

Mobile Hybrid Power System's Elements

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ABSTRACT

The effectiveness of elements comprising a hybrid electric power generating system was studied. The wind and photovoltaic renewable resources served as integral components of the hybrid systems configuration. A HMMWV towable trailer system provided an intermediary basis for formulation of methodology needed for optimization of power generation and energy storage capacity constrained by cost, size and weight of the system. The methodology employed in this paper is scalable from kilowatts to megawatts or from man portable systems to significantly larger systems which can be housed in 40 foot ISO containers.

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INTRODUCTION

A power system which employs two or more power generating sources is defined as a hybrid power system. A hybrid power system when optimally designed for particular load range can be an economical solution in spite of its higher initial costs. A fuel driven diesel generator serves as a primary power source. Focus of this study was on a HMMWV or JLTV towable hybrid system shown in [Figure 1](#).

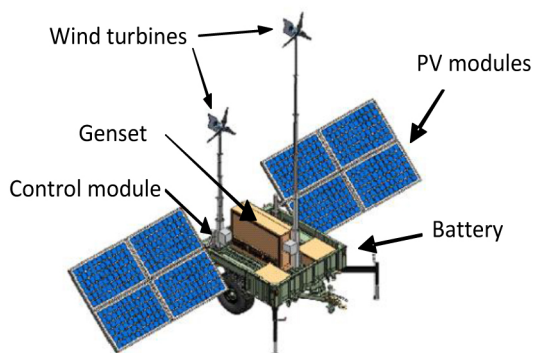


Figure 1. Concept of trailer mounted Hybrid System.
 Courtesy of Bren-Tronics Inc

Fuel is a decisive factor in the theater of war and an expensive commodity in military and other than war operations. The research focused on reduction of fuel dependence, is directed to improve engine efficiency, to develop alternative fuel generation methods [1], to implement renewable energy harvesting [2], and last but not least to reduce energy consumption.

Internal combustion engine efficiency has been significantly improved by introducing fuel injection and computerized control. With the best strategies employed the internal combustion engines can convert 33-50% of energy contained in fuel into useful work while allowing 67-50% to be wasted on heat, exhaust and friction. Conversion of waste to fuels is an ongoing work that will significantly reduce landfills and transform refuse into usable alternative source of energy. Renewable energy harvesting, specifically wind and solar, have considerable success in the areas where such resources are available. However the efficiencies in renewable energy conversion leave a lot to be desired. The commercially available products of solar photovoltaic technologies range from 8 - 20% [10] while small wind turbines have 20-25 % [2] capability to convert available natural resources to electrical energy.

Despite these dismal energy conversion numbers efficiencies of the individual components, when aggregated

into a system, may significantly reduce waste and improve overall fuel efficiency.

HYBRID SYSTEM

A hybrid system, when properly matched to the load, can save considerably on fuel and maintenance costs. To further improve on fuel economy such system should complement conventional power generation with alternative and renewable energy harvesting components. In addition to power generation both energy storage and power inversion capability are indispensable. To develop appreciation for the individual roles each element serves in a hybrid system we should proceed with a discussion of such system component by component [3, 4, 5, 6].

GENERATOR SET

Traditionally the generator sets or gensets are selected to satisfy maximum power requirements with additional capacity to meet anticipated needs. With fervor that bigger is better a next larger genset is intuitively selected. However, when a diesel engine operates at less than $\frac{1}{4}$ of its rated load the unburned fuel builds up in the exhaust causing an undesirable phenomenon called wet-stacking. This practice is environmentally unfriendly, damaging to the engine and wasteful.

The wastefulness in selection of a genset to match the load is unavoidable. Let us consider the anticipated load of a B-hut shown in Figure 2. The maximum power peak exceeds 9kW while the load averages 2.7 kW. The 3kW genset would seem to satisfy the average load requirements however at least a 10 kW would be chosen to meet the peak power requirements.

Table 1. Gensets from 2 to 100 kW [2]. Conversion efficiency computed by using energy per gallon of JP-8 equal to 36.87 kWh

Genset kW	Fuel use gal/hou	Weight lb	Energy/gal kWh/gal	Efficiency (total)
2	0.33	133	6.06	16.4
3	0.50	304	6.00	16.3
5	0.57	888	8.77	23.8
10	1.02	1,242	9.80	26.6
30	2.60	2,732	11.54	31.3
60	4.51	3,992	13.30	36.1
100	6.00	7,500	16.67	45.2

The table 1, compiled from data available on several gensets [5], shows significant increase in efficiency with genset size. The efficiency of fuel to electrical energy conversion is higher for 10kW genset when compared to a 3kW unit, however the latter is three times lighter and also costs less. By looking closer at the behavior of the load one could still use the smaller genset if the energy could be stored

during the period of lower power demand to be released later when needed.

Since running the gensets lower than 70% rated load leads to wet-stacking a set of a resistive load bank is frequently used. While adding electrical load mitigates the wet-stacking problem additional fuels is used to produce the power required for the resistive load apparently is not an economical solution.

ENERGY STORAGE AND DC TO AC INVERSION

Power generation industry addressed the problem of fluctuating loads by imbedding energy storage devices into the power distribution grid [8]. This strategy allows delivery of power on demand without committing additional generating assets. Unfortunately energy storage and power inversion come at the increase of cost, weight and size of the system.

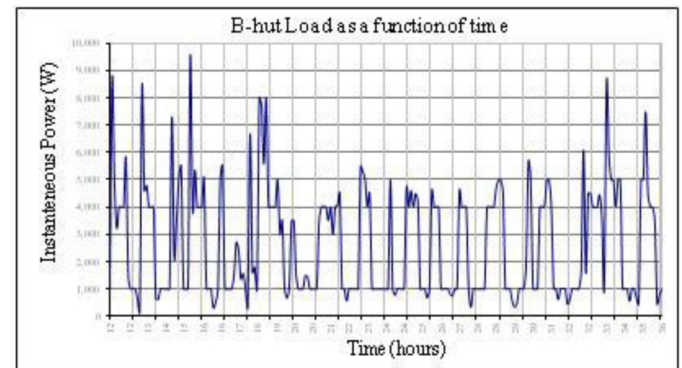


Figure 2. B-hut electric load within a 24 hour period. Maximum load is under 10kW and the average load is 2.7kW.

The energy density of an electrochemical system is well suited for mobile application. Such storage should be safe to accept full charge from the genset and deliver required power to the inverter. The inverter in turn should deliver maximum required AC power P_{Lmax} to the load.

When used with properly sized energy storage E_B a smaller genset can replace a larger unit. To estimate the duty cycle D for a genset of power P_G we have to know the average power consumption P_{Lavg} and system power losses P_{losses} , then:

$$D = (P_{Lavg} + P_{losses}) / P_G \quad (1)$$

To simplify concepts the system losses will not be used here in formulation, however they will not be ignored later. The duty cycle becomes:

$$D = (P_{Lavg}) / P_G \quad (2)$$