N80 24787

MILITARY MARKETS FOR SOLAR THERMAL ELECTRIC POWER SYSTEMS

J. S. Hauger
Consultant
P.O. Box 2760
Reston, Virginia 22090

ABSTRACT

The Department of Defense (DOD) is the single largest consumer of engine driven generators. Its procurement is responsive to factors other than first cost. Its non-combat applications are similar to the general market for non-grid power systems which is estimated to be over 2,000 MW/year in the U.S. and 28,000 MW/year worldwide.

The DOD maintains an inventory of over 1,800 MW of engine-generators 15 KW and larger, with an estimated procurement rate of over 140 MW/year. Most current systems are diesel driven, but nearly the entire requirement could be met by advanced heat engines of the types being developed as point-focussing, distributed receiver power plants. A conceptual system consisting of a heat engine which efficiently burns liquid fossil or synthetic fuels, with a "solarization kit" for conversion to hybrid solar operation could meet existing DOD requirements for new systems which are quieter, lighter, and multi-fueled. An estimated 24 per cent (33 MW/year) or more could operationally benefit from the solar option.

Baseline cost projections indicate levellized energy cost goals of 210 to 120 mills/KWh (15 to 1000 KW systems). Fuel cost escalation is the major factor affecting the value of the solar option. A baseline calculation for fuel at $0.59/gal in spring, 1979, escalating at 8 per cent above general inflation indicates a value of $2700/KWe for a solarization kit.

INTRODUCTION

The military power market is of interest in and of itself. The Department of Defense (DOD) is the single largest purchaser of engine driven generators. Its purchase decisions are based on factors other than first cost, and can be responsive to national energy goals. Current systems demonstrate recognized operational deficiencies, providing motives for conversion to a new technology. The services can provide controlled test beds with the support of the military laboratories where even secondary impacts such as parts stockage, training, and reduced fuel transportation can be studied.

The military market is also important because it is a readily defined and relatively centralized segment of the general market for non-grid power systems. According to information developed at the JPL workshop for Potential Military and Related Civil Users of Small Solar Thermal Technologies, civil applications resemble military requirements in duty cycle, environment, and service needs. The plant requirements imposed by non-combat military power applications can, as a first approximation, stand for non-grid electric power applications as a whole. According to a General Motors study, this amounts to over 2000 MW/year in the U.S. and 28,000 MW/year worldwide for systems larger than 35 KW.

MILITARY POWER APPLICATIONS

Application Categories

Military electric power requirements fall into six operational categories. One of these, electric generators permanently mounted on vehicles, was not considered. Space limitations would tend to prohibit the use of a solar collector for such systems. Four operational categories, tactical, theater, isolated, and emergency power requirements, are now met by diesel or gas turbine driven generators. Installation power needs are virtually all met with purchased power. The following table summarizes information by category for systems 15 KW and larger:

TABLE: INVENTORIES AND PROCUREMENT POTENTIAL

	INVENTORY	PROCUREMENT	SOLAR POTENTIAL	CRITICAL RQTS
TACTICAL	650 MW	81 MW/yr	16 MW/yr	size, weight, RAM*
THEATER	330 MW	17 MW/yr	7 MW/yr	fuel supply, size
ISOLATED	230 MW	11 MW/yr	10 MW/yr	RAM, fuel supply
EMERGENCY	600 MW	30 MW/yr	-----	1st cost, start up
INSTALLATION	**	**	**	life cycle cost

*RAM = reliability, availability, maintainability.
**Installations purchase the approximate equivalent of 5,000 MW generating capability. A theoretical potential of 250 MW/yr follows. If self sufficiency for critical requirements were sought, 30 MW/yr market potential would result based on emergency inventories.

Tactical Power Systems

Tactical power systems are mobile electric power systems which are assigned to troop units, both combat and rear area. They range in size from 0.5 to 750 KW. Most systems are smaller than 100 KW. Their standardization, requirements definition, DOD development, and product improvement are centrally managed by the DOD Project Manager for Mobile Electric Power. Standard sizes are 15, 30, 60, 100, 200 and 500 KW. Requirements are for utility and precise power at 50/60 or 400 **hertz.** All are three phase, four wire systems with voltage connections for 120/208 and 240/416 volts. They are skid mounted, and designed to operate at temperatures from -65°F to 125 F. Most are diesel driven. A growing number are gas turbine driven. Fuel cells are under development for sizes smaller than those dealt with here (0.5 - 5 KW).

DOD is interested in developing power systems that are lighter and more reliable than current generators. Lower noise and infrared emissions and a multi-fuel capability are also desired. Advanced Stiling or Brayton engines could meet these requirements and also be designed to utilize a point focussing solar heat source, when operationally feasible.

Based on Army holdings, no more than 15 per cent of current inventories (in MW) are held by units which would operate in the combat area. 22 per cent belong to non-combat support units or to air defense artillery. 7 per cent are used to supply power to remote areas in garrison. 16 per cent are estimated to be in garrison storage. 48 per cent are not specifically accounted for. These include units stored in depots and non-standard items. These estimates are rough, based on incomplete data. Marine Corps usage probably parallels the Army's. The Air Force and Navy should have much higher proportions of non-combat generators.

The average annual DOD procurement for 1979 - 1984 is projected to be 81 MW/yr. Given the available information, it is a reasonable estimate that not fewer than 20 per cent of military tactical generators could use solar concentrators as part of a hybrid solar/multifuel power system. A conceptual system would burn liquid fuel in its standard configuration. A standard "solarization kit" would be issued for integration with the standard engine-generator when fuel saving operation was feasible. The conceptual operational feasibility of such a system was confirmed by DOD engineers at the JPL workshop. There exists therefore a potential market of 81 MW/yr for a standard family of heat engine-generators and perhaps 16 MW/yr for a standard solariztion package.

Theater Power Systems

Theater power systems are large, prime power plants which are transported to a theater of operations for use in a semi-permanent location. Most systems in this category are air mobile. All three major services operate theater systems. They are "owned" by engineer units and are operated for the user under their control or supervision.

The theater-sized power plants are not standardized. Current holdings include 500, 700, 750, 1500, 2000, 2500 and 4500 KW diesel driven systems and 750 and 2000 KW gas turbine driven generators. Output power for all systems is 2400/4160 volts at 60 hertz with a 5o hertz capability. Approximately 40 per cent of Army and Navy systems are in peacetime use. These service inventories total 310 MW. Air Force bare base systems which total 20 MW are not used except when deployed. When in use, these prime power plants have a 24 hour duty cycle.

Transport is the critical requirement for theater power systems. Generators must be mobile and they must be supplied with fuel. The former characteristic tends to inhibit the use of solar collectors. The latter favors it. A conceptual system would consist of hybrid liquid fuel/solar heat engine generators which could be centrally located or dispersed. If the transportability of the engine generators are compatible with current systems' size and weight, the solar collection subsystem can legitimately be compared with the logistic fuel burden. Assuming a 20 per cent fuel displacement, current 750 KW systems would logistically justify solar conversion if deployment is anticipated for more than 120 days.

Current inventories are 330 MW. A 20 year life cycle implies a replacement rate of 17 MW/yr. Peacetime usage rates would justify a solar subsystem stockage of 40 per cent. A reasonable market potential estimate therefore is 7 MW/yr.

Isolated Power Systems

Military isolated power systems are remote permanent facilities which generate their own power. They are typically small (15-1000 KW), and include radar stations, communications sites, island installations and remote test facilities.

A survey was able to identify 88 MW in Air Force installations, 100 MW at Naval facilities and 40 MW at Army communication sites. The USAF total is most nearly complete. The Navy survey included only systems larger than 1 MW. The Army total is incomplete. Possibly twice the tabulated total of 230 MW is in the field.

Military remote facilities may use standard mobile systems or non-standardized generators to meet power needs. Generators are usually diesel engine driven with multiple redundant back up. The key operational requirements for isolated systems are availability and reliability. The Defense Communications Agency, for example, requires 99.99 per cent availability, allowing no more than 53 minutes down-time per year. Reliability requirements drive capital costs for uninteruptible power systems (UPS) as high as $1400/KW. A second important factor is the cost of fuel delivery. This is quite variable. It may involve no more than a 10 mile trip by tank truck or it may involve long distance supply by helicopter or tanker.

The higher cost of fueling isolated power systems and their requirement for multiple back up combine to make them attractive candidates for solar thermal powering. Unlike tactical and theater operations, isolated applications pose few requirements which would inhibit solar powering. Only rarely would the display of a solar concentrator enhance vulnerability. Duty cycles are often continuous and use rates are high.

A hybrid solar thermal power system used in a fuel displacing mode would be operationally valid in all but special cases. A representative conceptual system would include a buffer storage subsystem fed by a solar/liquid fueled heat engine-generator and one or more diesel or heat engine driven back ups. Such a UPS would have close to 100 per cent operational validity, and the potential market approximates the estimated procurement rate. Actual market penetration would be a function of array cost versus annual mean direct insolation.

Based on a twenty year life cycle and tabulated inventories, the estimated minimum procurement rate is 11 MW/yr. This implies a solar potential of 10 MW/yr. Because of the known gaps in the survey, the actual potential market is probably higher.

Emergency Power Systems

The duty cycle requirements imposed by back-up generators are incompatible with solar conversion. A large storage subsystem capable of meeting any short term demand would be required. The storage capacity might as well be operated off the prime power plant. Heat engines burning liquid fuels could be used to meet emergency power needs, but start-up times for such systems would likely be slower than for diesels.

Military emergency/back-up power inventories are estimated to be some 600 MW. A twenty year system lifetime would imply an annual replacement rate of 30 MW/yr. Although the potential market for solar thermal powering is nil, emergency power system inventories may be taken as a first approximation of mission critical power requirements at fixed installations. If self sufficiency of critical military power requirements is sought, both currently purchased power and existing back-up units could be replaced by solar thermal power systems with modular back up capacity.

ORIGINAL PAGE IS
OF POOR QUALITY

Installation Power Systems

U.S. military installations purchase electricity equivalent to approximately 5000 MW generating capacity. Using current DOD guidelines to project costs over 20 years, the equivalent uniform annual cost of power is 86 mills/KWh in 1979 dollars. Critical power needs constitute about twelve per cent of total consumption. A small cost bonus can be realized by replacing both purchased power and back-up.

The question of providing on-site power systems for military installations is primarily a political one. Congress would have to appropriate the capital funds required. Two policy questions will be of importance: 1) Will base self-sufficiency add to the ability of the armed forces to function in time of national emergency? 2) Is the national commitment to replace fossil fuel consumption with alternate energy sources one which warrants using the DOD as a market leader to achieve this goal? Once a political decision is made, the technical requirements are no different than those of civil small communities. Power systems being developed by JPL for the civil sector will meet military needs as well. The total potential market is approximately 30 MW/yr for critical requirements and 250 MW/yr overall.

COST GOALS

There are two measures of interest in determining cost goals for military solar thermal power systems. One is the cost of existing systems. The other is the value of the solar option for a hybrid heat engine. The first value can be calculated using a standard equivalent uniform annual cost equation, with measured data for inputs. The latter is calculated by determining the present value of fuel saved and subtracting out all solarization costs but the first cost of the solar subsystem. The standards of comparison are existing systems for the first value and an advanced heat engine burning liquid fuel for the second.

Cost calculations and sensitivity analyses show that the differential fuel price escalation rate is the critical variable driving costs. The value of the solar option is also a linear function of mean annual insolation as a first approximation.

Cost goals vary with the assumptions underlying projections. In spring 1979, an 11% discount rate, 10% general inflation rate, and 8% differential fuel escalation rate were chosen. The base cost of diesel fuel was $0.59/gal. The resulting base-line cost goals range asymptopically from 210 mills/KWh for 15 KW systems to 120 mills/KWh for systems larger than 1000 KW. The value of the solar option is then $2700/KWe at 1875 hours of annual direct insolation.

It should be noted that the market potentials estimated above are based strictly on operational considerations. Penetration will be a function of system costs compared to local insolation and of the costs of competing alternative systems.

Acknowledgement: Research underlying this report was accomplished by the author while an employee of the BDM Corporation. He was assisted by Mr. Mark Perry. Complete results are in BDM/W-79-751-TR, "Military Applications for Point Focusing Distributed Receiver Solar Thermal Electric Power Systems."