Integration of Wind into Diesel Power Systems

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Key Issues with Wind Diesel Systems

- Power Generation and Transmission
  - Penetration
  - Power Quality
- System Operation
  - Use of renewable energy when you have it
  - Issues of minimal loading on diesel engines
- System Maintenance
  - Level of system maintenance required
- The act of integration
  - Best to do a complete system retrofit
  - Always better to start with the plan to incorporate wind from the start

Issues of Power Generation and Transmission

- Power Quality of Systems
  - Variable renewable penetration of system
  - Power flow questions
  - Voltage variation on feeder lines
  - Level of technology/control existing in diesel plant

If at any time you are not producing enough power, power system will collapse

Complication with Uncontrolled Generation

Why are hybrids a complicated control question and need special attention in regards to power quality?

- By their nature renewables are stochastic (uncontrolled) and vary with the resource. The amount of variation and thus the amount required control depends on the renewable resource being used and the power system design
- Wind, river run hydro and solar technologies require adequate control to allow integration and insure power quality

System Penetration

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

These are really three different systems which should be considered differently

Elements of Power Quality

- Power reliability: Having power when you should have it.
  - System failures / Unscheduled blackouts
- Power Quality: Is the power supplied good enough for the needs.
  - Voltage and frequency within acceptable limits
  - Ability to supply reactive power needed for motors
  - Harmonic distortion – is the sub-cycle quality of the power acceptable to loads

Power Reliability

Is the power reliable?

- Driven by system maintenance, designed component redundancy, proper plant control and having enough capacity on line to meet the load
- All of these are factors that impact diesel plant reliability now - plant design, equipment age, and experience of station staff play a large part in ensuring operation
- Adding wind technology adds more components and makes the task more complicated
  - Clearly depends on the penetration of the system
  - More/new equipment to maintain
  - New processes and operational considerations
  - More complicated plant management and seasonal dispatch

Power Quality

If the power quality is poor, some loads will be negatively impacted and eventually the power plant or generators will trip off line – meaning that the lights will go out.

The prime elements of concern are

- **Voltage:** Amplitude of the power wave form. Generally maintained by the manipulating the electric field of rotating equipment (like generators or synchronous condensers) but can also controlled using solid state devices such as power control units.
- **Frequency:** Maintaining a balance of power supply and demand; to much power the frequency goes up, not enough and the frequency goes down. Generally controlled by the throttle of the diesel but can be implemented through combination of thermal loads, dispatchable loads, and power storage.

Power Quality – Continued

- **Power Factor maintenance & Reactive Power supply (VAR Support):** All impedance devices (motors, florescent lighting, electronics) require both active and reactive power. The power system must be able to provide reactive power and balance power factor. Normally done by the diesel but can be assisted or replaced by capacitor banks, synchronous condensers or advanced solid state power converters
- **Harmonics Distortion:** The quality of the power that comes down the line and can impact electronic devices.. Most rotating machinery provide high quality power harmonics (the power is very smooth) but the addition of more low quality loads and low quality electronics can increase distortion. This is generally addressed in the selection of power electronic equipment employed in the design of the power systems and continued assessment/tuning.

Maintaining High Power Quality

- Maintaining a high level of power quality is dependent on obtaining ways to control what is happening.
- Depends on
  - Configuration: Integrated solid state power power converter and controls, no storage with dump loads
  - Type and age of equipment: Diesel electronic and fuel controls
  - System integration: Overall system control
- There are supply and demand side solutions to this problem

Supply Side Options

Options that affect only the power system as seen from the grid

- Controlled Dump Loads: Fast acting devices that help to balance the generation and load
- Synchronous Condenser: Provides reactive power and controls voltage.
- Power Storage: Flywheels or advanced power converters and small battery bank: Used to assist in managing power flows, power smoothing.
- Active Power Control Devices: Monitor grid condition and act to insure high power quality
- Active Renewable Control: Control power output of the renewable device. Power control or simply turning off some of the units

Active Renewable Control

Control of the offending power generation device to smooth out power output.

- Controlled shut down of renewable devices during high wind or low load periods
- Active power control of renewable technology.
  - Variable speed technology using power electronics
  - Active wind turbine control, variable pitch blades
- Resource smoothing using multiple units
  - smaller turbines spread out over a greater area
- Short and long term forecasting of system power

Demand Side Options

Control options that can be completed on the grid side to support system power quality

- Load Dispatching: Active dispatchable of specific loads and making the distinction between critical and non-critical loads
  - Dispatchable loads like resistance heating
  - Loads shedding where non-critical loads are turned off
  - Protection of sensitive loads
- Capacitors Banks: Installation of capacitors to smooth out rapid system fluctuations and partially correct systems power factor.
- Active Load Control: Replacing large inefficient loads with better or different devices

Active Load Control

This principle may not be applicable in every setting and requires a higher degree of collaboration between the energy supplier and energy consumer

- Specific Use Applications: Working with high energy users to insure that equipment is operating properly. An ounce of prevention is worth a pound of ___
- Water Heaters: In many communities electric water heaters are a large source of energy usage which can be controlled
- Variable Electric Rates: Accounting for the different production costs of energy

System Operation

How complex is it to operate these power systems?

It really depends on what type of system you are talking about…

System Operation

Low penetration systems

- Can be operated as two independent power systems (wind/diesel), though active integration is preferred.
- Operators in full control of power system and use individual unit controls to turn components on and off as needed.
- May have some data monitoring to keep track of what has happened

Coyaique, Chile

- Large regional distribution system
- 3x 660 kW wind turbines
- 4.6 MW of mixed hydro
- 16.9 MW of diesel

- Manually operated through local control center
- Turbines turned off during low load or high wind pereods

System Operation

Mid penetration systems –

- Really must be operated as an integrated power system
- Minimal supervisory control required
- Some components in addition to the diesel used to maintain power quality
- Monitoring becomes more important

San Clemente Island, California

- U.S. Navy island off San Diego
- Diesel powered grid
- 850-950 kW avg; 1,400 kW peak with 775 kW wind

Older diesels require the use of a synchronous condenser to maintain voltage

System Operation

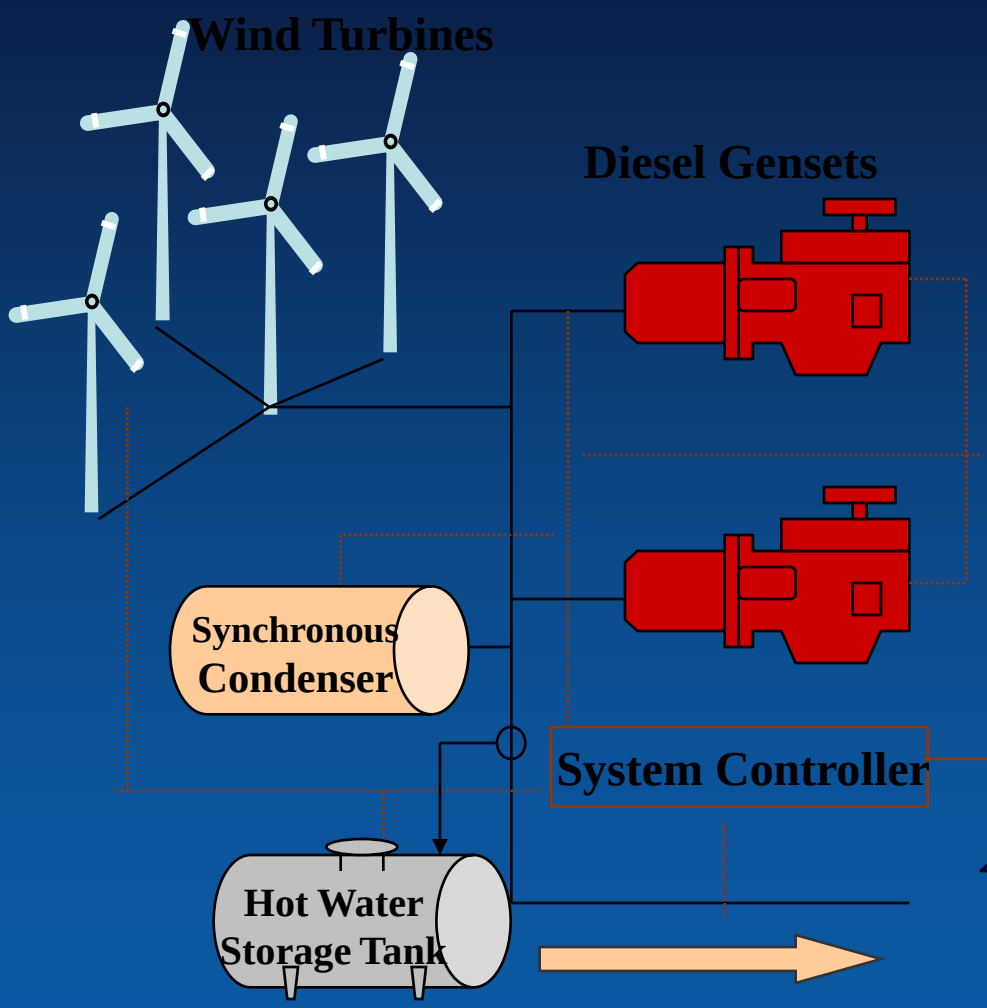
High penetration systems

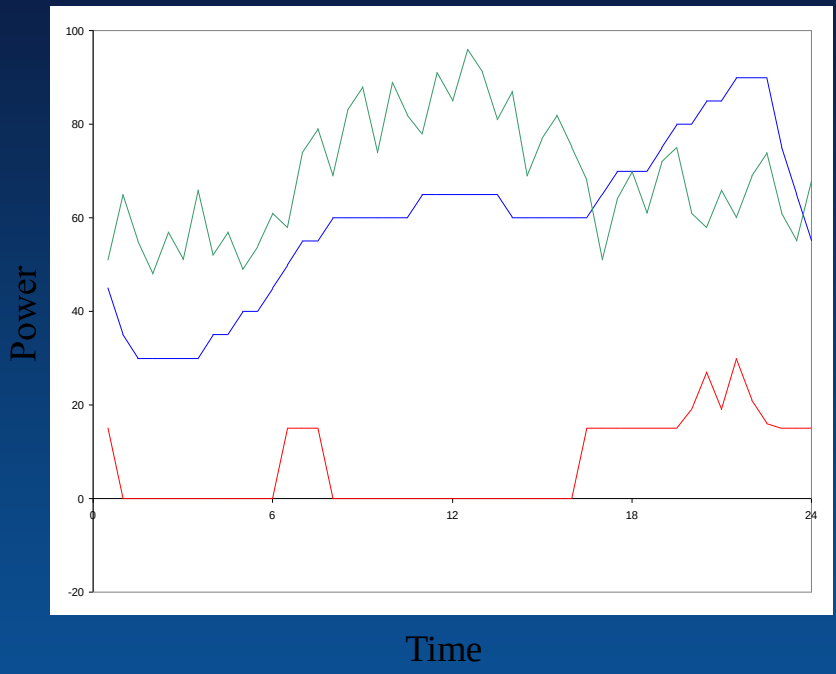
- Really must be operated as an integrated power system
- Advanced supervisory control required
- Individual component controllers oversee specific operation
- Since diesels are turned off, components added to maintain power quality
- Monitoring becomes more important and remote diagnosis generally advised

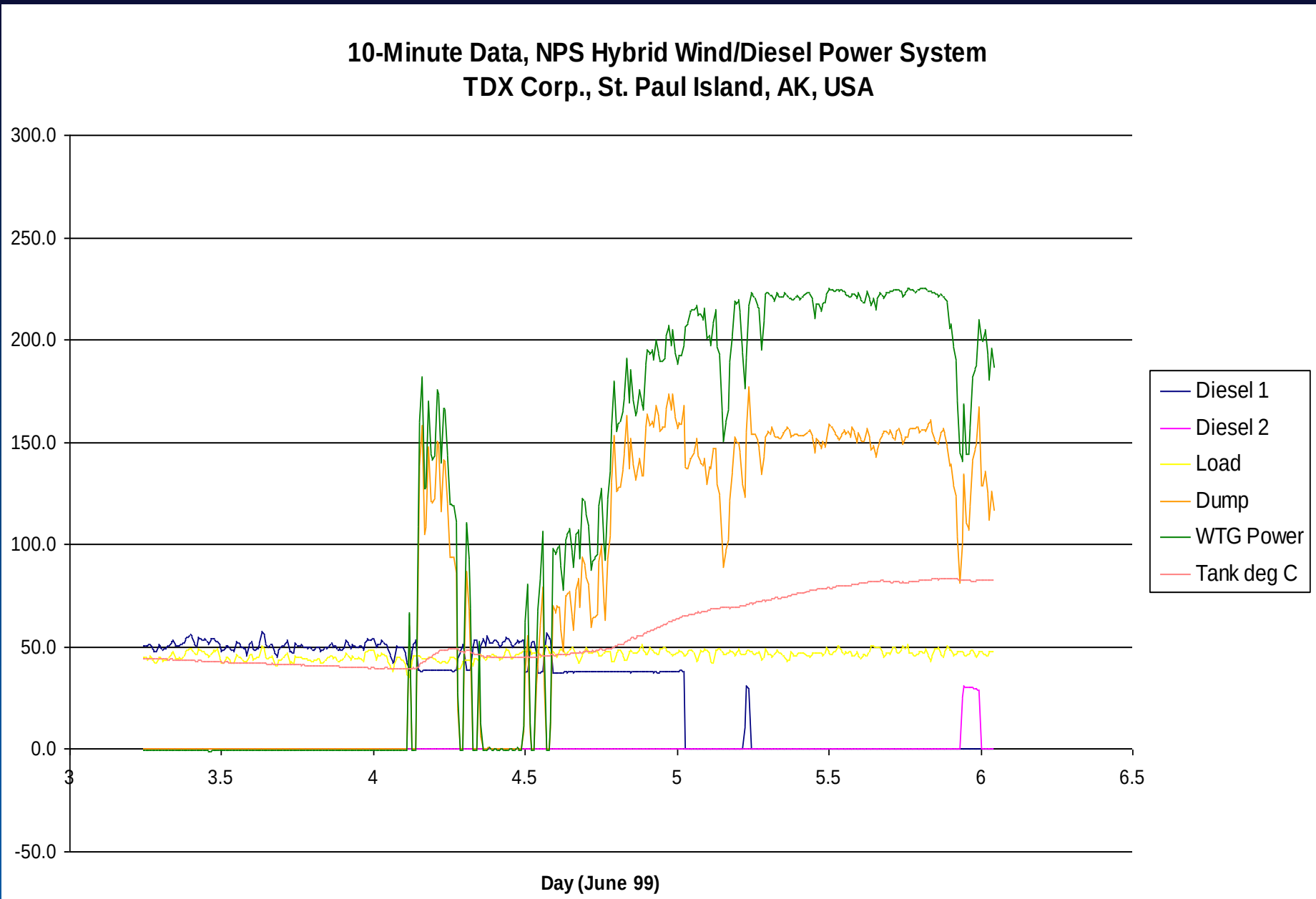
St. Paul Alaska, USA

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

Wind/Diesel Hybrid - Fully Integrated





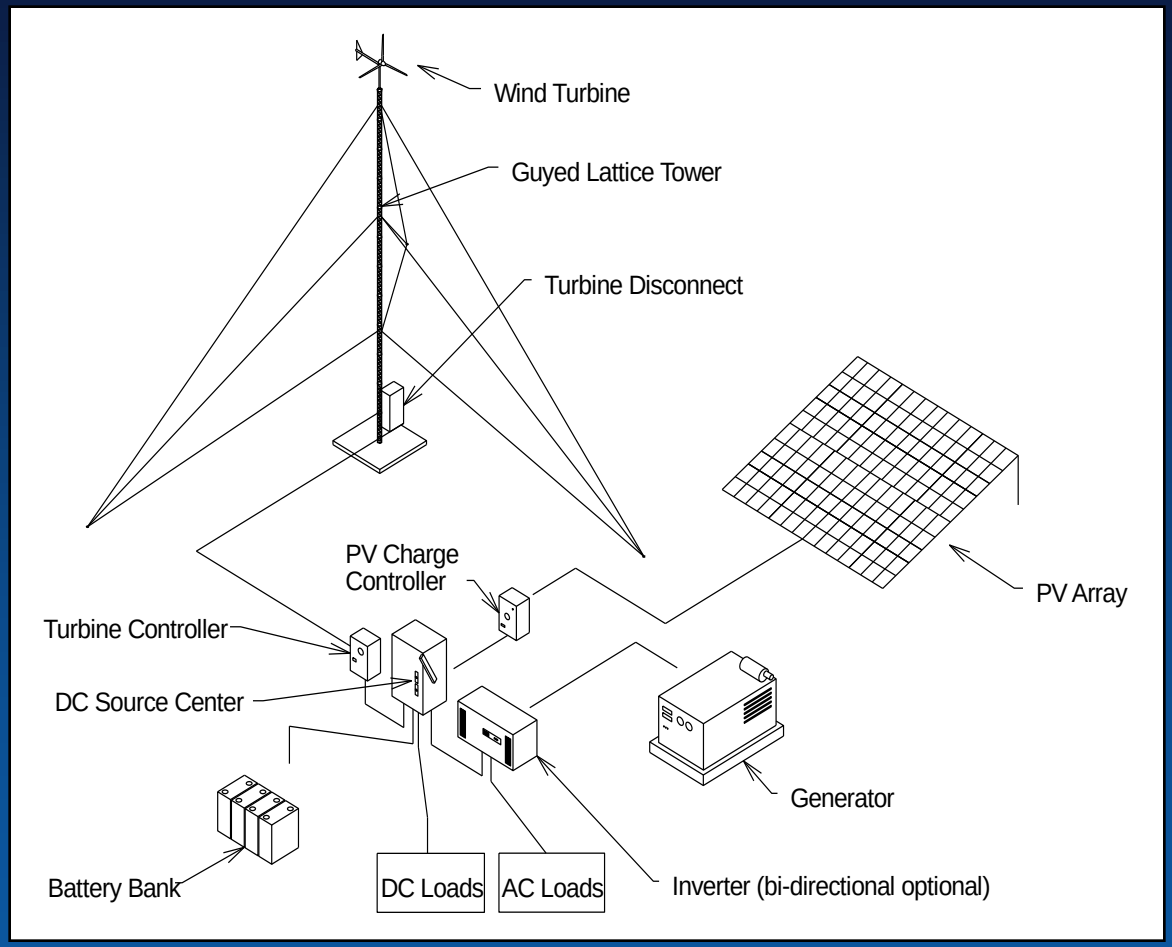

10-Minute Data, NPS Hybrid Wind/Diesel Power System
TDX Corp., St. Paul Island, AK, USA
300.0
250.0
200.0
150.0
100.0
50.0
0.0
-50.0
3
3.5
4
4.5
5
5.5
6
6.5
Day (June 99)
Diesel 1
Diesel 2
Load
Dump
WTG Power
Tank deg C

That looks simple – doesn't it?

The design and implementation of power systems is a complex matter and although the models (and initial presentations) make it look simple, it is never that easy.

Every power system is complicated, some much less than others but you do need to think about the design and how it will be implemented.

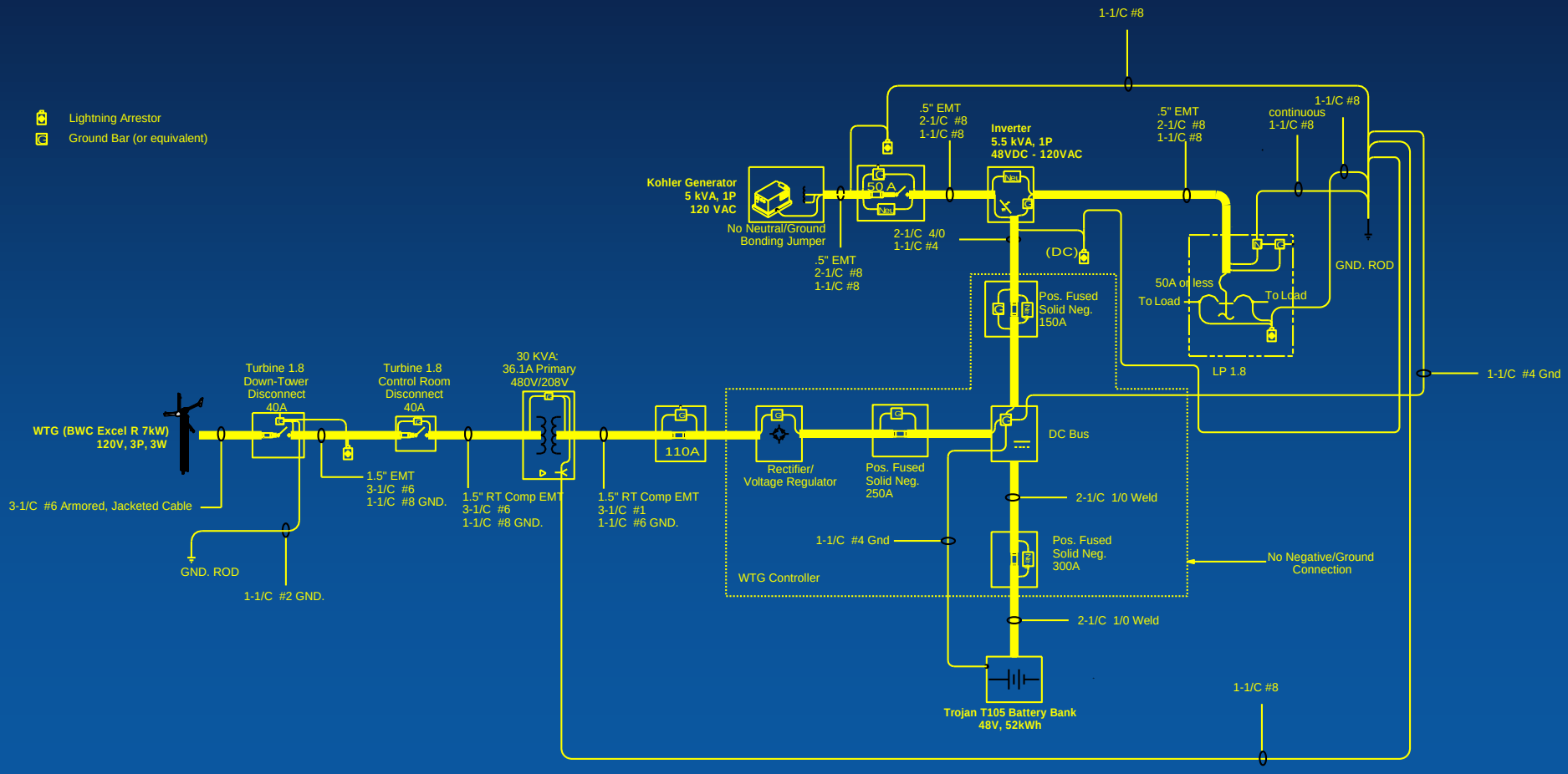
This is not a Simple Thing



"Simple" DC based small power system

Power system schematic

Site 1.8 One-Line Electrical Diagram for BWC Installation
(Chile Replication Project)



Other Integration Issues

In many cases it makes sense to implement wind as part of a complete system up-grade

- Complications with old diesel and controllers to integrated and automated operation
- Need for more space in the power house
- Modification to existing switch panels
- Integration with existing thermal loops

Adds to the cost and becomes much more complicated and time consuming

Final Thoughts …

- Lots of options for the configuration of hybrid systems - Depend on load, resource, and costs.
- Low penetration systems are common and “easy” to implement
- 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.

Conclusions

- Wind can be used to help supply energy to rural needs in a clean, inexpensive way.
- Optimal configuration depends on many factors
- Many working examples of wind/diesel technology and good experience here in Alaska
- The technology exists to provide power with all of the diesels off – maximize fuel savings
- Social/community issues are very important

Wind can play a role in supplying high quality and affordable energy in rural Alaska