Evaluating the Cost-Benefits of Utilizing Host Nation Power for US Military Bases

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1 Background

The Department of Defense (DoD) operates a significant number of bases outside of the United States in cooperation with the local host nation. Each base relies heavily on electrical power to accomplish their mission. In countries with poor electrical system reliability the power for these bases are typically provided by diesel generators with the fuel either purchased from the local population or transported from fuel depots. This incurs a significant cost for the DoD and introduces an additional vulnerability with the transport of fuel.

**Figure 1: A Host Nation power line runs in close proximity to a US military base,
which could provide significant fuel and cost savings.**

In many situations the host nation electrical grid is highly unreliable. In these instances, the host nation grid should be considered in much the same way as an intermittent renewable resource is treated. In fact, even the most unreliable host nation grids almost always have a higher availability then solar PV, which has at best a 30% capacity factor. For installations interconnected to unreliable grids, backup diesel generation would be used to provide power during grid outages. The host nation power does not remove the cost of having dedicated diesel generators, however it will offset much of the fuel required.

2 Estimating Savings from Host Nation Power

There are several critical parameters that will most greatly impact the decision of whether a military base should use HN power. These are related in the Simplified Host Nation Power (SHP) Equation,

$$C_E = \frac{cf}{\eta \times K_{diesel}} - \frac{\Delta I / L}{P \times R \times 8760}$$

Where:

- C_E is the price of electricity from the grid ($/kWh).
- cf is the cost of fuel delivered to the base ($/gal).
- η is the average annual efficiency of the on-base generators.
- K is the higher heating value of the fuel. For diesel fuel, this is 40.737 kWh/gal.
- ΔI is the cost of adding a connection to the HN power grid (including wires, transformers, etc.)
- L is the average power load of the base (kW).
- P is the desired payback period, in years. This should be the shortest of the life of the base, the life of the equipment, or investment guidance from the DoD.
- R is the reliability of the HN power grid as a percentage. For example, it can be calculated by taking the SAIDI value (usually given in minutes) and dividing it by the number of minutes in the year.
- 8,760 is the number of hours per year (conversion factor)

The SHP Equation can be rearranged depending upon what is being studied. Site-specific parameter values are used to identify local threshold points. For example, if a base paid $4 per gallon for diesel (fully burdened) and was going to be in place for 3 years, then that base should consider using HN power if electricity costs less than $0.30 per kWh.
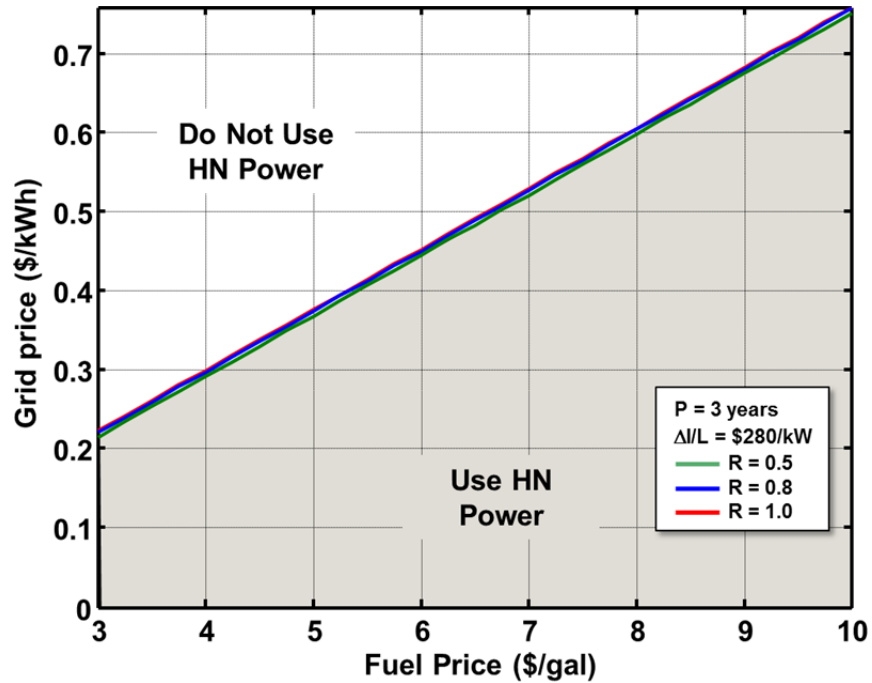
Figure 2: SHP Equation: Bases below the line should consider using HN power.

During some operational missions, cost is not a strong consideration; rather, the amount of fuel that must be transported to the base is much more important, especially in remote and/or dangerous locations with an extensive and exposed logistic tail. The percentage of fuel saved is essentially the same as the reliability. So if a Host Nation power grid is 90% reliable, then the fuel usage is reduced by 90%. High fidelity models confirm this intuitive and perhaps obvious relationship. Note that this relationship assumes the average efficiency of the generators remains the same. The average grid reliability, and therefore percent fuel saved, can be estimated by either SAIDI or MTBF statistics.

$$\text{Percent fuel savings} = \frac{SAIDI\ [\text{min}]}{525{,}600} \times 100 = \frac{MTBF_{grid}}{MTTR_{grid} + MTBF_{grid}} \times 100$$

3   High Fidelity Model Results

A higher fidelity model, the Host Nation Power Analysis Tool (HPAT), supports the estimates above. HPAT uses more detailed information about the base, the HN grid, the generators, and other backup power devices. HPAT then uses this information in a dynamic Monte Carlo simulation and calculates several metrics. For example, a 600-person was studied with a 3.6 MW base (average load was about 2 MW) in a location with a grid outages about twice a month. The cost of adding a substation to connect to the HN grid was estimated to be $3.2M. In this example, the Life Cycle Cost (LCC) is reduced from $0.41/kWh to $0.32/kWh, nearly $2.5M are saved in annual energy costs, and average fuel usage is reduced from 5,000 gallons per day to about 100. The payback period is 1.2 years with a savings-to-investment ratio (SIR) of 4.3.
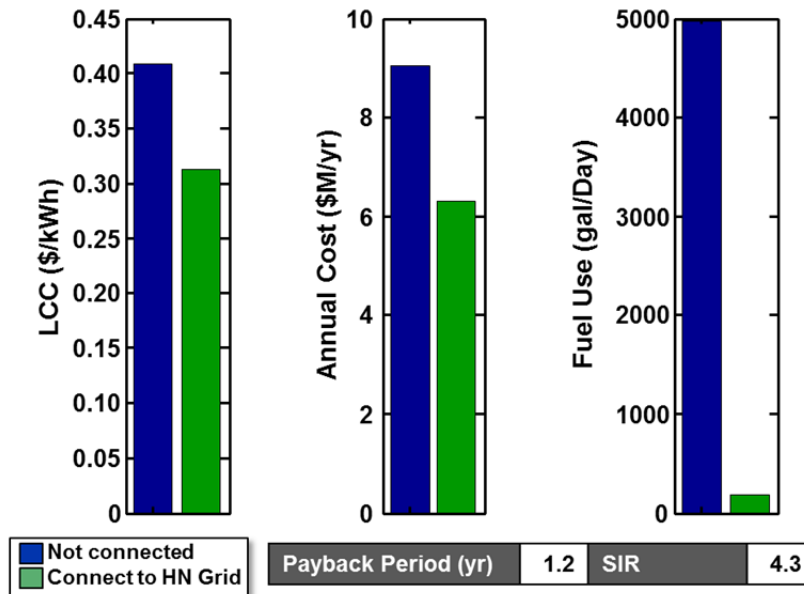
Figure 3: 600-person base HN power analysis results show the benefits of HN power.

Four other scenarios around the world were modeled and analyzed; in every case HN power provided substantial cost savings and improved endurance.

4   Qualitative Considerations

The electric power reliability in a Host Nation is generally based on the Host Nation's governmental capacity, interest, and economic ability to 1) maintain and operate an electric grid to meet urban, industrial, and rural energy demands, 2) expand the existing electric grid to address changing local or regional power needs, and 3) maintain the security of the electric grid from unintentional outages or malevolent attacks. Even with lower reliability, the previous sections show that there is a cost advantage to include HN power in a base's energy architecture.   However, there are also several other factors:

- Mission critical energy demands often are only 15-25% of the average base energy demand. That means that up to about 80% of base energy demand is interruptible without having a major impact on mission performance. If desired for cost reasons, one could leave non-critical loads only on HN power.
- One of the major considerations is the local transmission and distribution system capacity. Transmission and distribution systems already at or near capacity of the existing power lines often experience increased power reliability issues with even small fluctuations in local power demand fluctuations.
- Many host nations have interest in local grid and power supply improvements. In these cases, there may be an opportunity to foster a better relationship between the US military and the host nation through capability-building projects focused on improving or expanding power grid

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capacity. Not only does the host nation benefit from shared costs for upgrading their grid, they often also appreciate an established, consistent customer who pays their bills.

- While initial approximations can be made using a single reliability number (e.g., 75%) for a HN grid, the final decision and design requires a more thorough understanding of the nature of the reliability issues. The duration, frequency, and cause of power outages should be considered. For example, reliability issues caused by power generation capacity are much more difficult to address than local distribution system issues.
- One should be aware of a local or national government's ability to maintain political and social stability and the likelihood of intentional attacks on the power grid.

5   Recommendation: Use the Grid

Host Nation power should be strongly considered for OCONUS bases, even in areas where the power grid may be very unreliable. All indications from this analysis are that almost all OCONUS bases would benefit from connecting to the grid. These benefits include financial (saving money) as well as improved security (by reducing the amount of fuel being transported to the base).

It is recommended that every OCONUS base in the developing world should have on-base generation capability that can meet their full power demand. Once that is in place, a connection to the HN grid will only improve overall energy accessibility by providing a second channel beyond just the fuel supply. In this way, HN power is like other intermittent sources such as solar or wind power. HN power should not be thought of as a replacement for traditional on-base generation, but an augmentation.

For bases that do connect to the grid, the connection must be designed to "do no harm." Specifically, the connection should include circuit breakers that allow full isolation (or "islanding") of the base from the grid. All connection equipment should have redundancy and be sized to accommodate future base growth or surge capacity. Voltage regulation may also be added where necessary. Current and volt metering should be placed on the line from the HN grid, the on-base distribution feeders, and the generators. Switchgear should be automated for rapid response to disturbances on the HN grid line. Furthermore, all generators should have automatic startup and switch-over capability. All standards for safety and best engineering practices should be followed in design and construction of the connection point.