HybSim 3.3 - Hybrid Generation Simulator Model

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Introduction

The high costs of electricity generation and storage tank replacement in remote rural villages has lead state governments and rural utilities to seek ways to reduce fuel consumed in these villages. In response to this need for lowering the cost of generation, The Alaska Energy Authority, Sandia National Laboratories, and SENTECH Inc. have developed a simulation tool to help planners develop a more cost effective generation system for use in remote villages. This paper discusses HybSim, a software package designed to model hybrid generation systems and provide insight for planners and rural utilities in determining when it may be cost effective to install a hybrid systems for meeting remote generation needs.

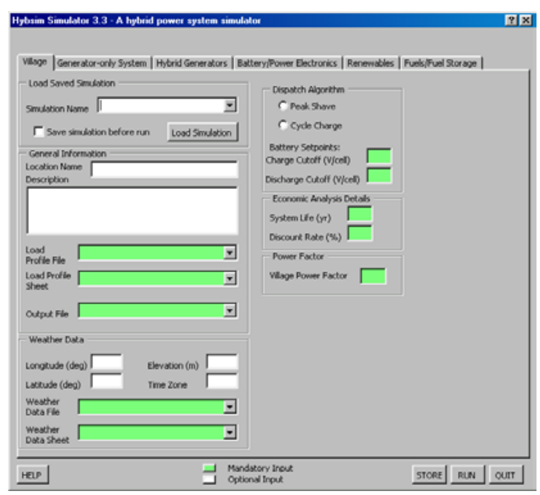
What is HybSim?

The Hybrid Simulation Model (HybSim) is an easy to use power system simulator written in Visual Basic for Applications (VBA) within Microsoft Excel™. The program was developed under contract with Sandia National Laboratories (#28478) with funding from the USDOE Energy Storage Program. The program is designed to allow the user the ability to quantify the benefits of installing a hybrid generating system by comparing the performance and economic profile of a diesel-only system (baseline case), to comparable profiles for a hybrid system. The model has the ability to model any combination of up to five diesel generators, an energy storage battery bank, two photovoltaic arrays, and a power-conditioning unit. The model also allows the user to input an average value for the village power factor and model the effect that power factor has on village energy profiles. The model compares the annual fuel use, annual operating cost, levelized cost of energy, and Green-House Gas emissions of the hybrid system to those for a diesel-only system.

HybSim Program

The program was written in Visual Basic for Applications inside Microsoft Excel. The objective was to create a program that would be assessable to any user familiar with this ubiquitous software package. The functions of the program operate as sophisticated *Excel Macros.* The program is designed to compare the two scenarios: the first is an all diesel power system, where system load is met using only diesel generators, and the second scenario involves simulating the same system load being served by a hybrid generation system consisting of a diesel generator, a battery system, a solar array, and a power conditioning unit.

Figure 1. HybSim Input Dialog Box



HYBSIM SIMULATION INPUT

All program input data are entered into Excel dialog boxes as illustrated in Figure 1. Each element of the system (Village parameters, diesel generators, batteries, solar panels, and power electronics) may be modeled based on existing or proposed system conditions. The model comes pre-populated with existing libraries for commercial diesel generators, batteries, and photovoltaic panels. Load data must be input from a suitably formatted Excel spreadsheet. Each entry must have a corresponding timestamp, however the time intervals between data points need not necessarily be uniformly distributed. The program is capable of accepting a series of single average load data values, or a series of *min., max., and avg.* values in a particular data set. Solar insolation data must be under a separate tab in the input spreadsheet, and can be accepted from the output of an on-site pyranometer, or

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constructed from TMY2 data made available from the National Renewable Energy Laboratory[2]. The HybSim Program contains macros designed to automatically format TMY2 data files into the required HybSim format.

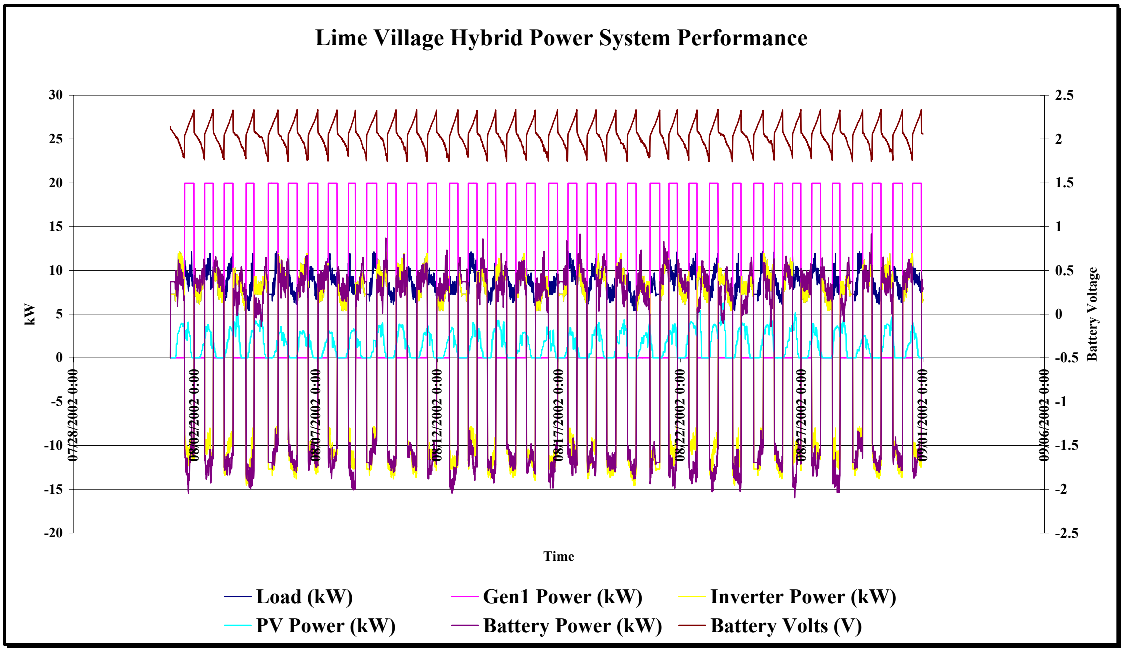
HYBSIM SIMULATION OUTPUT

The HybSim program outputs the following Excel spreadsheets and graphs:

- Output Summary Splash Screen
- Output Summary Sheet
- Details of the simulation
- Details of Economic Analysis
- Plot of overall system performance
- A plot of diesel-only system performance,
- A plot of hybrid power system performance.

Figure 2 below illustrates a typical plot of systems performance.

Figure 2. HybSim System Performance Output Plot.



Help Screens

In order to facilitate ease of use, the ***HybSim*** program contains two extensive ***Help*** features; the ***Help*** Button and ***Context Sensitive*** help features. The ***Help*** button is located on the bottom left corner of the user input screen. Clicking on this button brings up the help file containing the *Contents* and *Find* two tabs. The *Contents* tab contains instructions in a sequential order designed to facilitate running the model successfully. This function corresponds to standard Windows™ based help programs.

Context-Sensitive Help

Context-sensitive help provides the user with instantaneous and germane help. To get information about any element of the user input interface, clicking on the question mark at the top right corner of the interface and then on the input box of interest displays a pop-up box containing the relevant information.

[2] http://rredc.nrel.gov/solar/old_data/nsrdb/tmy2/

CASE STUDY: LIME VILLAGE BATTERY REPLACEMENT

In 2003, the ***HybSim*** model was used to model the performance of the electrical generation system in Lime Village, Alaska. Lime Village is small (pop. 46), remote village in Alaska, approximately 150 miles west of Anchorage. Lime Village is accessible only by small boats or airplanes and was the last village in Alaska to be electrified. The diesel generator power plant was opened in 1998. Because of the remote nature of the site, all fuel had to be flown in via airfreight. Subsequently the electricity cost was $0.56/kWh. The Alaska Energy Authority, along with the U.S. Department of Energy decided to utilize Lime Village as a test bed to examine the feasibility of installing hybrid system in areas of high electricity cost. In 2001, a hybrid diesel-solar-battery system was installed and began operation.

The Lime Village system parameters were as follows:

- 35-kW diesel generator
- 22 kW diesel generator
- 530 Ahr Absolyte IIP battery
- 5 strings of 15 Siemens SM55 PV panels
- 7 strings of 15 BP Solar BP275 PV panels
- 24 kW AES inverter

For reasons not totally understood at the time, the system battery bank failed after approximately one year of operation. It was suspected that the battery was not optimally sized for the load and charge regime, resulting in poor charge and discharge profiles for the battery. Moreover, the battery had an uncertain history prior to installation in this application, and the original condition was not known.

The ***HybSim*** program was used to model the system to determine the optimal size of the replacement battery. Modeling various scenarios utilizing varying battery sizes and power factor considerations, it was found that the Lime Village battery bank could theoretically be reduced from 530 Ah to approximately 350 Ah without loss of system functionality. However, a far more robust battery charging control system would be required in order to take advantage of the optimized battery size. This charge control scheme was not available at the site at the time.

Fuel Costs and Tank Replacement

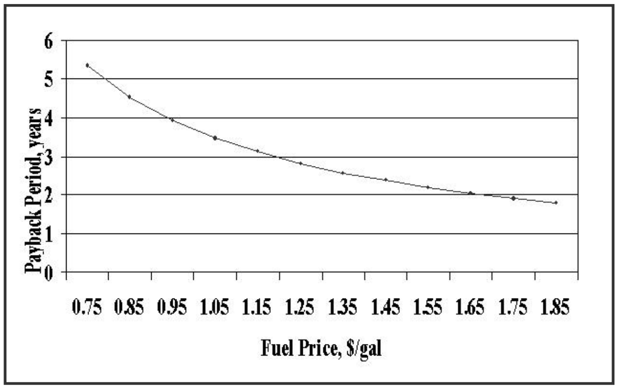
HybSim was used also to quantify the benefits of operating diesel-battery hybrid generating as compared to diesel-only systems in remote villages. As an example, the village of Chistochina, AK, has two diesel gensets, 60 kW and 100 kW. The average village load was approximately 26 kW, however the 100-kW diesel generator was operated year-round to cover transient load spikes, which could often exceed 80 kW. An analysis performed using HybSim showed that operating the 60 kW genset with a 14.4 kWh peak-shaving battery system could reduce fuel consumption by 16%, or roughly 4,500 gallons of diesel fuel per year. The annual monetary savings from such a system, about $2,900 per year, would pay for the capital investment in the battery energy storage system in a little over four and a half years.

Another scenario in which hybrid system installation could result in significant savings occurs was when the existing diesel storage tanks at a village need to be replaced. Since a hybrid system uses less fuel, the amount of fuel storage needed is also reduced, lowering the cost of replacement tanks. A survey of planned storage tank replacement projects in Alaska revealed tank replacement costs ranging from $6.94/gallon to $13.66/gallon.[3] The wide range of costs is due to variability in site characteristics such as tank size, geography, transportation access, and soil conditions. Reducing the fuel storage requirements by the 4,500 gallons as shown in the above example would avoid approximately $31,000 in fuel tank cost (at $6.90/gallon of tankage), more than paying for the $14,400 battery storage system. Even a modest $4.00/gallon of storage capacity would result in a reduced fuel storage cost of about $18,000, again paying for the cost of adding the energy storage system.

[3] Communication with Dennis Meiners, Alaska Energy Authority

Chistochina is somewhat unusual among small Alaskan villages in that a road services it. Most Alaskan villages are more remote and therefore must receive fuel shipments by barge, or in extreme cases, by air, resulting in even higher fuel costs. Fuel cost used in the above analysis was $0.85/gallon, at the low end of the range in prices paid in Alaska. Villages similar to Chistochina with higher fuel prices could have payback periods much lower than the five and a half years predicted above, as seen in Figure 3.

Figure 3. Variation in Payback Period versus Fuel Price.



Conclusions

The *HybSim* Model has been successfully used to quantify the value of hybridizing diesel generation power systems. Using *HybSim*, it has been shown that battery/solar/diesel hybrid systems can reduce fuel consumption in rural Alaskan villages by over 20%, and in certain conditions, it may be cost-effective to install a battery/solar hybrid system. Some relevant scenarios include:

- When a village has a smaller, unused genset that can be retrofitted with a battery system
- When an existing generator needs to be replaced
- When fuel storage tanks need to be replaced

Current Development Activities

The development of the HybSim model is reaching its final stages before it will be made available to the public. Current development efforts involve validating the model against real-world operating conditions. The most critical aspect of the model is the fuel consumption calculations, and as such efforts are now underway to locate data from existing hybrid systems with *metered* fuel consumption data. After the calculation accuracy has been firmly established, the user interface will be modified to enhance the end-user experience. The final stage of the development will involve making the package website downloadable. In this manner the tool will be widely available.

Future developments for the model will involve three areas of improvements/upgrades: Additional libraries, adding a wind-turbine module, and improving financial modeling capabilities. Additional libraries would enhance the flexibility of the model. We are investigating adding more power electronics models, as well as other battery technologies (e.g. nickel-cadmium). Additionally we are planning to add a module that permits the modeling of wind turbines. Finally, depending upon funding availability, we would like to enhance the financial calculations module by making it possible to use *Real-Options* and *Adjusted Present Value* calculations in the financial projections. These features would allow for more realistic estimates for the project financing over the 20-year system life cycle that the program uses as its base calculation period.

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