Deep Space Network Feasibility Study of Terminating Southern California Edison Electrical Service to Goldstone

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A preliminary study on cost comparison of purchased power versus generated power for the Goldstone Deep Space Communications Complex (GDSCC) shows that there are economic incentives to generate the A-C power requirements for the complex. The justification can only be sustained if the waste heat from the cooling water and/or exhaust systems is recovered for reuse.

I. Introduction

The purpose of this article is to explore the feasibility of eventually terminating Southern California Edison's electrical service to the Goldstone Deep Space Communications Complex (GDSCC) by totally supplying electrical power to the complex from existing GDSCC power generation systems. The advantages of this method of operation include:

(1) Utilization of the diesel generator waste heat to reduce the overall complex energy consumption by 25 to 50 percent;

(2) More consistent power supply source, hence better system reliability;

(3) Optimization of equipment and manpower usage.

It is understood that present GDSCC power generation systems cannot generate power as economically as Southern California Edison when comparing kW for kW; however, the fact that there is a need to maintain a standby diesel power generation system to support Edison's commercial power has, in itself, increased the kWh cost on a purchase basis, as compared to the cost of running on 100 percent GDSCC-generated power alone.

II. Cost Comparison

Attached is an overview analysis of kW-for-kW cost comparison, between commercially purchased power and DSN-generated power (for GDSCC alternating current (A-C) power requirements), based on March 1979 operating costs and 1978 consumption. Table 1 summarizes the details of cost estimates (see Appendix A for calculations), which indicate that the difference is about $0.102/kWh in favor of Edison's purchased power. Offsetting the higher-generated cost/kWh is the waste-energy available in the diesel engine cooling water and exhaust systems which, if recovered for reuse, would substantially reduce the generated power cost. Table 2 shows that the waste-energy has an equivalent of about 2,766,900 liters of diesel fuel per year, worth about $321,624 at $0.11624/liter. Reuse of this waste energy could also substantially reduce the current liquified petroleum gas (LPG) consumption. In 1978, about 374,300 liters of LPG were consumed at GDSCC. At $0.108 per liter, this is equivalent to an expenditure of approximately $40,000 per year. Data sources used in the cost estimates and calculations are listed in Table 3.

III. Energy Conservation and Recovery Systems

Waste energy constitutes about 67 percent of diesel fuel consumption in power generation. Recovering 25 percent of this waste energy for reuse could reduce the total power consumption by about 25 to 50 percent, depending on reuse efficiencies. This reduction should contribute significantly to JPL's goals in energy conservation programs. The waste energy recovered could be used for:

(1) Comfort heating

(2) Absorption chillers

(3) Water distillation

(4) Steam generation, and

(5) Preheating of equipment, etc.

Various successful systems for recovering waste energy from diesel generator power plants have been in existence for several years. In the DSN, two diesel generator waste heat utilization systems are in operation. At DSS 61/63 heat from the power plant engine cooling water system provides comfort heat for the complex. The DSS 62 waste heat recovery system provides both comfort heat and operation room rack cooling. The system most suitable for GDSCC will depend upon the type and cost of the equipment needed to recover waste energy and how this energy is utilized. In-depth studies will be required prior to initiation of a design effort.

IV. Action Plan

Present analysis indicates that there are potential economic incentives to further pursue the concept of supplying (all) power for GDSCC from existing power generation systems. However, before the concept can be implemented the following actions need to be carried out:

(1) A thorough analysis to accurately define the generated kWh cost;

(2) Determine total fossil fuel utilized for generated power vs. purchased power;

(3) Establish diesel fuel availability;

(4) Establish equipment viability in using the potential waste heat energy;

(5) Estimate a cost factor for the change over; and

(6) Draw up a schedule for implementation.

Table 1. Cost comparison between purchased power and generated power

Power consumed (kWh cost)	1978 Actual purchased power mode: 91.7% time on commercial	1978 Actual purchased power mode: 8.3% time on generators	Generated power (100% time on generators)
1978 Power consumption	13,236,555 kWh/yr	1,194,560 kWh/yr	14,431,115 kWh/yr
Diesel fuel cost, kWh	\$0.0370	–	–
Diesel fuel cost, kWh	–	\$0.0332	\$0.0332
Preventive maintenance cost/kWhr	–	\$0.0100	\$0.0067
Overhaul cost/kWh	–	\$0.0097	\$0.0032
Lube cost/kWh	–	\$0.0043	\$0.0009
Operator delta cost/kWh	–	\$0.0135	\$0.0060
kWh cost	\$0.0370	\$0.0707	\$0.0500
Average cost/kWh	\$0.0398[a]		\$0.0500

[a]Computations: (\$0.0370 X 0.917) + (\$0.0707 X 0.083) = \$0.0339 + \$0.0059
= \$0.0398

Table 2. GDSCC—Power generation potential energy savings[a]

Fuel Expenditure:

- 30% Diesel fuel converted to electricity
- 30% Diesel fuel loss due to engine cooling water system
- 37% Diesel fuel loss due to engine exhaust
- 3% Diesel fuel loss due to radiation and other contributing factors

Energy available for reuse	Computations
Estimated liters of diesel/kWh generated or total liters of diesel/year	= 0.28617 l/kWh = 0.28617 l/kWh X 14,431,115 kWh/yr = 4,129,730 liters of diesel/yr
Equivalent fuel loss due to cooling water system	= 4,129,730 X 0.30 liters of diesel/yr = 1,238,900 liters of diesel/yr
Equivalent fuel loss due to exhaust system	= 4,129,730 X 0.37 liters of diesel/yr = 1,528,000 liters of diesel/yr
Total energy available for reuse @ 100% efficiency	= 1,238,900 + 1,528,000 liters of diesel/yr = 2,766,900 liters of diesel/yr
This energy is worth	= 2,766,900 X \$0.11624/yr = \$321,624/yr

[a]Based on 1 kWh generated requiring 0.28617 liters of diesel fuel.

Table 3. Data sources

Caterpillar Model G389 and G399 specifications
GDSCC power consumption ECM[a]/400
GDSCC diesel fuel consumption ECM/200
GDSCC LPG consumption ECM/100
GDSCC utilities summary ECM/600
GDSCC meter reference file ECM/610
GDSCC monthly utility usage reports
GDSCC experience on power generation
1978 total power = 14,431,115 kWh
1978 generated power = 1,194,560 kWh
LPG cost/liter = \$0.108 (Mar. 1979 price) (1 gal = \$0.41)
Diesel cost/liter = \$0.1162 (Mar. 1979 price) (1 gal = \$0.44)
Lube cost/liter = \$0.449 (Mar. 1979 price) (1 gal = \$1.70)
1 gallon = 3.7853 liters
1 kilogram diesel = 17,100 kcal equivalent heat value (1 pound = 19,500 Btu)
Edison power cost/kWh = \$0.037 (Feb. 1979 price)

[a]ECM = Energy Consumption Management Files.

Appendix A

Cost Comparison of Commercially Purchased Power vs. Generated Power for GDSCC—Cost Estimates and Calculations

1978 Power and Diesel Consumption

	DSS 10	DSS 11	DSS 12	DSS 14	Total[a]
Purchased power kWh (metered at station)	6,823,434	–	–	6,413,121	13,236,555
Generated power kWh	–	213,120	171,040	810,400	1,194,560
Total power consumption kWh	–	–	–	–	14,431,115
Purchased diesel fuel	–	–	–	–	341,847 liters (90,300 gal)

Fuel Cost ($/kWh)

Basis:

Percent power generated $= \frac{1{,}194{,}560 \text{ kWh}}{14{,}431{,}115 \text{ kWh}} \times 100 = 8.3\%$

Liters of diesel fuel/kWh $= \frac{341{,}847 \text{ l/yr}}{1{,}194{,}560 \text{ kWh/yr}} = 0.28617 \text{ l/kWh}$

Diesel fuel cost = $0,11624/liter

Diesel fuel cost $/kWh

Diesel fuel cost/kWh = $0.11624/l × 0.28617 l/kWh
= $0.0332/kWh

[a]For entire GDSCC.

Preventative maintenance costs – ($/kWh)

Basis:	Computations:
(1) 100% generation (i.e., 14,431,115 kWh/yr)	Model G398 costs $1.20/engine-hour-run Model G399 costs $2.00/engine-hour run Smaller model cost $1.00/engine-hour-run
(2) 8.3% generation (i.e., 1,194,560 kWh/yr)	Above cost × (factor of 1.5)[a] × % engine-hour-run
Preventive maintenance costs:	Computations:
For 100% generation	= (Model & no. of engines) × (hours-run/yr) × (maint. costs/hr) = [(4 × G399) $2.00 + (10 × G389) $1.20 + (2 × others) $1.00] 4380 hr = [8 + 12 + 2] 4380 = $96,360.00
Cost/kWh	$= \frac{\$96{,}360.00/\text{yr}}{14{,}431{,}115\ \text{kWh/yr}}$ = $0.00667/kWh
For 8.3% generation	= (Above) × 1.5 × 8.3% × engine-hour-run = $96,360.00 × 1.5 × 0.083 = $11,996.82/yr
Cost/kWh	$= \frac{\$11{,}996.82/\text{yr}}{1{,}194{,}560\ \text{kWh/yr}}$ = $0.01004/kWh

[a]Factor of 1.5 is used to take into account additional frequent start-and-stop operations.

Overhaul costs/kWh and lube costs/kWh

Basis:	Computations:
(1) 100% generation (i.e., 14,431,115 kWh/yr)	
Hours run between overhaul	= 30,000 hr
Lube oil requirement	= 30,300 l/yr (total) (8000 gal/hr) (estimated)
(2) 8.3% generation (i.e., 1,194,560 kWh/yr)	
Hours run between overhaul	= 10,000 hr
Lube oil requirement	= 11,400 l/yr (total) (3000 gal/yr) (estimated)
(3) 1 liter lube = \$0.449 (Mar. 27, 1979) (\$1.70 gal)	
(4) Each overhaul cost	= \$20,000.00
Overhaul costs (\$/kWh):	Computations:
For 100% generation no. of engines requiring overhaul	$= \frac{\text{(no. of engines)} \times \text{(hr run per year)}}{\text{hours run between overhaul}}$
	$= \frac{16 \times 4380}{30{,}000}$
	= 2.336 no. of engines/yr
Overhaul costs/yr	= 2.336 × \$20,000.00/yr
	= \$46,720.00/yr
Costs/kWh	$= \frac{\$46{,}720.00/\text{yr}}{14{,}431{,}115 \text{ kWh/yr}} = \$0.00323/\text{kWh}$
For 8.3% generation no. of engines requiring overhaul	$= \frac{16 \times 364}{10{,}000}$
	= 0.5824 no. of engines/yr
Overhaul costs/yr	= 0.5824 × \$20,000.00/yr
	= \$11,648.00/hr
Costs/kWh	$= \frac{\$11{,}648.00/\text{yr}}{1{,}194{,}560/\text{kWh/yr}}$
	= \$0.00975/kWh
Lube cost (\$6Kwh):	Computations:
Cost/kWh	$= \frac{\text{(Cost per gal of lube)} \times \text{(amount used per yr)}}{\text{generated power per year}}$
For 100% generation	$= \frac{\$0.449 \times 30{,}300 \text{ liters}}{14{,}631{,}115 \text{ kWh/yr}}$
	= \$0.00093/kWh
For 8.3% generation	$= \frac{\$0.449 \times 11{,}400 \text{ liters}}{1{,}194{,}560 \text{ kWh/yr}}$
	= \$0.00428/kWh

Power house operator – delta cost ($/kWh)

Basis:		Computations
(1)	@ 100% generation (i.e., 14,431,115 kWh/yr) requires 3 operators on 3 cycle, 8 hr shifts, total manning	= 12 operators
(2)	@ 8.3% generation (i.e., 1,194,560 kWh/yr) requires 3 operators on 2 cycle, 12 hr shifts, total manning	= 9 operators
(3)	Existing manpower availability	= 9 operators
(4)	Current wages and associated costs per operator/yr	= $28,700.00/yr
(5)	2 cycle, 12 hr shifts, involves operator on overtime on actual time worked @ 1.5 times wages, and associated costs but no additional operators	
(6)	3 cycle, 8 hr shifts, involves no overtime but requires hiring 3 additional operators	

Operator delta costs ($/kWh):	Computations:
For 100% generation	= 3 operators × $28,700.00/yr
	= $86,000.00/hr
Delta cost/kWh	= $\frac{\$86,100.00/\text{yr}}{14,431,115\ \text{kWh/yr}}$ = $0.00595/kWh
For 8.3% generation	= (9 operators) × (50% overtime × 1.5 rate) × (actual time worked/yr)[a]
	= 9 × $14,350.00/yr × 1.5 × 0.083
	= $16,079.16/yr
Delta cost/kWh	= $\frac{\$16,079.16/\text{hr}}{1,194,560\ \text{kWh/hr}}$ = $0.01346/kWh

[a] Assuming same as 8.3% generation time.