Design and Control of a Hybrid Energy System for a Remote Telecommunications Facility

Stephen S. Smith, Masters of Engineering Candidate, Faculty of Engineering, MUN
St. John's, NF, Canada A1B3X5,
Ph: 709-754-4767, Email: ssmith@engr.mun.ca

M. Tariq Iqbal, Masters Supervisor, Faculty of Engineering, MUN
St. John's, NF, Canada A1B3X5
Ph: 709-737-8934, Email: tariq@engr.mun.ca

***Abstract* -** Providing uninterrupted power to a remote telecommunication site has been a problem for the industry for many years. As these sites are far removed from the utility power grid, the use of diesel generators and cycle charge batteries has been the industry norm. However, the use of a hybrid energy system can reduce diesel run times and the associated maintenance issues. A pre-feasibility study was performed to determine the optimal location, equipment selection, and plant sizing. Also, there was a requirement for a master controller that has been designed to control the overall hybrid system. This paper describes the designed system and proposed master controller for a remote telecommunication facility in Labrador. This study shows that the designed wind-solar-diesel system, will lead to a reduction of overall diesel run times by approximately 80%.

***Keywords* -** Hybrid energy systems; Wind–Diesel systems; Wind energy; Solar energy; Renewable energy; Sizing hybrid energy systems; Hybrid energy master controller.

I. Introduction

Within the communications industry there is an on-going analysis to determine the optimal solution of providing uninterruptible power to remote telecommunications facilities. The local communications provider, Bell Aliant®, has been using microwave repeater stations to deliver telephony / data services to the remote coastal regions of Labrador. These sites are generally at higher elevations, to provide line of site transmission to a large area, and are often far removed from the utility power grid. Therefore the use of commercial power is cost prohibitive.

The configuration has undergone a couple of changes since the original sites have gone in service. The original powering system was the continual use of diesel generators with a 220V 60Hz AC output. This was then rectified to the telecomm standard -48V DC. The system would have one operational and one backup generator. The downfall was the inefficient loading of the diesel generators which caused large fuel consumption and reduced diesel life. Another offset of the constant inefficiency was increased maintenance costs / repairs.

The second configuration was implemented during the 1980s, when a cyclic battery system was added to the system [1]. This consisted of a large battery bank with a diesel generator acting as a battery charger / backup power supply. The battery bank would provide the required -48V DC. As the battery voltage dropped below a given threshold, this would trigger the generator to start and provide a charging to the battery bank back to 100% capacity. Also, if there was a loss of the battery system, the diesel generator would provide primary power to the equipment load. This arrangement resulted in less fuel consumption and relatively lower maintenance costs, but is still expensive to operate.

We propose to take this system a step further by adding renewable energy converters. Wind and solar energy can provide a constant source of energy to charge batteries, thereby further reducing fuel consumption and even lower the maintenance costs.

II. System Definitions

a. Hybrid Energy System

A hybrid energy system is any system that has 2 or more different power sources. Typically when one thinks of a hybrid energy system it contains, but may not be limited to, a traditional power source (i.e. utility grid), a renewable energy device (e.g. wind turbine), energy storage, power converters (if required), and a controller.

For this paper, the hybrid system consists of: a diesel generator, wind turbines, photovoltaic panels, battery banks, controlled rectifiers, converters, and a supervisory controller.

b. Remote Facility

The term 'remote facility' is relative. For the purposes of this paper, we will define it to be a site which is only accessible by helicopter and is well removed from the commercial utility grid. Figure 1 is an example of a remote telecommunications facility on the coast of Labrador. Due to the wind atlas for the region (later section), the greatest potential site was deemed to be Double Mer (Latitude: 51°13' N / Longitude: 59°39' W).

Figure 1: Remote Telecommunications Facility

c. Load Data

Double Mer site load data collected over an annual period (Aug 25 / 2006-2007) shows a daily average loading of 72.74A, with daily standard deviation of 8.15A. It is noteworthy that since telecommunications operation is a 24/365 service, the hourly load fluctuations are minimal. With the minimum occurring between midnight and six AM due to the reduction of telephone calls during this period. Since the system runs on a -48V DC bus, the daily power consumption is approximately 83.8kWh/day. This leads to annual power consumed at 30.6MWh. Figure 2 is an annual graph of the site loading as produced by HOMER® software. [4]

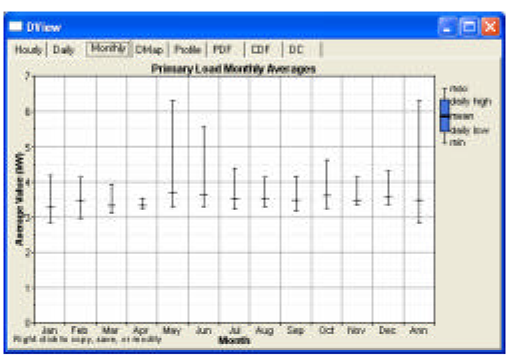

Figure 2: Load kW/h by Month for Double Mer

III. Renewable Resource Data

a. Wind Data

At this point of research, site wind data is still being collected. The preliminary study was done using data obtained from Environment Canada (www.windatlas.ca). Figure 3 is a chart which shows the areas of coastal Labrador with respect to their average wind speeds at a height of 30 metres. The areas on the dashed circles are the highest potential sites with average wind speed between 8 to 10 m/s.

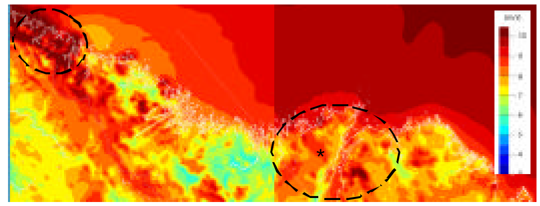

Figure 3: Wind Atlas of Coastal Labrador

As there are no repeater sites in the boundaries of the upper left circle, site selection was based on the potential of the lower right area. As stated earlier, the site with the greatest potential within this area was a facility located at Double Mer. The site has been denoted on the above graph (Figure 3) with a '*'.

Figure 4 is a monthly chart provided by HOMER software of the site wind speed data. The resulting average wind speed is 8.64 m/s.

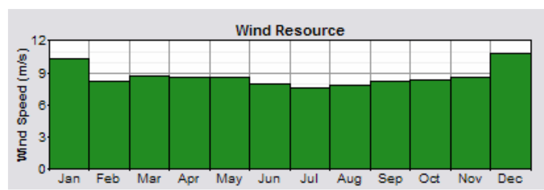

Figure 4: Annual Wind Data for Double Mer

b. Solar Data

Unfortunately there are no measured data sets available for the solar irradiance, therefore a data set was provided by HOMER software. The data set was based on site Latitude / Longitude. The resulting annual average was 2.845 kWh/m^2/d. Figure 5 is the HOMER chart showing the monthly variance of solar irradiance for the Double Mer location.

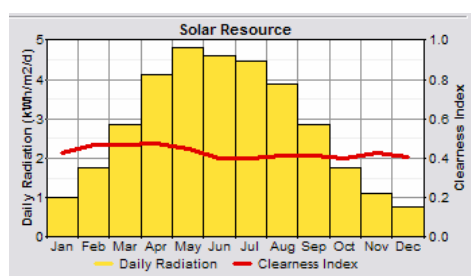

Figure 5: Annual Solar Data for Double Mer

c. *Diesel Consumption Data*

AC power is delivered to the facility by a Perkins® 1004G Diesel Engine – Electropak. The rating of the generator is 46.7 kWe at 1800 rev/min, with a 3 phase output at 220V AC. The continuous full power rating is 42.5 kWe with the ability to handle a 10% overload for one hour in every twelve hours. Based on a HOMER simulation (explained in the next section), the generator will consume 15 695L of diesel fuel annually. The cost of diesel fuel delivered to site by a helicopter is budgeted at $1 per litre, due to transportation costs. Therefore the annual fuel costs is approximately $15 000. Figure 6 is the efficiency chart provided by the manufacturer.

Fuel Consumption (litres/hour)	
Power Rating %	**1800 rev/min**
110	15.2
100	12.8
75	9.5
50	6.8

Figure 6: Generator Efficiency of Perkins 1004G

IV. System Sizing

a. *HOMER Simulations*

The existing system consists of a variable equipment load, fed from a DC bus. A Deka Unigy® battery bank with 6000Ah capacity is supplies a constant -48V DC to the bus. This capacity to run the site for 5 days before battery bank is fully discharged, i.e.: allow time for a maintenance crew to arrive to switch out problematic cells / fix diesel generator. To keep the batteries charged or provide primary power during battery failure, a Perkins 1004G 42.5kW AC diesel generator is used. The rectification from AC to DC is done by a 10kW Argus® 3 phase rectifier. Figure 7 is a block diagram of the existing system.

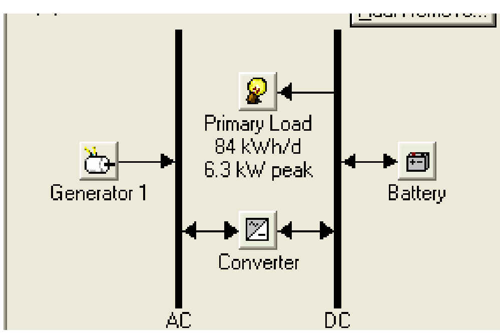

Figure 7: Existing power system at Double Mer

The operation parameters are that the diesel generator will assume equipment load and provide charging current if the state of charge (SOC) of the battery bank drops below 80% which equates to the bus voltage dropping below -48V DC. Other diesel run triggers include low room temperature, maintenance crew on-site (need AC for stove, etc.). System was simulated in Homer. Figure 8 is the results of the HOMER simulation. Results shows diesel consumption of 15 695L per year and an annual generator run time of 6 101 hours.

	Gen1 (kW)	Batt.	Conv. (kW)	COE ($/kWh)	Ren. Frac.	Diesel (L)	Gen1 (hrs)
	20	1	10	0.971	0.00	15,695	6,101

Figure 8: HOMER existing system simulation

To reduce diesel fuel consumption and associated operation / maintenance cost, addition of renewable energy devices to the system has been investigated. Using the load data, as well as the wind / solar data, a new hybrid system is proposed for the site. This new system would consist of wind turbine(s) and / or photovoltaic array(s) in addition to existing diesel. The search space of the simulation was defined to allow for 2 sizes of wind turbines (3kW and 5kW) in quantities of 0-8 units, 220W solar arrays in quantities of 0- 10. Figure 9 shows search space of the proposed hybrid power system [2].

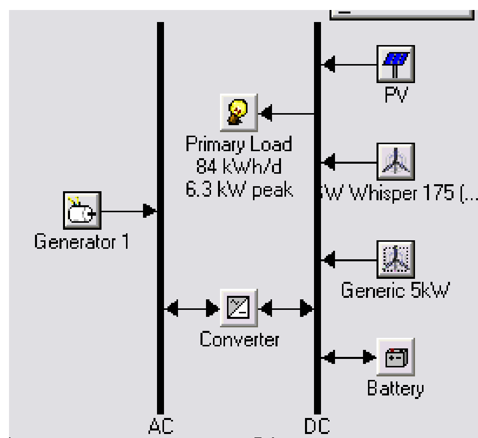

Figure 9: Hybrid power system at Double Mer

The results of the optimization simulations shows a system consisting of the original equipment with the addition of five Southwest Windpower® Whisper 175 (3kW) wind turbines and one 220W Siemens® PV array (consisting of two series 110W panels which operate at 24V DC each for the required 48V DC with Maximum Power Point Tracker (MPPT) for optimal efficiency [3]). The result of the simulation is shown in figure 10.

	PV (kW)	W175	G5	Gen1 (kW)	Batt.	Conv. (kW)	COE ($/kWh)	Ren. Frac.	Diesel (L)	Gen1 (hrs)
		5		20	1	10	0.481	0.88	2,990	1,285
	0.22	5		20	1	10	0.487	0.88	2,937	1,263

Figure 10: HOMER proposed hybrid power system

Figure 11 is a block diagram of the optimized system. Homer indicated that renewable energy fraction for this system would be 88%. Proposed system will consume only 2937L of diesel in a year (81% reduction) and diesel run time will reduce to 1263h/year.

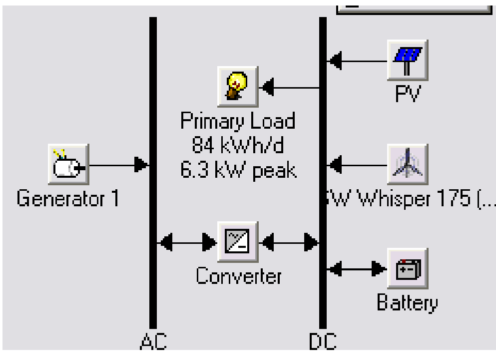

Figure 11: Optimized system for Double Mer

V. Supervisory Control Strategy

For any remote system, the interconnections of devices need to be monitored and controlled due to the absence of on-site technicians. When working with an essential service, the level of diversity and redundancy must be further safeguarded. In terms of energy production and consumption, the target is to keep the system running at an operating point where if any failures occur there is enough time to take counter-measures. The control strategy for this application is to use a master controller to monitor the state of the system and make decisions based on the information gathered.

Figure 12 is a proposed control system block diagram to illustrate the interconnections of all devices and the master controller

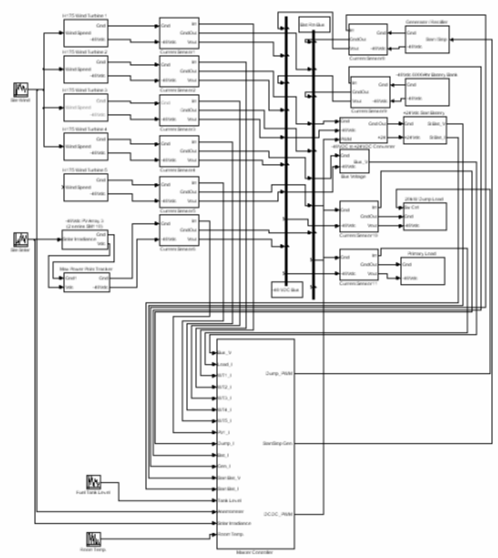
Figure 12: Block Diagram of the System Control

From start up, the controller will poll sensors at regular intervals, the most critical being the level of battery charge. The battery is considered at full charge when each of the 24 series cells is at -2.25V DC, resulting in a bus voltage of -54V DC. The recharge point is set to trigger at 80% state of charge (SOC) or 20% depth of discharge (DOC), this equates to a -48V DC bus voltage. In parallel we measure the ambient temperature of the equipment room; if this value drops below 5°C then heating is required. This is to prevent batteries from freezing and becoming damaged. If either of these conditions is met, then a signal is sent to start the diesel generator. Once the diesel is at full speed (1800 rpm), then it is connected into the system to: a) assume equipment loading, b) charge batteries to 100% SOC, and c) heat the equipment room to a preset value (< 25°C). The diesel generator will continue to run until both conditions b) and c) are met. If there is any trouble with the generator, and the power output is zero then a trouble condition is initiated which disconnects / shuts down the generator and technicians will be deployed.

During normal and generator operation, the renewable energy devices will have the ability to deliver power to the system as either load shedding and / or battery charging. If there are issues with any device (i.e.: acts as a 'load' or zero energy produced for extended periods of time) then a trouble condition is initiated and the effected device is disconnected from the system.

The next level of control is the prevention of over-charging of the battery bank to ensure longevity of the lifecycle. If the battery capacity climbs above

100% SOC, then a dump load is engaged in parallel with the equipment load. This dump load is switched in / out using a PWM signal. This allows for better control of battery discharge and load protection.
Alarm is generated if the battery capacity falls below 75%. If this state occurs, there is evidence that the generator or renewable devices are not supplying enough power to maintain the system within safe parameters. At this point, a technician crew is dispatched to fix any issues / damages. Figure 13 is a flow chart to outline the process / decisions made by the master controller.

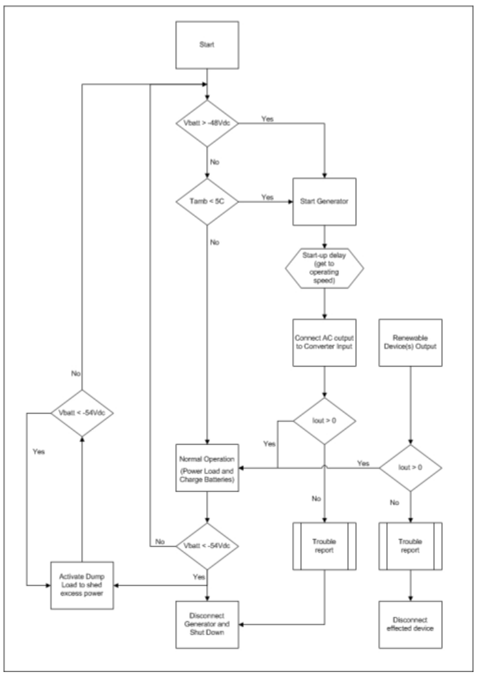

Figure 13: Flow Chart of Control Strategy

VI. Results

There are many advantages to adding renewable energy devices to the existing system, some of which are reduced emissions, reduced fuel and other environmental impacts. However the immediate impact for business is cost savings. The proposed system will reduce the cost of energy production from 0.971 $/kWh to 0.487 $/kWh, given that the yearly consumption is 30.6MWh this equates to approximately $15 000. Another advantage is the reduction of yearly diesel fuel consumption from 15 695L to 2 937L. This has a large environmental impact as well as reduced helicopter trips required for diesel fill-ups. Lastly, as the diesel generator is operating less frequently (1263hrs vs. 6101hrs) there will be a savings in terms of less operation / maintenance costs and longer period of service before generator replacement is necessary.

VII. Conclusions

Providing uninterruptible power to a remote telecommunications facility on the coast of Labrador is possible using a hybrid renewable energy system. The analysis has shown a significant savings to capital while meeting a high level of service demanded by the telecommunications industry. The final results are that the proposed energy system would reduce overall diesel run times by 80% and save the company a minimum of $15 000 annually in operating costs. Another benefit is that it makes the company more environmentally responsible.

VIII. Acknowledgements

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