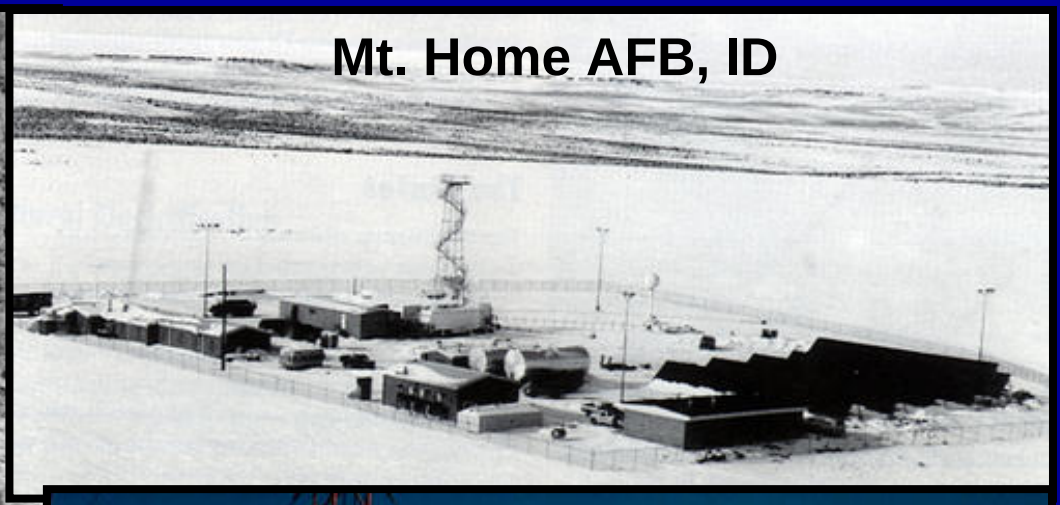
Hybrid Power Systems

Roger Taylor

Hybrid Power System Examples: "Communications"



Hybrid Power Systems

- Hybrid power systems use local renewable resource to provide power.
- Village hybrid power systems can range in size from small household systems (100 Wh/day) to ones supplying a whole area (10's MWh/day).
- They combine many technologies to provide reliable power that is tailored to the local resources and community.
- Potential components include: PV, wind, micro-hydro, river-run hydro, biomass, batteries and conventional generators.

Agricultural Water Pumping

- Livestock watering at the Bledsoe Ranch Colorado, USA
- PV, Mechanical wind and diesel backup solves problems with seasonal variations in resource

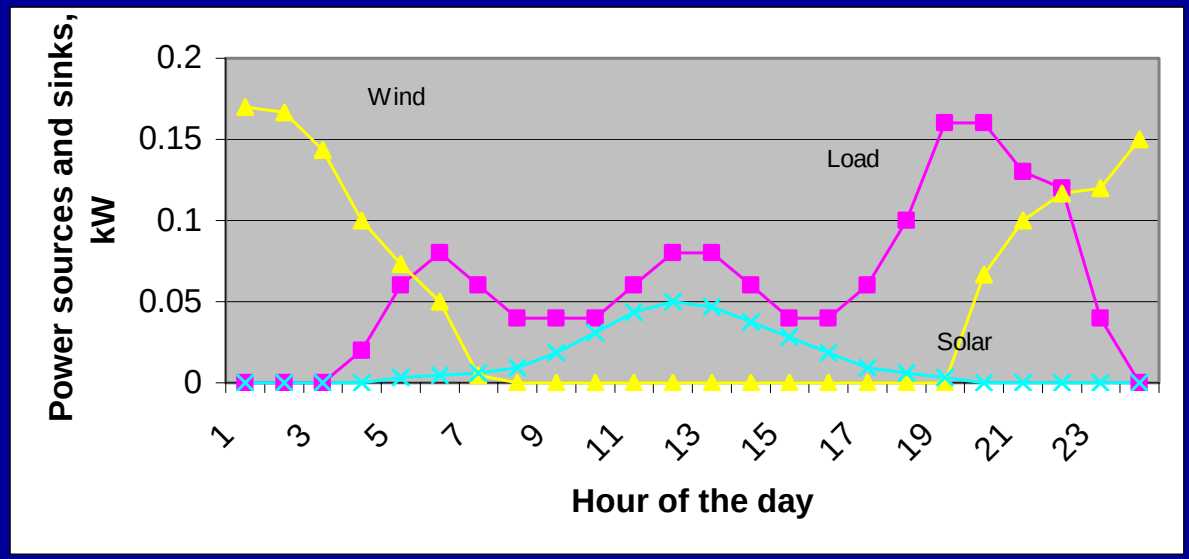
NEOS Corporation

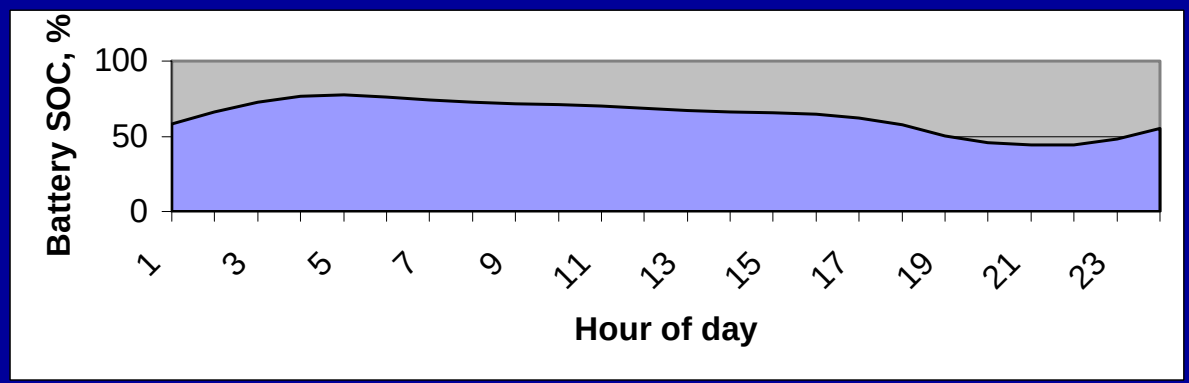
Home Power Systems

- Systems do not have a dispatchable backup generator like most hybrids
- Very simple architecture:
  - Turbine, PV, Disconnects, Batteries
  - DC Loads or AC power through an inverter
- Primarily PV dominated for small loads, wind has potential at larger loads.
- In many instances a combination of PV and wind make most sense
- Can vary in size, power output

Inner Mongolia, Wind/PV Home Systems

Energy Flow for all Renewable Hybrid





Single Home Systems/mini-grids

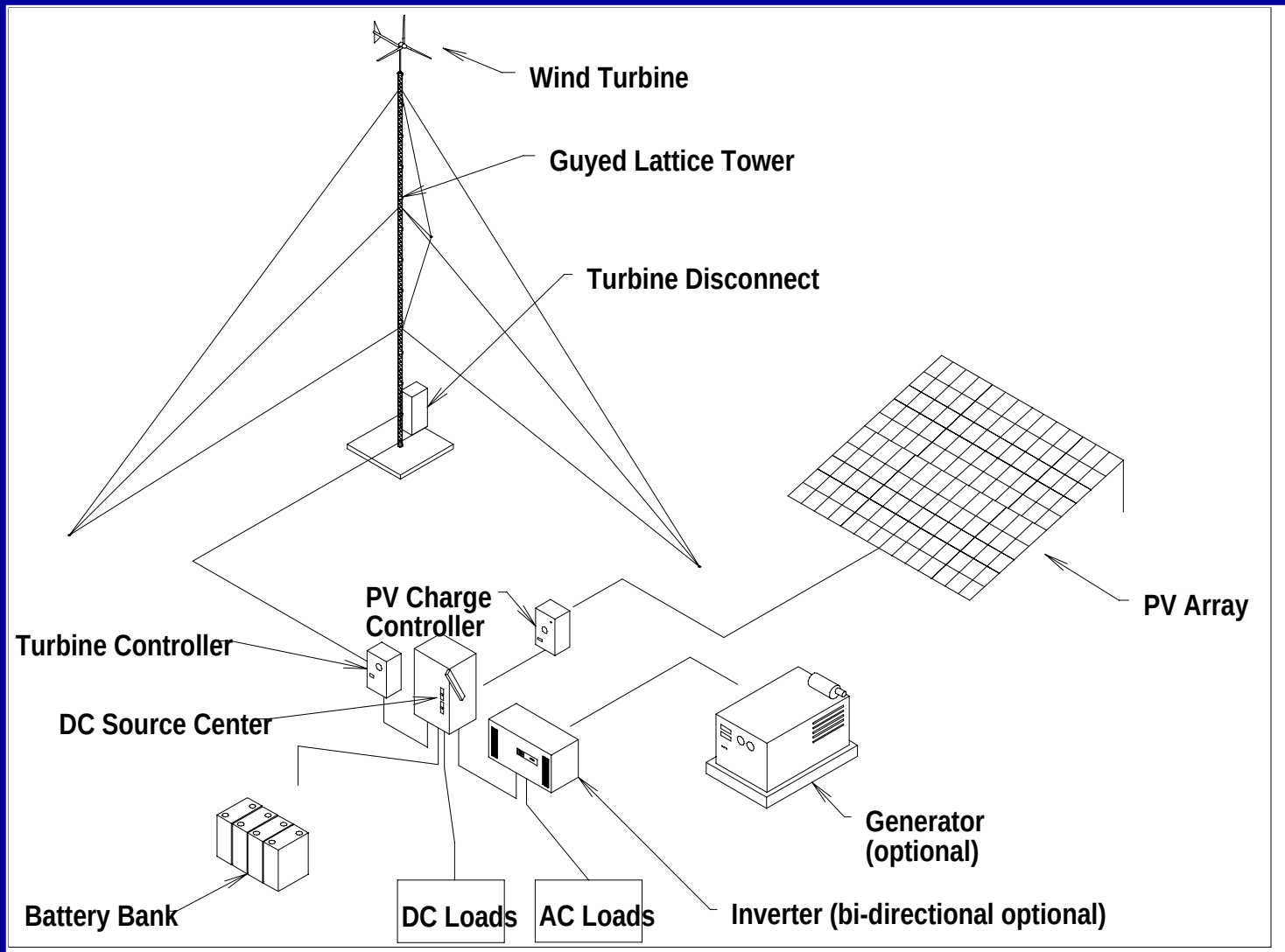
- **Chipepte, Mexico**
  - Windseeker 503
  - 1000Ah, 12V, “No maintenance” Battery Bank
  - < 100W DC Loads
- **Pez Maya, Mexico**
  - 2 AIR Marine 403 turbines
  - 1000Ah, 12V, “No maintenance” Battery Bank
  - 1100W inverter
  - power to a small mini-grid for homes and cottages

Pez Maya

Village Scale Power Systems

- Larger, village scale power systems can further be distinguished into two sizes.
  - Micro-grids
  - Mini-grids
- All have the same feature that they are centrally located and used by the whole community or area through a common distribution system

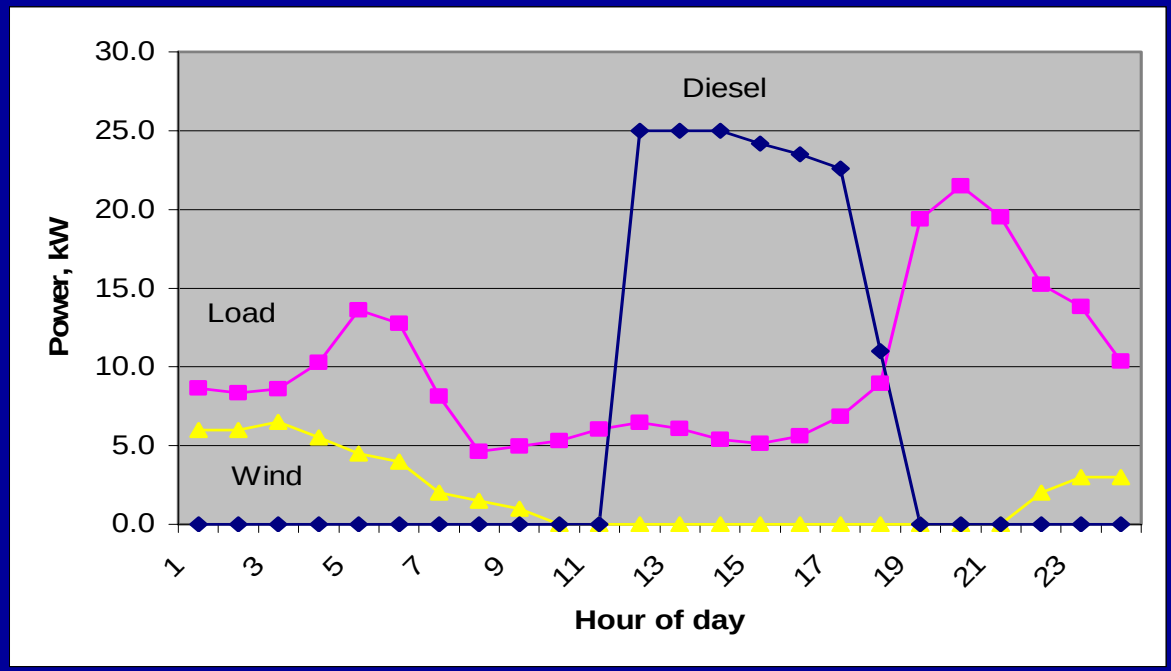
Micro-grid System Architecture

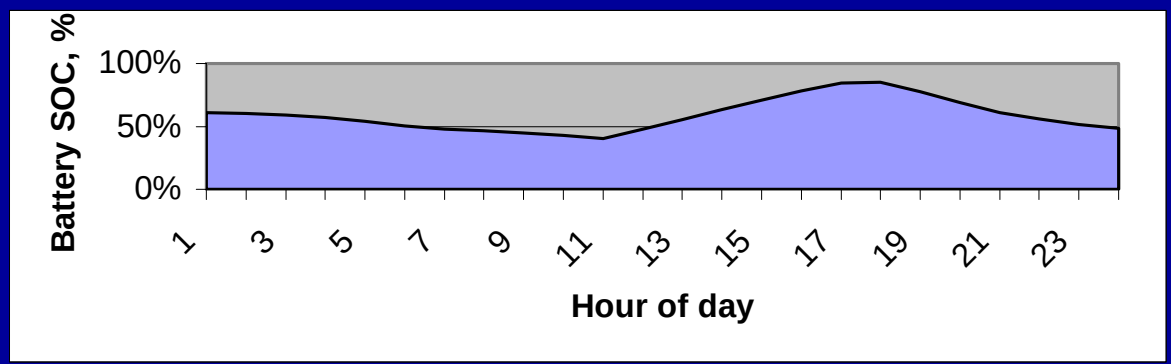


Micro-Grid Power Systems

- Small systems with demands up to ~100kWh/day load (15 kW peak load)
- Components of wind, PV, batteries and conventional generators
- Provide AC and potentially DC power
- Use of batteries to store renewable energy for use at night or low renewable times
- Generator used as backup power supply
- Mature market

Energy Flow for Small Hybrid





Sunwize Power System

- Whisper 3000 wind turbine
- 1.8 kW PV (Siemens)
- 5.8 kW diesel generator
- 25.6kWh battery bank
- 2-SW4048 4kW inverters

Santa Cruz Island, California, USA

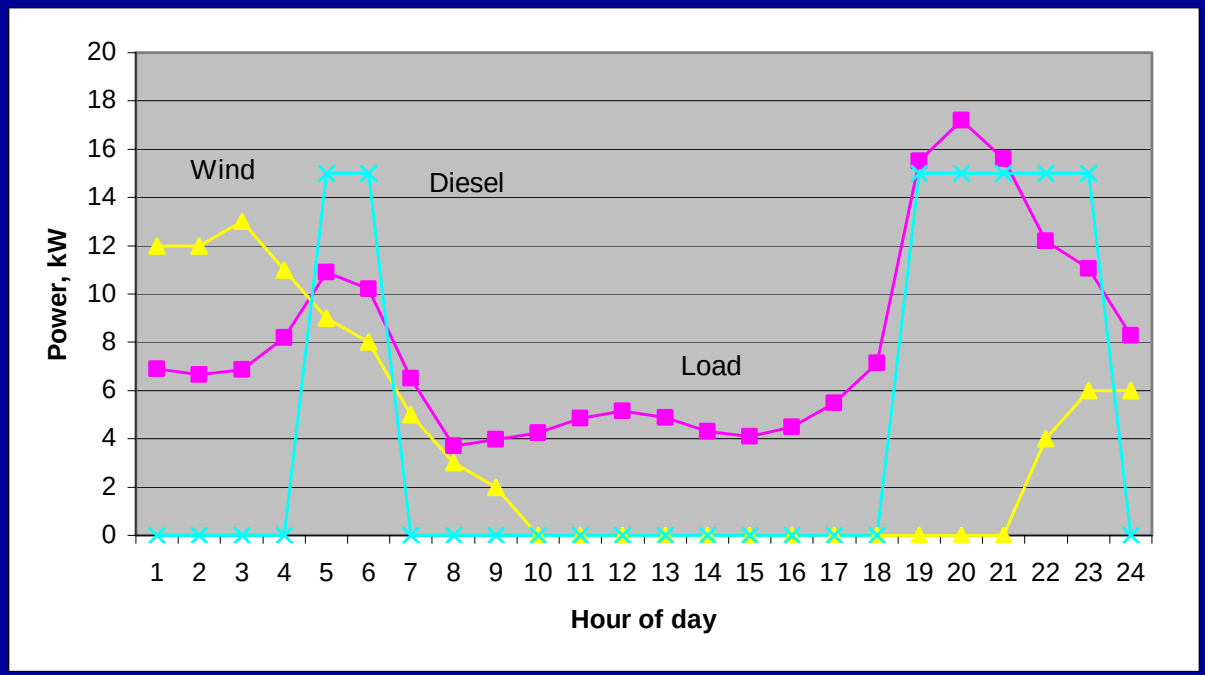
- Remote Telecommunications station
- Power System
  - PV array
  - Two wind turbines
  - No Backup generator
- Vary costly access/site visits
- Remote operation and monitoring of system

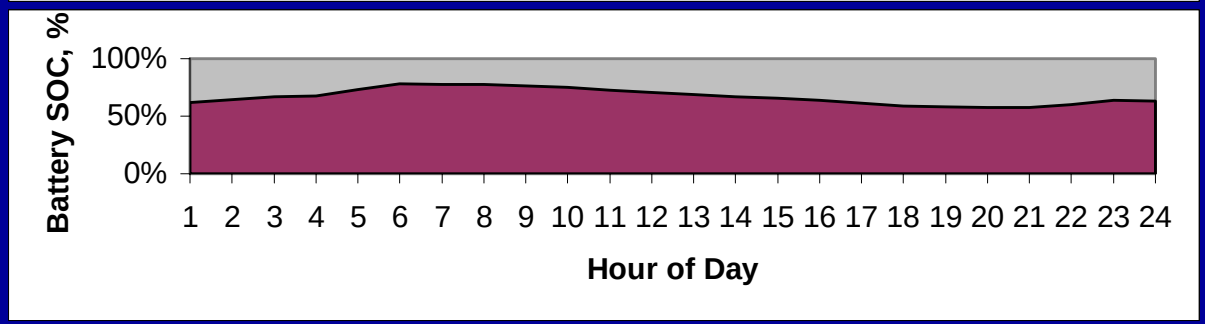
Northern Power Systems

Mini-Grid Power Systems

- Larger systems with demands up to ~700kWh/day load (100 kW peak load)
- Same components used as in Micro-Grids, just more of them and larger
- Use of batteries to store renewable energy for use at times of light loading
- Generator used to supply large loads
- Mature market though fewer examples
- Provide AC power

Parallel System - Smaller Diesel

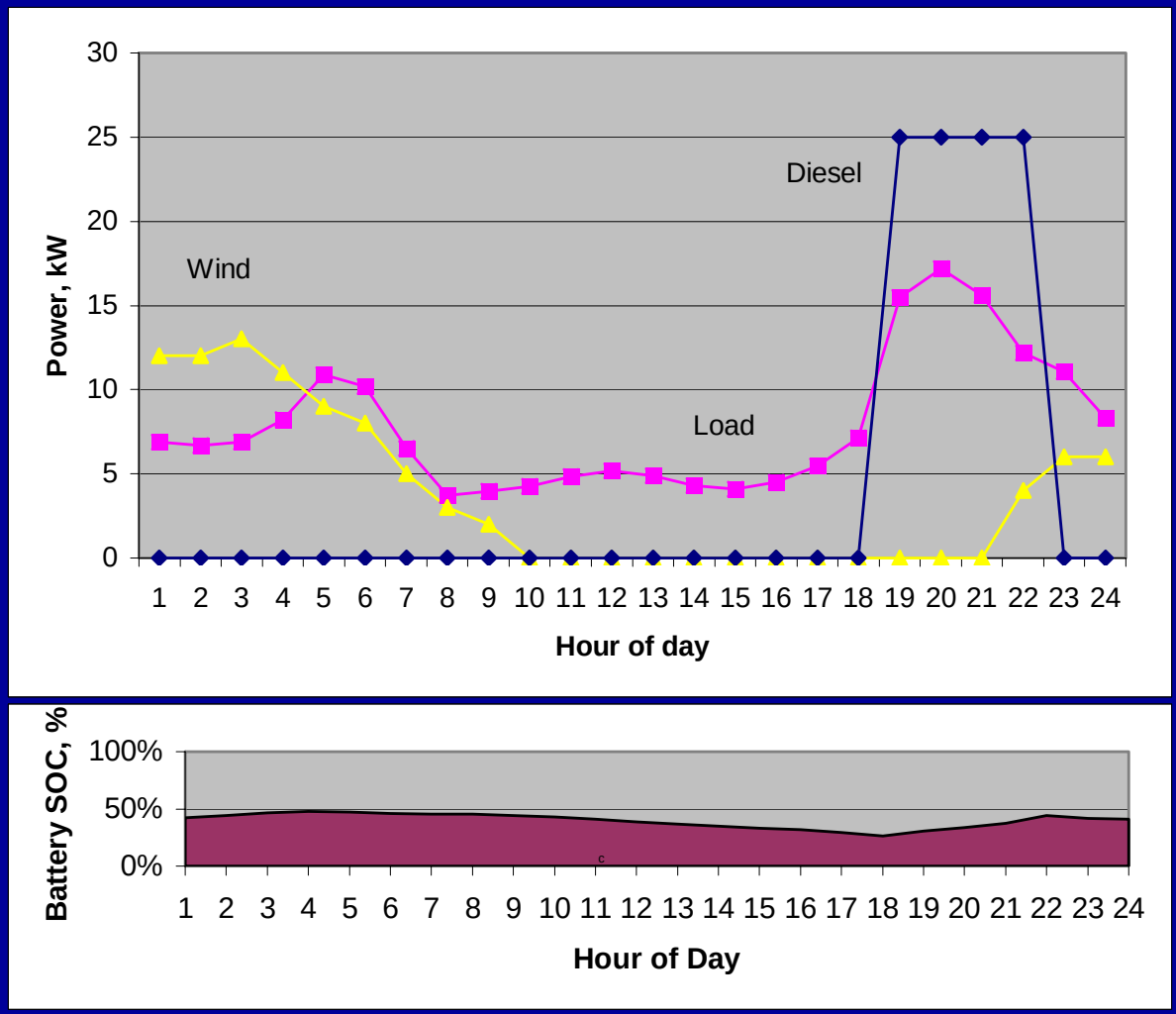




Both diesel and inverter needed to cover the maximum load.

Both units run together.

Switched System - Larger Diesel



Both diesel and inverter sized to cover the complete load. Only one runs at a time.

Village power system in Joanes, Brazil

Remote village the Island of Marajo

50kW Power System

- **PV array**
- **Four wind turbines**
- **Backup generator**

Northern Power Systems

Power system used to support local grid

Hybrid Power System Examples: "Parks"

Dangling Rope Marina, Lake Powell, UT (160 kW PV/Propane)

Hybrid Power System Examples: Xcalac, Mexico

Now Running on Diesel Only

60 kW Wind, 12 kW PV, 40 kW Inverter

Hybrid Power System Examples: Campinas, Brazil

50 kW PV
50 kVA Inverter
300 kWh Batteries

San Juanico, Mexico

Remote fishing & tourism community of 400 people

Power System

- 17 kW PV
- 70 kW wind
- 80 kW diesel generator
- 100 kW power converter/controller
- Advanced monitoring system

Wind-Diesel Power Systems

- Larger systems with demands over ~ 100 kW peak load us to many MW
- Based on an AC bus configurations
- Batteries, if used, store power to cover short lulls in wind power
- Both small and large renewable penetration designs available
- Large potential mature with fewer examples
- Provide AC power

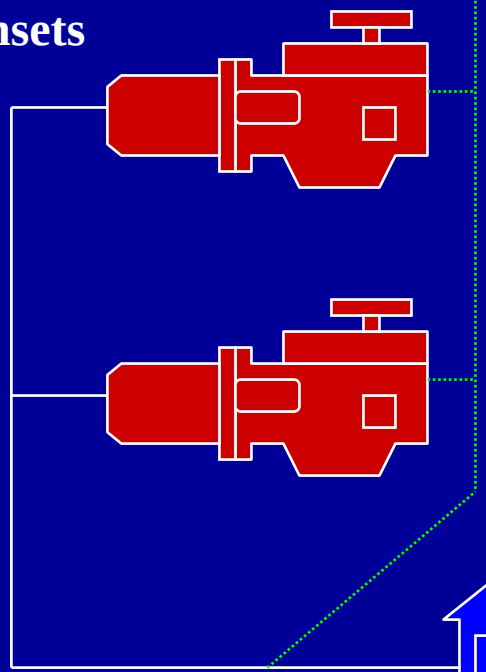
Wind-Diesel System Penetration Ranges

	Low	Medium	High
Peak Instantaneous	<50%	50 – 100%	100 – 400%
Annual Average	<20	20 – 50%	50 – 150 %
Commercial status	Fully utilized	Well proven Fully commercial Multiple use	System prototype Operating
Examples	Denmark, Greece	San Clemente, CA Kotzebue, Ak Coyaique, Chile	St. Paul Wales Ak

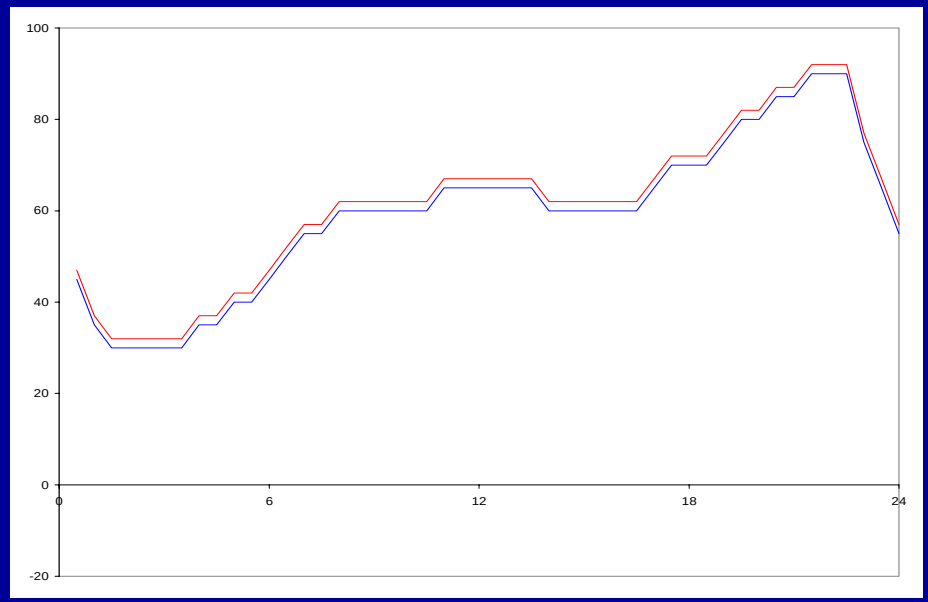
Diesel Only Power System

System Controller

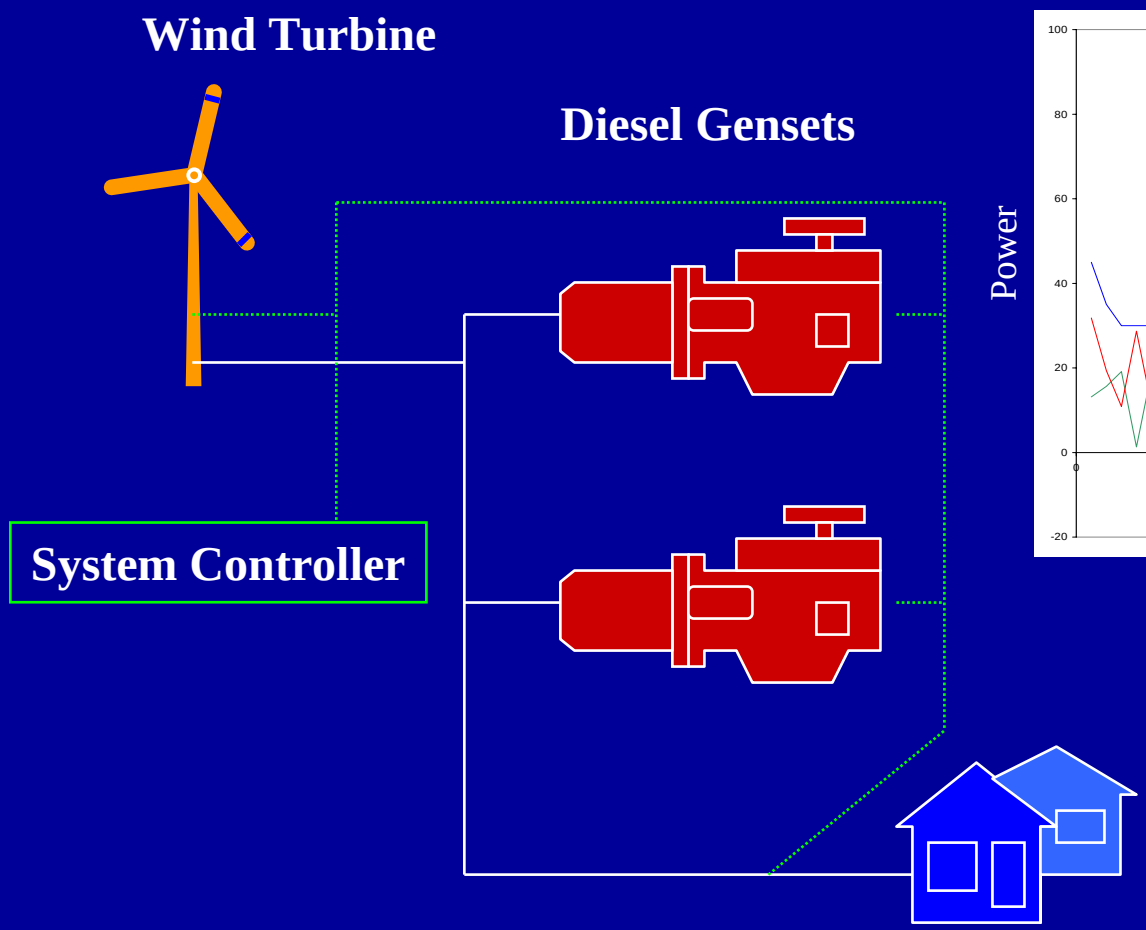
Diesel Gensets

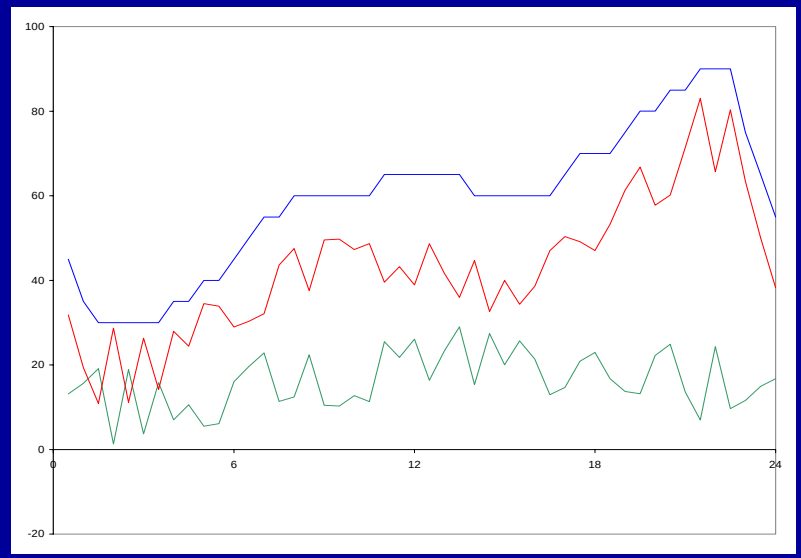


Village Load



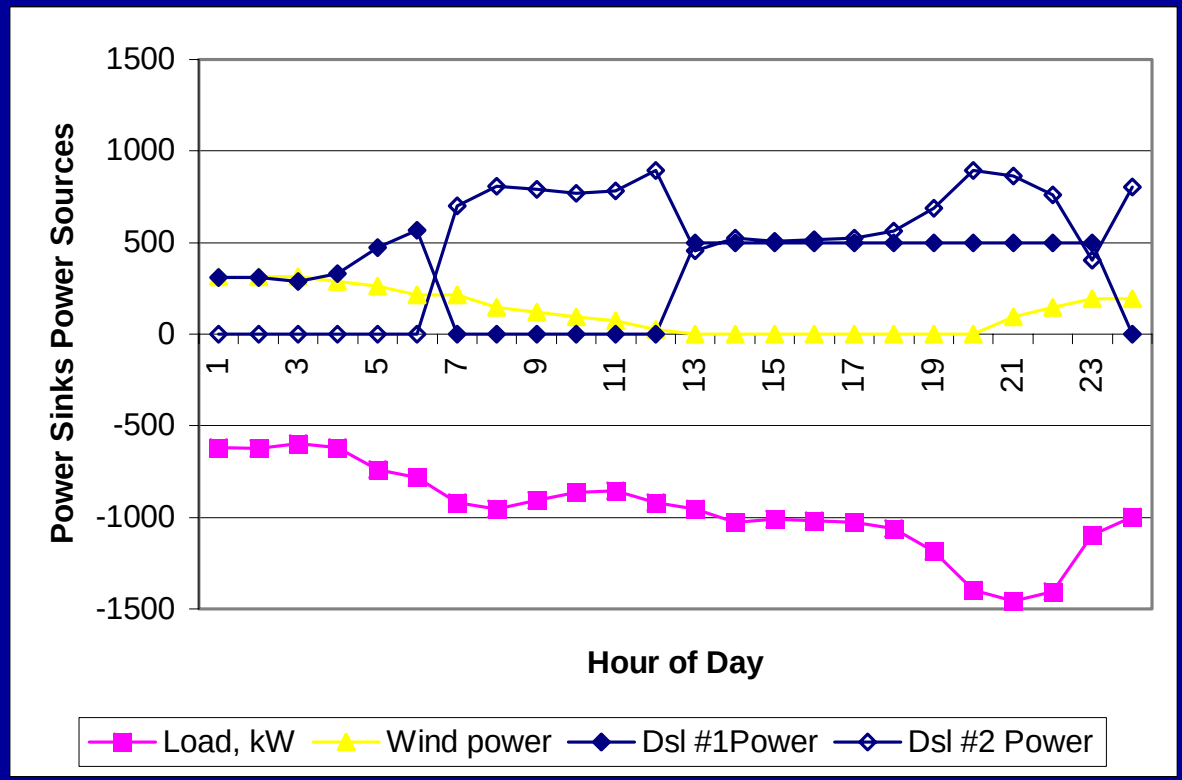
Low Penetration wind/diesel system





Multiple diesel plants with control

In multiple diesel systems the diesels may be dispatched to take advantage of the renewable energy. Requires automatic diesel control.



Ascension Island

Four NEG-Micon 225 kW turbines installed in 1996.

- **U.S. Air Force installation on British island in mid-Atlantic ocean.**
- **Prime diesel generation with rotary interconnect to British 50 hertz system**

Coyaique, Chile

Isolated Community

Private Utility

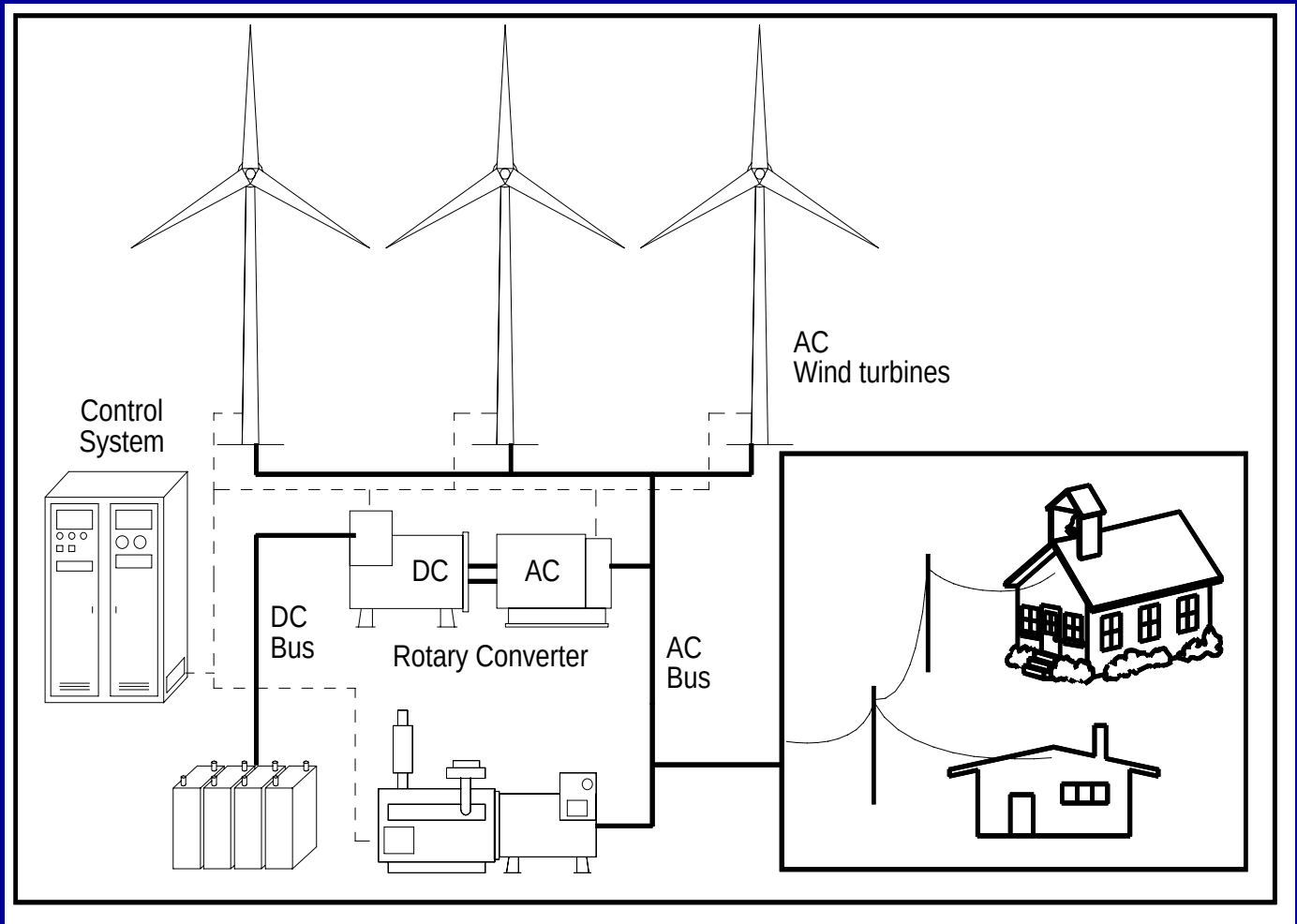
- 2 MW Wind, 4.6 MW Hydro, 16.9 MW Diesel

Remote installation

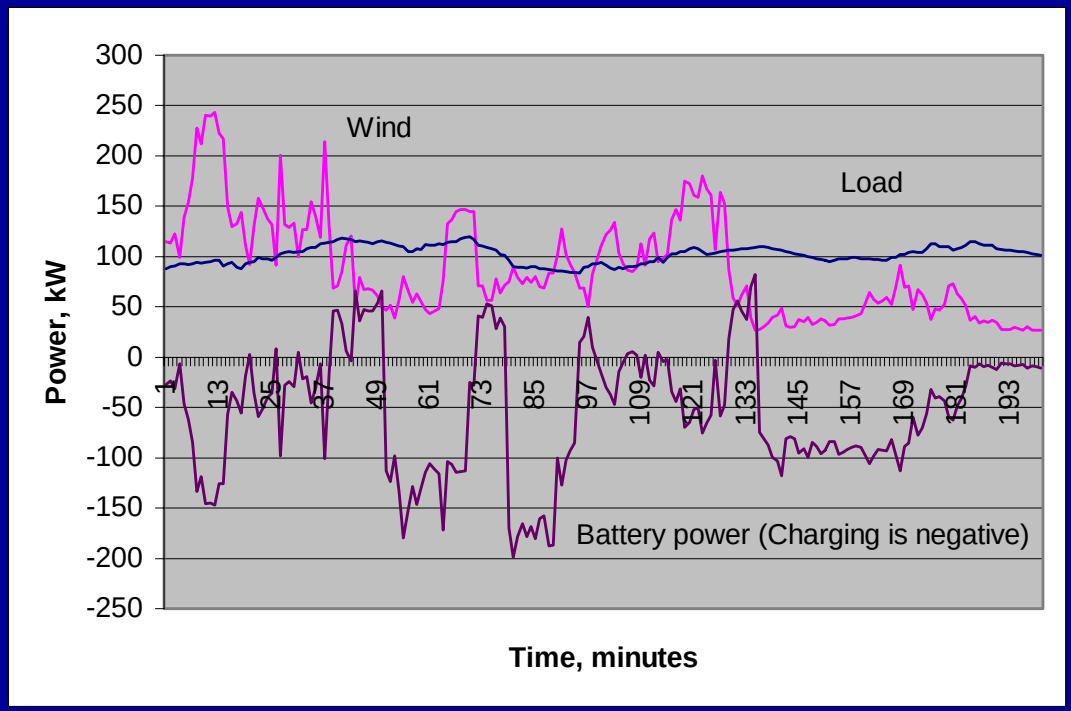
EDELAYSEN S.A.

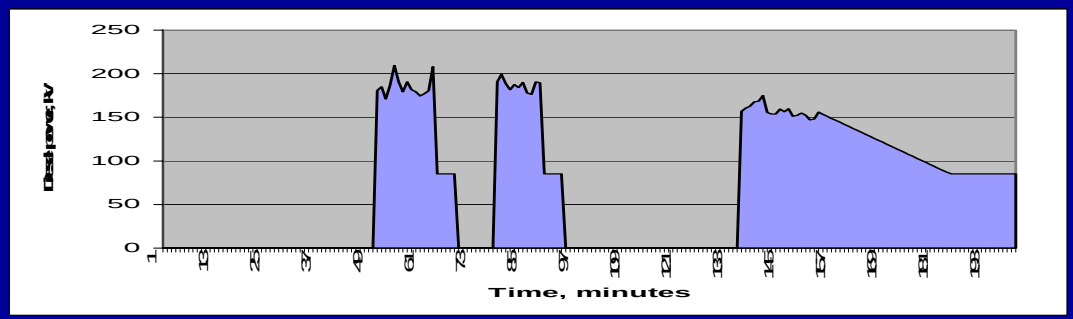
saesa
LA LUZ DEL SUR

High Penetration Wind-Diesel with storage



Wind/Diesel with short term storage





- Diesel used to provide power to system when the wind can not cover load.
- Battery used to fill short gaps in or to start diesel

Wales Alaska Wind Diesel System

High penetration system

- 80kW average load with 130kW of wind power
- Short term battery storage
- Resistive loads used for heating and hot water

Wales Alaska

Wind Turbines
(Induction, Stall-Regulated)
2 X 65 KW = 130 KW

Diesel #1
142 kW

Diesel #2
75 kW

Diesel #3
148 kW

Battery Bank
240 VDC, 130 Ah
~30 kWh

DC

AC

Rotary Converter
156 kVA

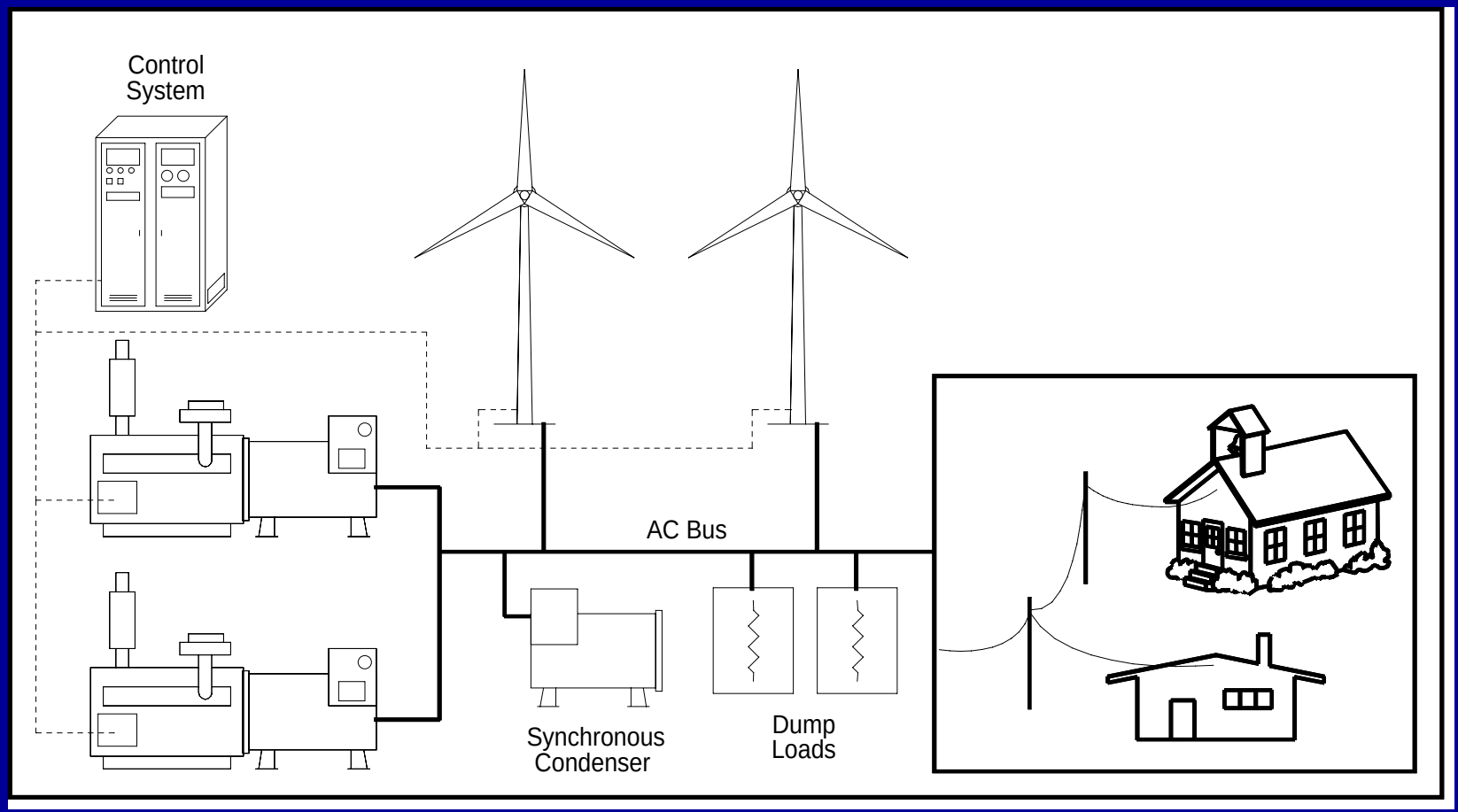
Secondary Load
Controllers

School Heating
System

Resistance
Heaters

Diesel
Plant
Hydronic
Loop

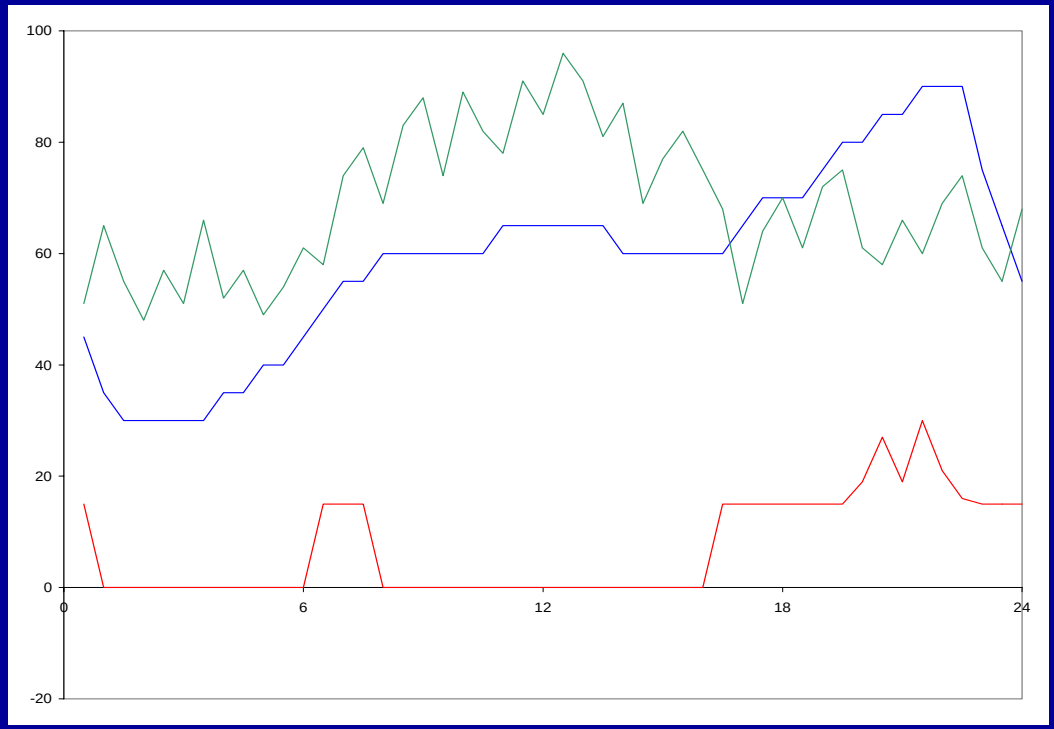
Schematic of Wind-Diesel without storage



Wind Diesel without Storage

When the wind power is larger than the load by some margin - Diesel is shut off.

- Frequency controlled by dump load
- Voltage controlled by condenser



Red = Diesel

Blue = Load

Green = Windpower

St. Paul Alaska, USA

Island in the middle of the Bering Sea
Peak load of 160kW
Cost of Power, ± $0.21/kWh
Waste energy used for heating

St. Paul Power System

- **225 kW Wind Turbine**
- **2 x 150 kW Diesel Gensets**
- **Digital Engine Controls**
- **NPS Components**
  - System Controllers/ RemoteView™
  - Synchronous Condenser
  - Heating and Thermal Plant
  - Integrated Shelter
  - Dump Load Regulator

Key Points of Large Hybrid Systems

- **Differences in Energy Storage**
  - Long term energy storage: Larger battery bank to transfer energy from one time to another. Order of hours.
  - Short term power storage: Energy used for very short periods to provide grid stability and allow controlled diesel engine starting. Order of minutes.
- **Power Quality issues**
- **System Control**
  - DSP based advanced control is required

Power Balancing Alternatives

- **Control wind generation:** mechanical pitch control, electronic control, individual machine switching in multiple machine windfarms.
- **Dispatchable Loads:** Installations of controllable incremental loads like resistance heating to consume extra power.
- **Load shedding** where non-critical loads are temporarily shut off to quickly reduce system load.

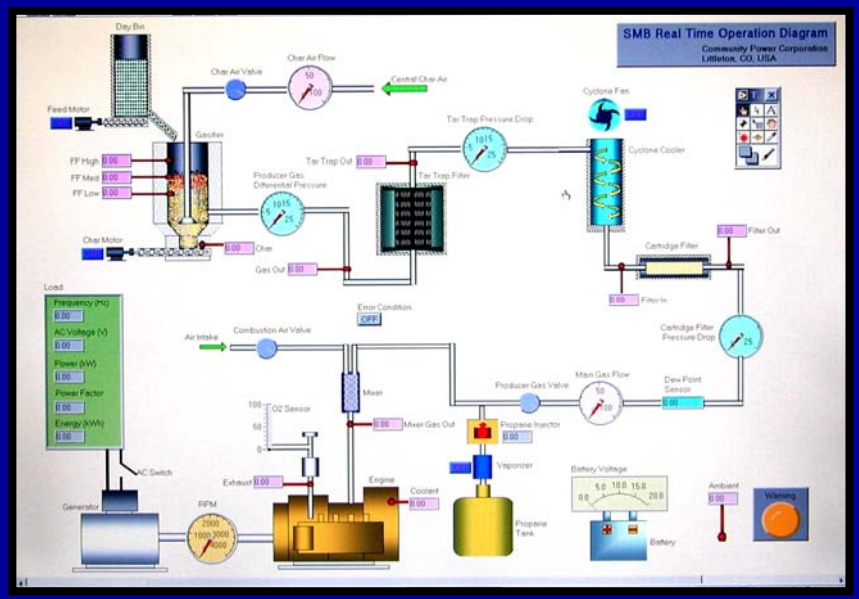
More Power Control Alternatives

- Back-driving the diesel generator, a process where power is actually put into the generator to overcome the generator losses while keeping the generation running so that it can be loaded quickly. Installing systems, like block heaters, to allow quick starting of generators.
- Installation of a synchronous condenser or rotary converter, which is used to produce reactive power
- Installation of a capacitor bank to smooth out rapid power transients and partially correct the systems power factor

Conclusions

- Lots of options for the configuration of hybrid systems - Depend on load, resource, and costs.
- Medium penetration wind-diesel systems are operating in various isolated locations around the world. Instantaneous wind penetration levels exceeding 50% of load are common.
- Several high penetration systems, with and without energy storage, have been successfully demonstrated.
- High penetration systems are capable of prolonged diesel-off operation.

CPC's 5 to 25kWe
Small Modular Biopower System



Village Power Hybrids

Simulation Models for Options Analysis