Green Energy Backup for Communication Towers

Project Proposal

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1.0 Introduction

1.1 Purpose

Our project is to create a backup power system for electronics at communication towers. Many times the electronics are fed from spotty power lines and do not allow back up diesel generators. Our plan is to implement both wind power and solar power to prolong the life of the backup batteries. These additional sources of power will also be used to power the electronics via charging of the batteries. This can range from controlling the trickle charging of the batteries to complete power of the system based on a user-defined control.

1.2 Objectives

1.2.1 Goals

- Increase runtime of communication towers in the event of power outage
- Reduce power drawn from grid during normal operation
- Allow user to remotely control percent of backup battery drained
- Allow user to monitor system operation and backup power lifetime

1.2.2 Functions

- Charge backup batteries with solar and wind power
- Smart switching from grid to battery power

1.2.3 Benefits

- Prolonged operation of communications tower during power outage
- Decreased usage of grid power
- Cost savings on power
- User knowledge of power consumption and use

1.2.4 Features

- User defined backup battery depletion limit
- Calculation and display of remaining backup power lifetime
- Seamless integration with existing equipment and system

2.0 Design

2.1 Block Diagrams

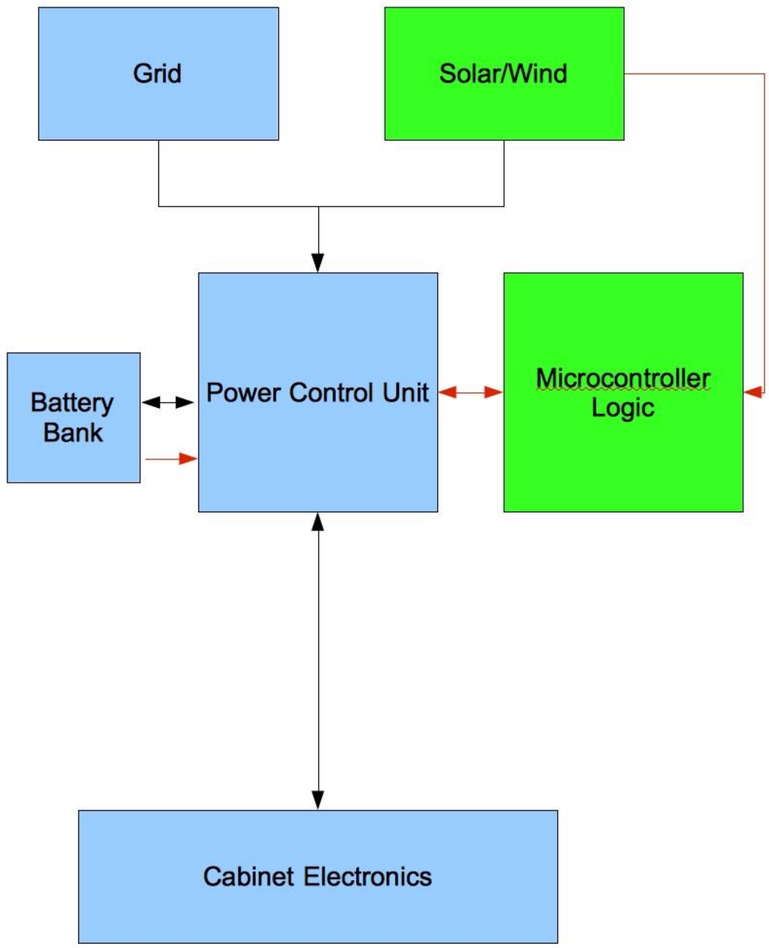

Figure 1: System Level Block Diagram

Green Blocks: newly implemented equipment

Blue Blocks: Existing equipment

Black arrows: Power feed

Red arrows: Logic signals

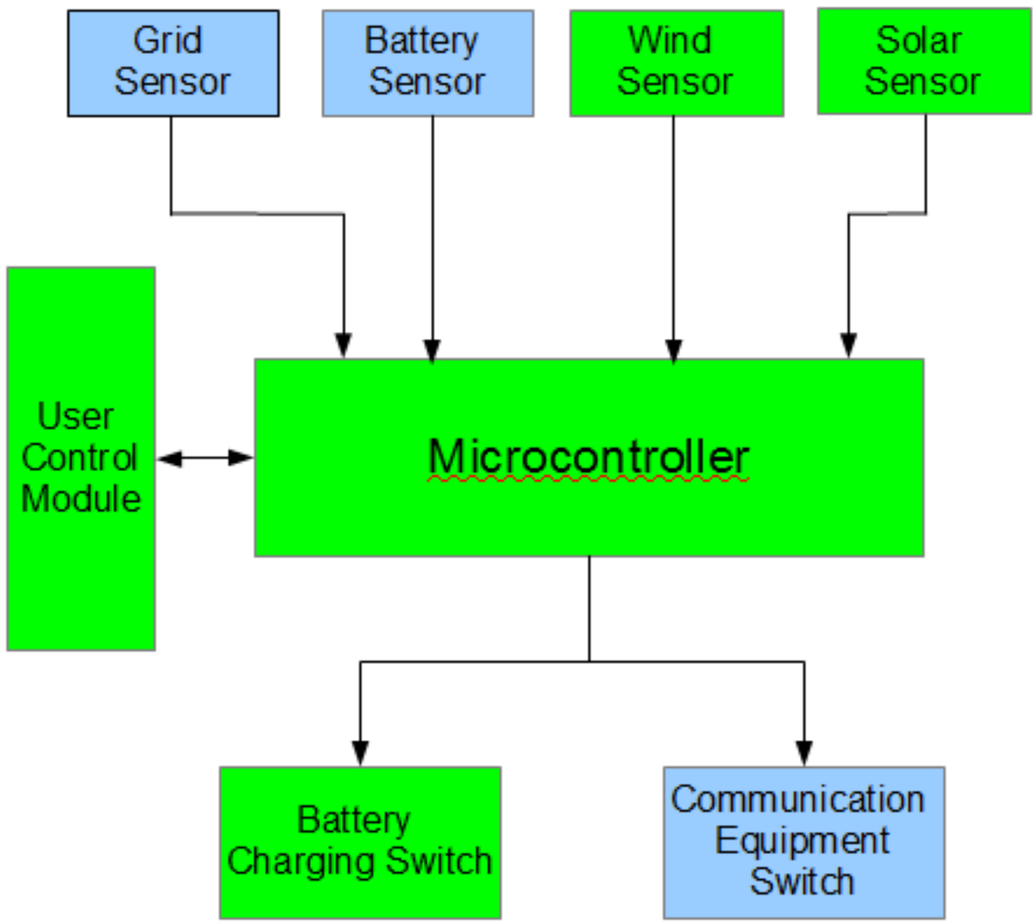

Figure 2: Logic Block Diagram

Blue Blocks: Existing power control equipment

Green Blocks: newly implemented control equipment

2.2 Block Descriptions

Figure 1

Wind Power:

The wind power block consists of the wind turbine itself as well as a diode and a current sensor. When the wind turbine is providing power the diode will turn on and the current sensor will provide a reading. The reading from the current sensor will be sent to the microcontroller logic block and used to determine switching. The output power from the turbine will be sent to the power control unit to be used to charge the batteries. The turbine will also have to have a remote “kill switch” available for workers to stop it from spinning while they are working on the tower.

Solar Power:

The solar power block consists of the solar panels as well as a diode, current sensor, and DC-to-DC voltage converter. When the solar panels are providing power the diode will turn on and the current sensor will provide a reading. The reading from the current sensor will be sent to the microcontroller logic block and used to determine switching. The output from the solar panels and diode in series will be sent to the DC-to-DC converter and then to the battery block to be used to charge the batteries.

Battery:

The battery block is an array of batteries which will be charged by solar or wind power, and alternatively the grid when neither of these sources is available. There will also be sensors on the batteries that will send signals to the power control unit so that we can calculate the remaining charge and up time. The batteries will be charged by the three power sources and then routed to the power control unit to be used to power the cabinet of communication equipment.

Power Control Unit:

This piece of existing equipment will be used to coordinate the switching between our three energy sources. It features a rectifier in it that will convert the incoming power from the grid into 48V DC power to be used by the communication equipment. It will also take in power from the wind turbine and solar panel as a second input. Using logic from the microcontroller, these three sources will power the batteries and communication equipment. It also contains two switches that are used to change the input power for the batteries and the communication equipment. The logic for this switching is outlined in the microcontroller section. The power control unit contains the sensors used on the batteries and the sensor used on the grid input. These sensors will be used as inputs to the microcontroller.

Figure 2

Wind Sensor and Solar Sensor:

These sensors will both be added to the output of the solar and wind power. They will be ammeters to test the amount of power being produced by both. The sensor outputs will be used for the switching logic in the microprocessor as outlined in the microcontroller section.

Grid Sensor:

This sensor is part of the existing power control unit. It tests the incoming power from the grid for faults, over current, and power loss. The sensor will be used for the switching logic in the microprocessor as outlined in the microcontroller section.

Battery Sensor:

This sensor will test the amount of energy left in the batteries. This information will be relayed back to the user via the user control module and also be used by the microcontroller for switching decisions.

Microcontroller:

The microcontroller will be the centerpiece of our design. The microcontroller receives inputs from the grid, batteries, solar panels, wind turbine, and the user control module. The microcontroller processes these inputs and then sends appropriate output signals to the power control unit. The signals will then control the functionality of the switches. The input from the grid will alert the microcontroller of a fault, overcurrent, and power loss. The input from the batteries will tell the microcontroller how much charge is left in the batteries. The inputs from the solar panels and wind turbine will tell the microcontroller how much power is being produced by these sources. The input from the user control module will tell the microcontroller how much of the battery should be drained before switching to grid power.

Our microcontroller will have two main operating modes: grid power present, and grid power not present. When grid power is present, the communication equipment will draw power from the batteries until they are drained to a user defined level. At this point, it will switch to drawing from the grid until the batteries are fully charged. During this time the batteries will be charged using the green energy sources. When the green technologies can no longer support the charging of the batteries, grid power will be used to charge the batteries until the green technologies become available. When grid power is not present, the microcontroller will draw power from the batteries until the grid sensor indicates that the grid is back online.

When grid power is present the batteries will primarily be trickle charged from wind and solar power. They will be switched to charging from the grid when there is insufficient power being produced from the wind and solar sources.

User Control Module:

The user control module will allow the user to remotely set how much the batteries are drained before switching back to grid power. It sends this input to the microcontroller, which handles the switching. To maximize the time of backup lifetime the batteries will be kept at 100% charge. In this case the wind and solar energy will be used to trickle charge the batteries while they are able to. If the control is set to less than 100% the batteries will power the communication equipment until they are drained to the user-defined amount. At that time the cabinet electronics will revert back to grid power and the battery will be charged back to full capacity. Using input from the battery sensors and microcontroller, the user will also be able to see how much battery life is left and the predicted time until complete power loss in the event of grid failure.

Battery Charging Switch:

The battery charging switch will simply choose either the grid or the green technology to charge the batteries based on an input signal from the microcontroller.

Communication Equipment Switch:

The communication equipment switch will choose either the batteries or the grid to power the cabinet electronics based on an input signal from the microcontroller.

3.0 Requirements, Verification and Tolerance

3.1 Performance Requirements

1. Wind and solar produce sufficient power at 48V to charge battery rack
2. Microcontroller logic detects change in power availability and sends switching signal within 10 ms
3. Power switching is fast enough to ensure zero power loss
4. User can remotely monitor and control system
5. Sensors provide quick and accurate measurements in an outdoor environment
6. Battery rack lasts 48 hours at 4A @ 48V without supplemental power
7. System implementation integrates smoothly with existing equipment
8. Equipment can be mounted on ice bridge and other components fit into 2 RU of cabinet space

3.2 Verification Procedure

1. Two current sensors produce correct reading of current from wind and solar sources. We will do this by using simulated weather conditions and compare output to necessary power requirements.
2. Grid sensor detects fault, power loss, and overcurrent. Sensor will be connected to function generator with sporadic inputs.
3. Sensor correctly calculates power remaining in battery bank. Battery will be drained to known levels and connected to sensors to verify up time and charge time.
4. Code for microcontroller produces correct output signal using test inputs.
5. Microcontroller outputs are properly received by the PCU and the switching functions accordingly.
6. Turbine produces expected power using artificial wind source based on average wind statistics.
7. Solar panel produces expected power in similar outdoor setting.
8. Solar and wind power, properly integrated, charge battery rack to verify sufficient charging levels after 48hr period.
9. Correct battery statistics are reported to user control module.
10. Switching function properly controlled through user control module.
11. System produces expected switching functions under all possible input conditions

3.3 Tolerance Analysis

The one component that most affects our project is the switching speed. We need to ensure that in the event of a power outage the power will be switched from being supplied by the grid to being supplied by the batteries fast enough such that the tower will remain active throughout this process. This will allow the communication equipment to keep functioning normally through power outages and other grid to battery switches with zero packet loss. In order to do this, the detection of a power outage and the subsequent switch must be completed in less than 20ms.

One condition that will affect our switching speed is the frequency at which the microcontroller polls the grid sensor to check for a loss of power. After the switch receives the signal from the microcontroller the switching time is constant but the time from the sensor detecting a power outage to the microcontroller sending the switch signal is dependent on the polling frequency. We have determined that to complete the switching process in less than 20ms our polling frequency must be 100 Hz ±10%. We will test this by varying the frequency at which the microcontroller polls the grid sensor in the logic and ensuring that we can still switch from grid to battery power without losing any data. We can test this additionally by putting the signal that indicates a switch and the signal of the switch on an oscilloscope and measuring the delay, rise and fall times.

4.0 Costs and Schedule

4.1 Cost Analysis

Part	Price	Quantity	Total
Solar panel ET-660	$258.00	1	$258.00
Wind Turbine AIR40	$1,000.00	1	$1,000.00
Rectifier/Switch*	$3,000.00	1	$3,000.00
Microcontroller TI MSP430	$4.30	1	$4.30
Boost Converter VIC-ORI244836100	$333.00	1	$333.00
Battery Marathon M12V155FT*	$770.48	8	$6,163.84
ACS715 Current Sensor	$9.95	2	$19.90
		Total Parts Cost	$10,779.04
*Existing equipment		**Additional Parts Cost**	$1,615.20

Name	Hourly Rate	Hours	Total
Miles Cernauskas	$35.00	200	$17,500.00
Devraj Banerjee	$35.00	200	$17,500.00
Ryan Madigan	$35.00	200	$17,500.00
		Labor Total	$52,500.00

Parts Cost	$1,615.20
Labor Cost	$52,500.00
Grand Total	**$54,115.20**

4.2 Schedule

Week	Task	Team Member Responsible
2/4/2013	Finalize Proposal	Miles
	research weather conditions, determine and order wind turbine	Ryan
	determine and order solar panels, implement DC-DC converter	Devraj
2/11/2013	Finalize Switching Design	Miles
	Test sensors for wind and solar power	Ryan
	Prepare Mock Design Review	Devraj
2/18/2013	Design and Program Microcontroller	Miles
	Test microcontroller output with input from sensors	Devraj
	Assemble switch	Ryan
2/25/2013	Prepare Design Review	Miles
	test switching method to ensure speed meets requirements	Devraj
	Design mount on tower	Ryan
3/4/2013	Assemble battery charging circuit	Miles
	Test switching and interconnectivity with microcontroller	Devraj
	Design and test battery depletion and power switch	Ryan
3/11/2013	Site visit	Ryan, Devraj, Miles
	Revise design to client specifications	Ryan
	Adjust system to size specifications	Devraj
	Test system with design modifications	Miles
3/18/2013	Spring Break	Ryan, Devraj, Miles
3/25/2013	Design and test user feed of system information	Miles
	Design and test user input to microcontroller	Devraj
	Test full system in lab setting	Ryan
4/1/2013	Test proper system response from user	Miles
	Make all equipment weather proof	Devraj
	Test complete system in outdoor setting	Ryan
4/8/2013	Prepare battery usage statistics	Miles

	Make system deployable and ready for intended use	Devraj
	Coordinate final adjustments with client	Ryan
4/15/2013	Finalize Project	Miles, Devraj
	Prepare Demo	Ryan
4/22/2013	Finalize Presentation	Ryan, Devraj, Miles
	Finalize Paper	Ryan, Devraj, Miles