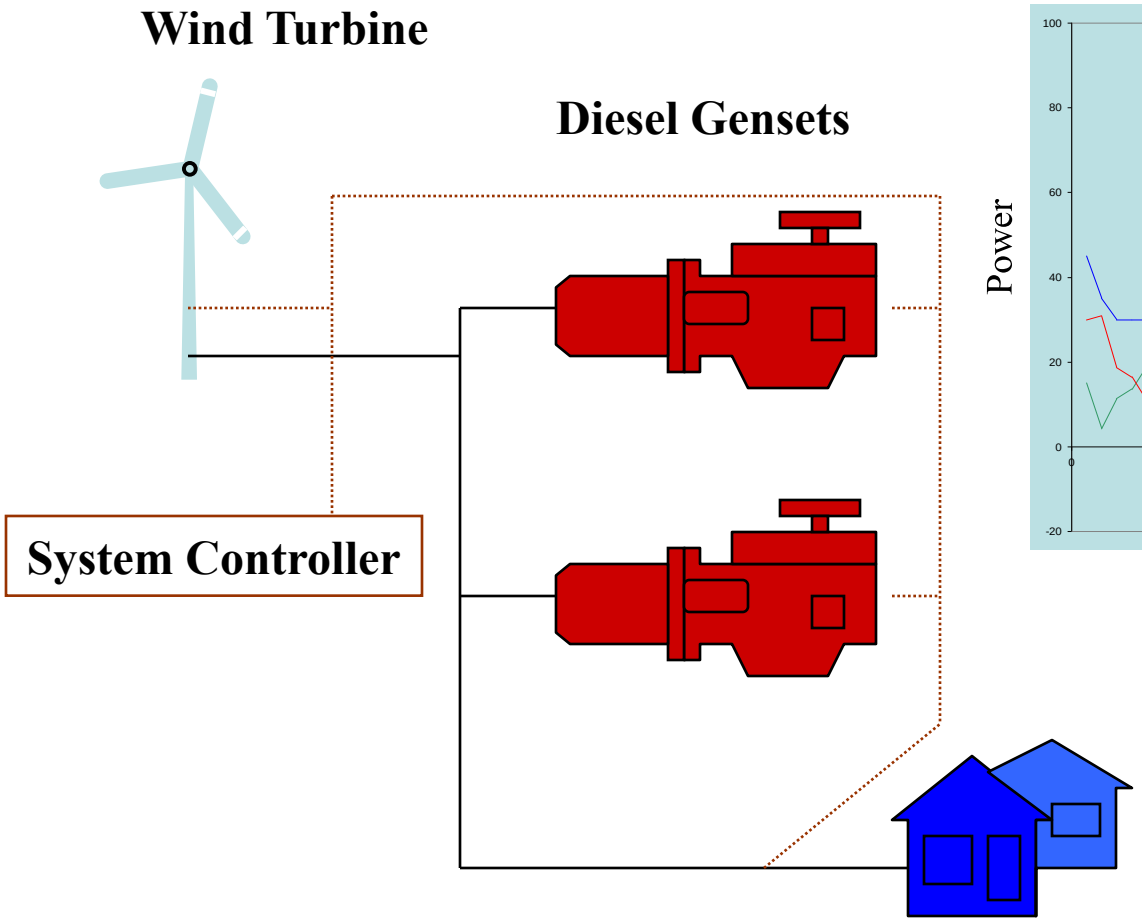
These are really three different systems which should be considered differently

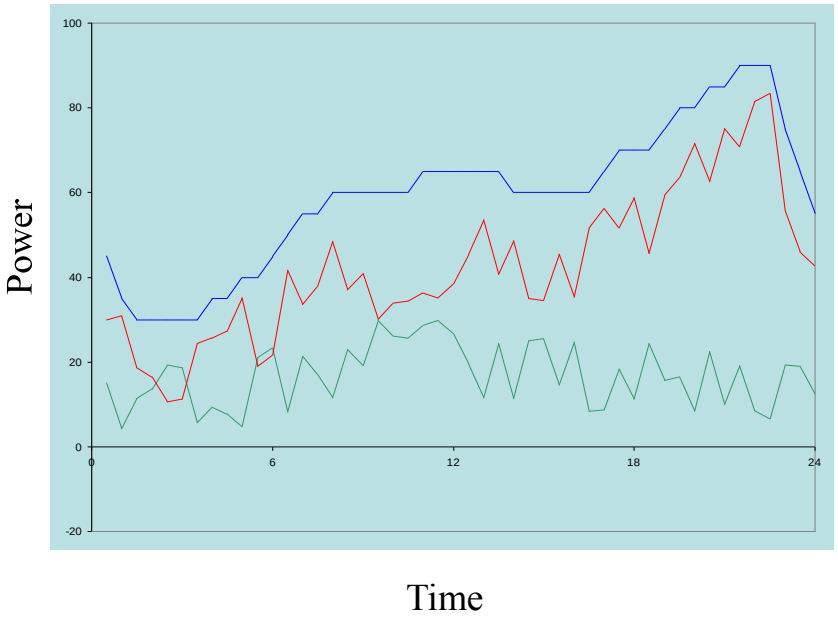
Note: People play loose with the definitions

# Diesel Only Power System



# Low Penetration wind/diesel system



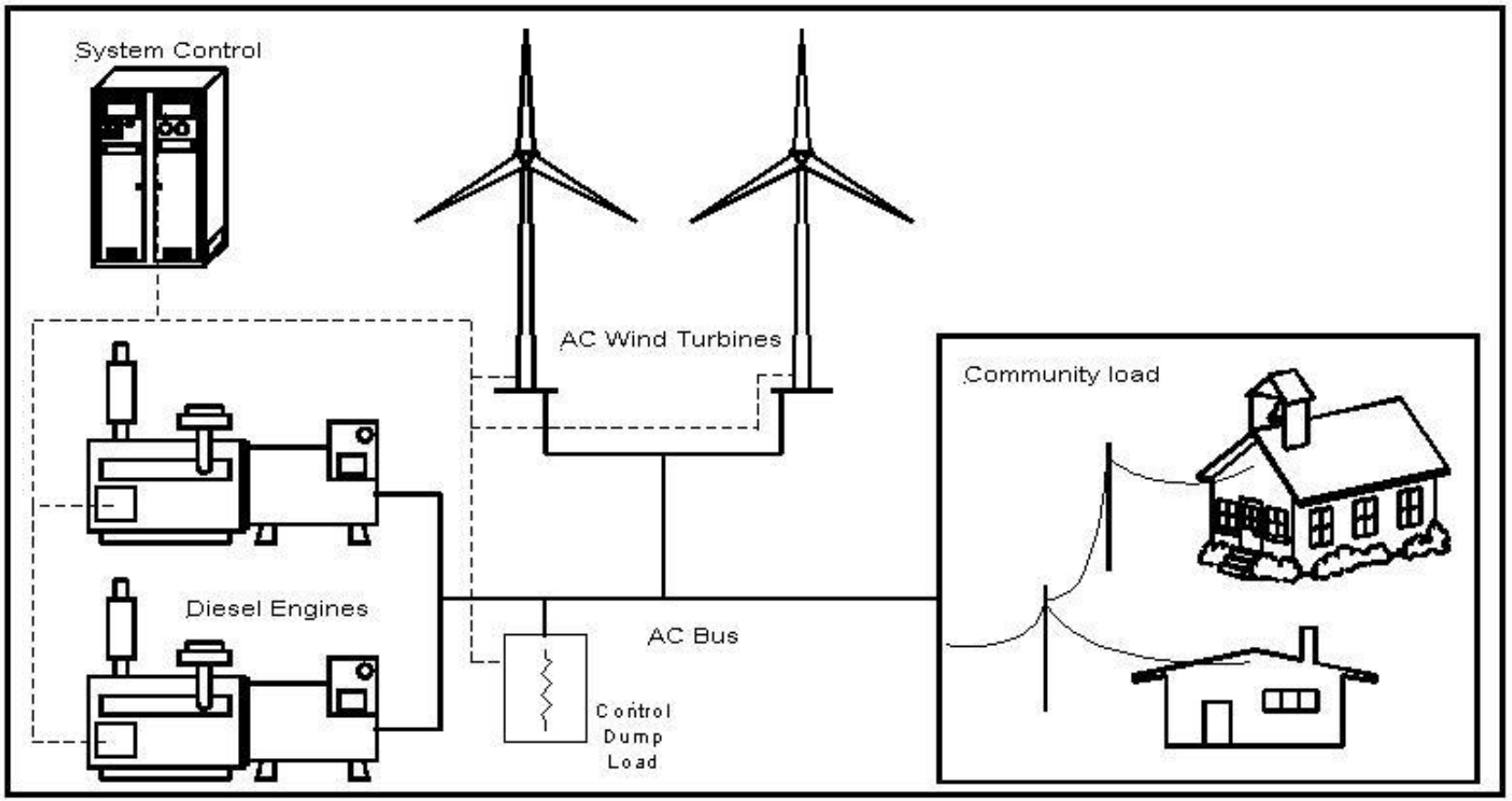
# Kotzebue, Alaska

- Community of over 3000 located above the Artic Circle
- 11 MW installed capacity diesel power station
- 2 MW peak load with 700kW minimum load
- 915 kW wind farm comprised of 15, Entegrity e50, 50kW; 1 remanufactured V17 65kW; and one NW 100/19, 100kW wind turbine
  - Generated ~667,580 kWh from wind last year – saving ~45,500 gal of diesel fuel
  - High turbine availability due to strong technical capabilities of the Kotzebue Electric Association
  - Turbine curtailment used to control at times of high wind output

# Low Penetration

- Generally easy integration with existing diesel system, little or no diesel modifications required
- Diesel engines provide all frequency, voltage and reactive power control requierments
- Switch gear would need to be modified to add turbines and turbine control software installed
- Modest fuel savings of up to ~20% possible.
- System support requirements.
  - Wind turbine maintenance.
  - No change in staffing or potential increase

# Medium Penetration W/D System



# Selawik, Alaska

- Small community in Northern Alaska
- ~830 permanent residents
- Power system operated by the Alaska Village Electric Cooperative
- Average load around 330 kW
- 4 Entegrity e15, 50 kW turbines
- Dump load used to help support system control
- Turbines installed as part of a complete diesel plant retrofit
- Initial reduced wind performance due to a number of issues – low wind resource, system integration issues, and turbine maintenance problems

4 50kW wind turbines sit above the community of Selawik, AK

# Toksook Bay, Alaska

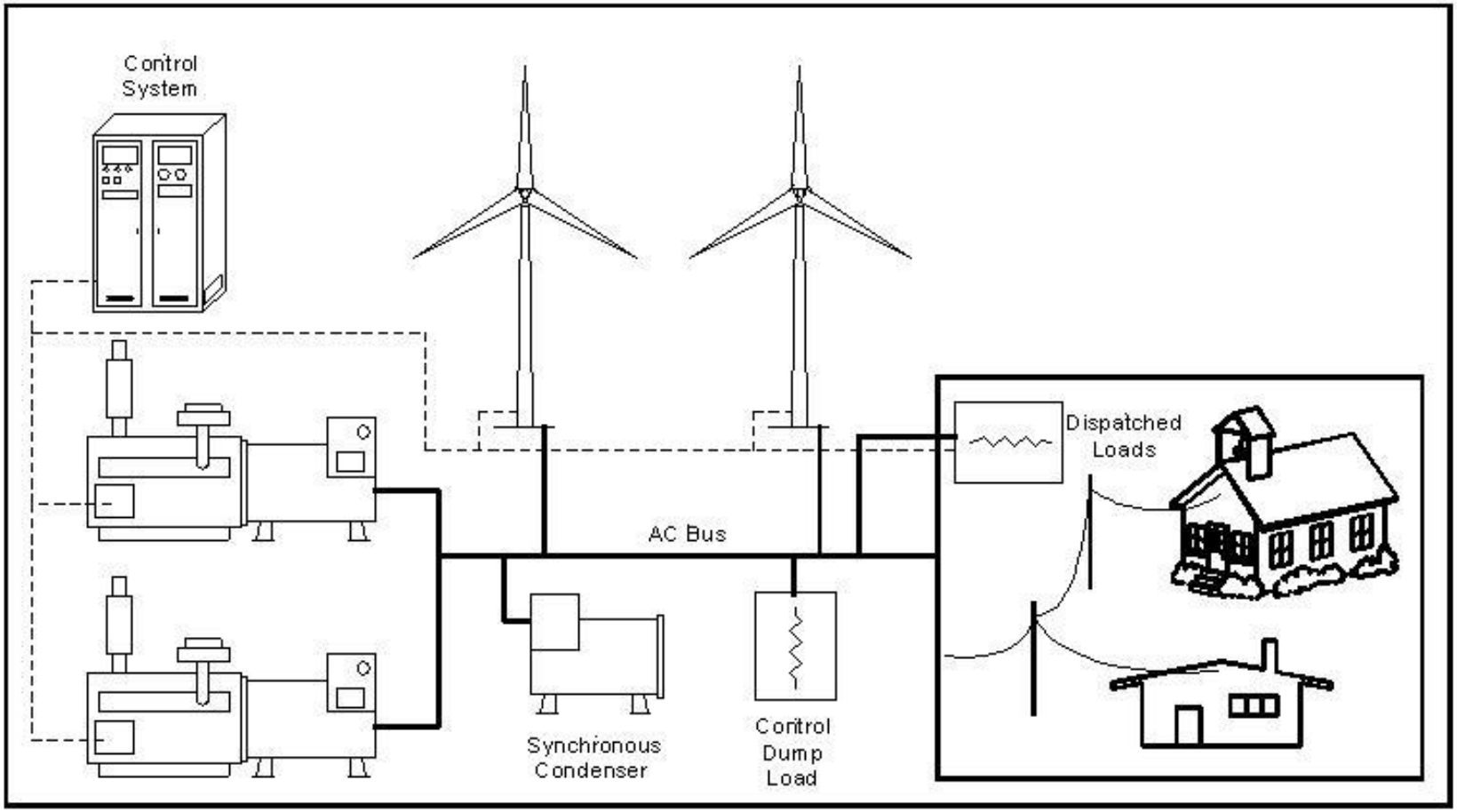
- Small community in western Alaska with a population of ~560
- Power system operated by the Alaska Village Electric Cooperative
- Average load just under 300 kW
- 3 NW100kW turbines and community heating dump loads
- Installed in the fall and winter of 2005/2006
- Just over 20% average wind penetration with much higher instantaneous penetration
- Almost 630,000 kW of wind generated last year

Wind turbines and Toksook Bay

# Medium Pen W/D Principles

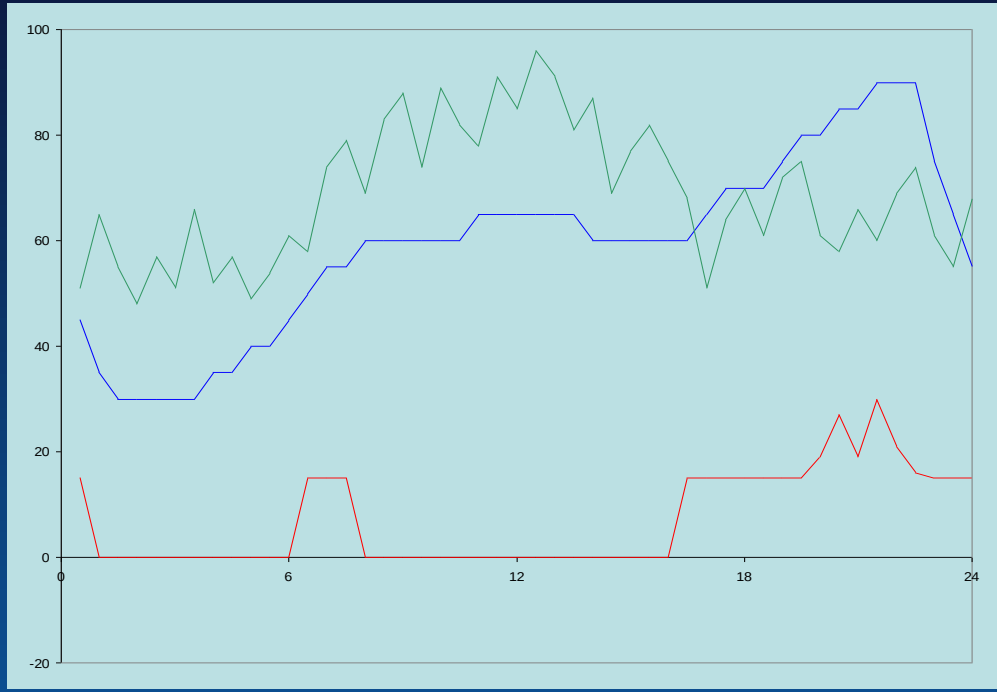
- Wind acts as a negative load on diesels
- Diesel(s) are expected to operate at all times and provide main system stability control
- Will need devices to help control system frequency, eliminate excess energy and provide VAR support
- Lead diesel have advanced control capabilities
- Secondary diesels may be shut off when not needed, reduces diesel operating hours and fuel use.
- In high peak wind periods, primary diesel runs at low loading and/or thermal loads used to set minimum loading
- Diesels may operate outside of their “standard” operating region, not critical but may require more maintenance

# High Penetration without storage



# Operation without Storage

All diesel engines are allowed to shut off when the energy from the wind turbines power is larger than the load by some specified margin




- System frequency maintained by controlled dump and dispatchable loads
- System voltage and reactive power is maintained by synchronous condensers or other conditioning devices
- Active control of turbine output helps reduce variability

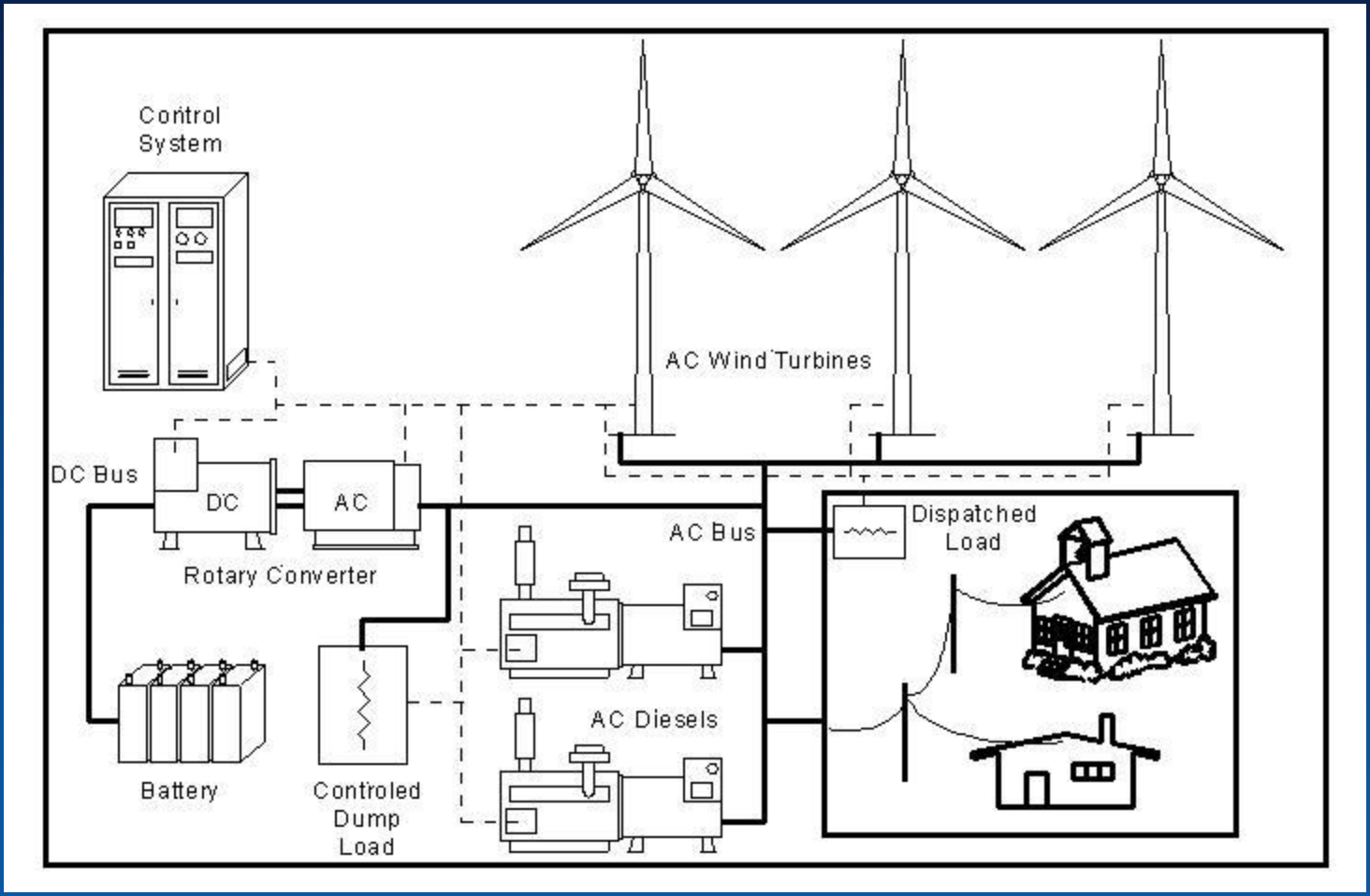
Red = Diesel
Blue = Load
Green = Windpower

# St. Paul, Alaska

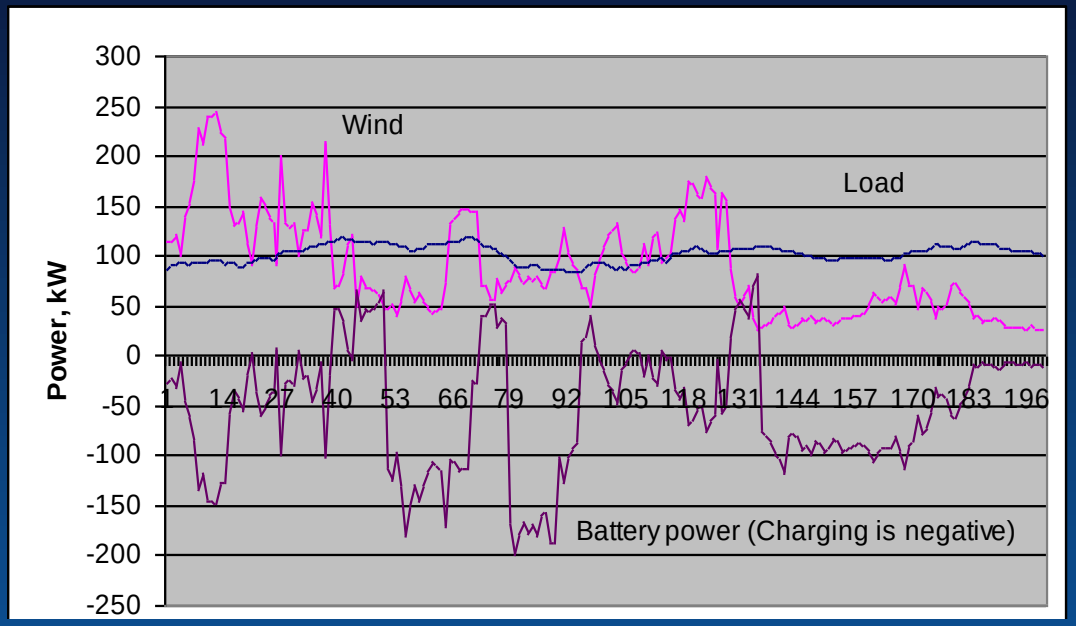
- Island in the middle of the Bering Sea
- Airport and industrial facility, currently expanding to serve local municipality of St. Paul
- 1 Vestas, 225 kW turbines installed in 1999, with two more installed in 07 for municipal expansion
- Current peak load around 200kW
- Waste energy used for heating
- Tanadgusix Corporation (TDX) Power

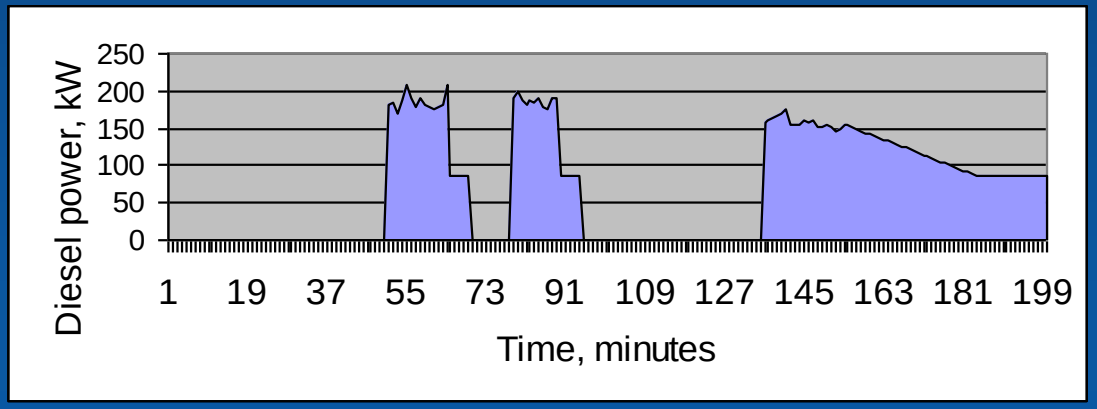
Wind turbine has been used to operate the TDX airport facility, in many cases with all diesels turned off

# High Penetration with Storage



# Operation with Short Term Storage




All diesel engines are allowed to shut off when the energy from the wind turbines is greater than the load

- Short term storage (up to a portion of an hour) is used to fill short gaps in wind energy or to start diesel when required.
- Power converter, flywheel and/or controlled loads used to maintain system voltage, frequency and reactive power requirements

# Wales, Alaska

- Remote community in Northern Alaska with a population ~150
- 70kW average load with 2 AOC 15/50 wind turbines
- Short term battery storage with rotary converter
- Resistive loads used for heating and hot water
- Operation with all diesels turned off
- System has had many problems associated with system complexity, maintenance and confidence of the local population to operate with all diesel engines off line
- Operated by Alaska Village Electric Cooperative with the implementation assistance of Kotzebue Electric Association and NREL

The community of Wales Alaska in summer and winter

# High Penetration W/D Principles

- Use of wind allows all diesel engines to shut down during mid to high wind periods, reducing fuel consumption and operation hours
- Other hardware used to maintain system voltage, frequency, and reactive power requirements
- System controller continually monitors power system and dispatched equipment as needed to maintain system integrity
- Very technology dependent system architecture that required automated operation
- Should include a fail safe operation strategy so if components are not working, the diesel engines can be operated to provide power

# Systems and Components

- Hybrid power systems are made up of separate pieces of equipment that are brought together to form a cohesive power system
- Configuration and component size depend on the load and resource available at site
- Controlling the power systems is a complicated question, both logically and technically, especially as system penetration increases
- Designers must understand the different components and their use

# Dispatchable Generators

- Generators that can be turned on with short notice.
  - Diesel, Gas, Natural Gas, Bio-gas
- Usually require a lot of maintenance
- Role depends on system design.
- Wide range of old and new technology
- Wide range of control

40 kW Diesel Generator

10 kW Diesel Generator w/ Fuel tank

# Wind Turbines for Hybrids

Northwind 19/100

- Range in size from 300W to 750kW
- Large AC turbines for diesel plants
- Small turbines designed for remote applications, generally DC but also AC being developed
- Self erecting or tilt up towers common
- Installed cost $3-6/W with production from $0.10-0.20/kWh

Entegrety e15

Bergey XL10

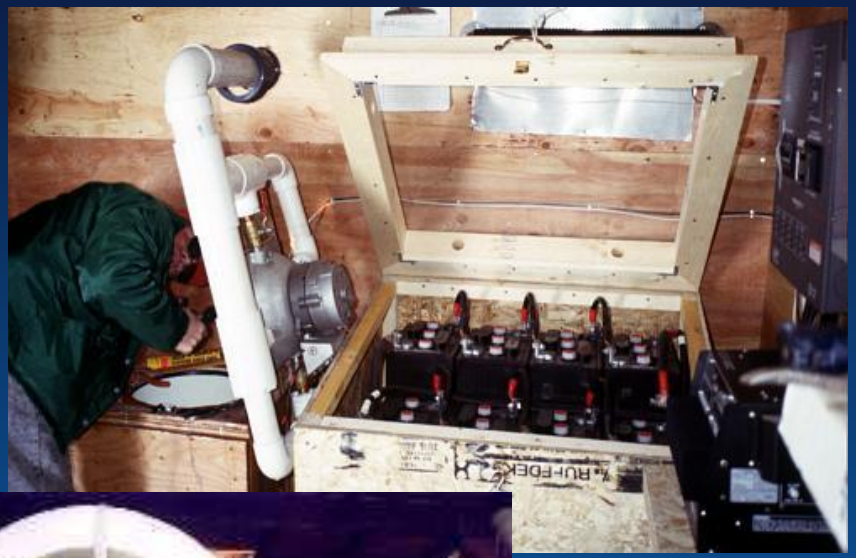
# Photovoltaics

- Applicable for small, remote applications
- Installation cost of ~$10/W, LCC of $0.22/kWh
- Low maintenance requirements
- Quite accepted internationally
- Not used commonly in large applications but there are some examples

PV on Active Tracker

# Micro and Run of River Hydro

- Applicable for areas with a dependable resource.
- Lower head systems available
- Run of river up to 50kW pre-commercial
- Generally larger infrastructure cost



Micro Hydro facility at remote ranch

UEK 50kW flow turbine

# Hybrid System Power Converters

Trace Tech 100 kW converter


Wales AK 156 kW rotary converter


- Convert energy from DC to AC and back
- Some units contain power system control
- Solid state or rotary systems
- Solid state range in size from 1kW to 300kW
- Rotary systems built to size depending on needs
- Combined with batteries for storage

Xantrax 4kW converter

# Batteries

- Many types
  - Lead Acid (deep cycle and shallow cycle)
  - NiCad
- Two uses/sizing:
  - Store energy to cover long periods
  - Store power to cover short periods
- Requires periodic replacement
- Sensitive to environment
- Life dependent on use and the environment


# Other Active Power Control

Flywheels - provide short term energy storage while smoothing fluctuations in wind and load

Low load diesels - operate down to below 10% rated power while maintaining control over voltage and frequency

- Allows active control of grid stability
- Allows access to small amounts of instantaneous power
- Generally modular
- Spinning losses
- Long research history, very short operational experience

# Power Smoothing and Conditioning

- Help to control voltage and balance active and reactive power needs on the grid
- Primarily used when all diesel engines have been shut off
- My provide limited “storage”
- Has a standing loss

Grid Conditioner

Controlled dump loads, synchronous condensers, and grid conditioners to control system voltage, frequency and reactive power

# System Controls and Switch Gear

- The controller makes everything work together
- Generally have central switch gear/controller and then individual controllers for each component
- Operates at very high speed to monitor system stability while allowing general component control
- Can reduce staffing costs while increasing system performance
- Controllers are not created equal – just because they say something is “wind ready” does not mean that it is

# Monitoring and Remote Access

- Remote access allows oversight of system performance
- Enables real time system interrogation and troubleshooting even when off site
- With expert analysis system reduces maintenance and down time
- Small incremental cost

# Issues faced in implementing Alaskan Wind/Diesel Projects

- High cost: Power in rural areas is always expensive, but many elements drive up the cost of wind in rural areas
  - Shipping and stranded installation equipment (Cranes)
  - Turbine foundations in melting permafrost
  - Cost of doing business in rural Alaska
- Community development project: Requires all levels of community support – people, leadership, and existing power company.
  - Projects in several communities have been held up to do internal community politics and power struggles.
  - Provides a general community wide benefit with a generally long return on investment

# Issues faced in implementing Alaskan Wind/Diesel Projects – Continued

- New Technology: Wind-diesel technologies are relatively new, implementation in rural areas can be operationally challenging
  - Power system in Wales has seen extended down time due to control system and community social problems
  - The first wind turbine in St Paul was down for months waiting for contracted maintenance to be completed
  - Ice, snow, and very cold temperatures can impact performance and life of equipment
  - Although some turbines in Alaska are operating at very high availability, there is a lack of a long term track record

# 2008 International Wind / Diesel Workshop

April 23rd to 27th, 2008

Hotel Alyeska in Girdwood, AK

Pre-conference Worshops: Wednesday

Workshop: Thursday & Friday

Power System Tours: Saturday & Sunday

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For more information or to help sponsor visit:
*www.windpoweringamerica.gov/wind_diesel.asp*

# Conclusions

- There are a lot of options / configuration of hybrid power systems using local renewable resources to reduce the dependence on imported fuels for rural electricity generation.
- Its not only the cost of imported fuels that need to be considered - the cost of fuel storage, transportation, and potential environmental impact should be assessed as well.
- Options for larger communities include advanced diesels and control, locally derived bio-fuels & renewable technologies.
- Projects should be implemented with the support of the whole community and as part of energy education/efficiency campaigns.
- Several very successful wind-diesel projects have been implemented in artic areas, but every project is not successful
- Social sustainability issues dominate over technical ones
- Its never as easy as it seems

Renewable power systems, specifically wind-diesel, can be implemented successfully in artic areas