DESIGN OF A POWER SYSTEM (SOLAR-DIESEL GENERATOR) FOR A GARMENT INDUSTRY AND LOAD OPTIMIZATION

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Abstract— **Due to adverse effect of global warming and environmental pollution, future world is looking for decontaminated green energy resources for power generation. Economy of today's world is based on commercial activities and rapid industrialization. To ensure sustainable economic activity we need to fulfil the energy demand of equipment as well as to serve the automation technology of industrial sector. This results an excess pressure on electricity demand significantly. In spite of many restrictions and proper technical support Bangladesh is looking forward to extract energy from its available renewable resources like other countries. Hybrid power system is a good choice to serve this purpose. This work mainly emphasis on the design and feasibility study of hybrid power system in the context of a particular garment industry, as the garments are the major source of foreign currency and employment in our country. The system is comprised of solar PV and diesel generator. Cost analysis and load optimization is done by HOMER Pro. System validity and advantages are also discussed in explicit way.**

Keywords— **Solar power, Hybrid system, Garment industry**

I. INTRODUCTION

Solar, biomass & wind are the extended aspirant among the easily reached renewable energy sources in Bangladesh. Putatively, Bangladesh gets 69,751 TWh energy every year which is 3000 times greater than the traditional electricity generation [1]. In Bangladesh yearly, solar radiation has a regular power density of 100-300 W/m^2 which can produce 100 MW electricity with an area of 3-10 km^2 with a panel of 10% efficiency [2]. In a year with 6.8% (10,000 km^2) of the land of Bangladesh, per capita 3000 kWh electricity decree can be achieved [3]. The government of Bangladesh acmes the necessity of installing rooftop solar PV system due to the paucity of land. Researcher have found that 1000 MW of solar PV electricity with 75 W capacity of the solar module can be produced by the total accessible sunny rooftops area in Dhaka city which is 10.554 km^2. [4] The efficiency of solar PV decreases significantly because of non-linear characteristics of solar PV and atmospheric conditions which comprises the variation of irradiation as well as the different weather condition. [5] Depletion of power, more installation of PV panel, premature battery failure, capacity loss, lack of proper end-of-charge, higher voltage can be reduced by using MPPT solar charge controller with PV system. [6, 7] There is no doubt that the power demand of Bangladesh is increasing day by day. There should be a balance between production and supply in the economy of a country. Excess demand requires greater production capacity that can create power crisis. Bangladesh is a developing country with a reduced production of electricity due to traditional power plants with de-rated machineries. According to a survey, gap between the produced power and demanded power is about 1000-1500 MW [8]. For this measurable condition, people of remote areas as well as the industries are deprived of grid connection. Many industries in our country are using captive power (natural gas) to meet their energy demand. But this is not possible in everywhere (due to lack of capital, space, technical skill, proper maintenance etc.). Considering the current situation, one possible solution of this problem is to produce electricity from hybrid distributed systems from different energy resources. This type of system can also be integrated to national grid with proper mechanism. Ready Made garments are the most discernible sector of largest foreign currency of country. According to a survey of World Bank about 81.69% of total GDP are covered by this sector [9]. It contributes almost 45% of total employment and 5% of total national income. The production of textile industry often requires a high level of energy consumption with a lowest efficiency in energy consumption [10]. Higher competitiveness and productivity result more benefits. So from business point of view it's important to minimize energy cost and energy consumption

and thus increase energy efficiency. The objective of the work is to design a solar hybrid system (with a diesel generator) to ensure sustainable energy supply for a particular garment industry (Knit Concern's Ltd.). In terms of reliability, better services, operational life, efficiency, the hybrid system has brought forth a modified perfection in electricity generation process. The concept of solar- diesel generator to be used as hybrid system is becoming popular day by day, due to its frequent usability and cost effectiveness. Solar power is often considered as the most economical alternative solution to power crisis. Solar irradiation which is both free and abundant by nature that can profitably be used in many applications along with conventional fuel generators. The price of fossil fuel is unreliable and depends on many facts (including both purchase and carrying cost). Implementation of both system together can significantly reduce the system operating cost as well as the emission of co2 gas in nature.

II. DESIGN OVERVIEW

The purposed work was to design a power system for a particular garment industry (Knit Concern Ltd.). Exact location of the industry is on the bank of Shitalakhya River, Godnail, Narayanganj. This industry covers a premises of 18 acres. It consists of different sections such as Ginning, Spinning, Dying, Washing/ Hydro Section, Processing, Weaving, Knitting, Cutting, Stitching etc. with a variation in load. Since the production of the industry is too large, so the amount of load is also high respectively. The prime goal was to design the system at reduced cost and energy consumption without affecting the productivity. The necessary data was collected to found out the most suitable unit, that's more techno-economically feasible for our proposed system compared to others. Thus by considering the audits, it was found that the apparel division (cutting & stitching) is much suitable to serve the purpose.

The system is oversize type consists of both solar PV and diesel generator. Solar energy can be easily extracted and can be stored in a battery to serve at night by solar cell with less maintenance cost. Due to high load management purpose, a diesel generator is added with solar PV. Both are chosen to serve the purpose of power source of the system, because of their ease of use. They will operate simultaneously. By applying this method the cost can be minimized of the system for a long term satisfactory operation. The components of the system include a diesel generator (30 kW), converter, generic flat PV modules and system load. There were no storage mechanism in our system, because the capacity of diesel generator is such that it can supply the load without the association of solar PV, during the absence of solar irradiation. The system was oversized to feed the industrial load. Total system capacity is 369 kWh/day with a peak value of 55.94 kW. The schematic diagram of the system is given below.

The system is an off grid system. The system is especially designed to supply the load of two floors (light and fans) of the apparel division. The system is designed according to the energy consumption of the load. The value was computed as
Energy consumed by lights = 12*12*65*2 = 18.72 = 19W
Energy consumed by fans = 12*7*75*2 = 12.6 = 13kW
So the total energy consumption is= 19kW+13kW= 32kW.
The system is able to supply 32 kW at peak hour. Extra capacity can be added to the system by providing additional sources.

Fig.1. Homer Pro system model

The system capacity with respect to total amount of load is given as a pie chart as shown above. Though it covers a very small portion of total load, still it's able to provide continuous supply to desired load without any interruption. The system would be implemented on the rooftop of the building. Generators should be placed on shaded area. To design this system 269 piece PV modules, three diesel generators/ one (30kW) generator and one converter was required. Total net present cost of the system was therefore $2, 48, 052 with liveliest cost of electricity $0.1293 and operating cost $13,569.
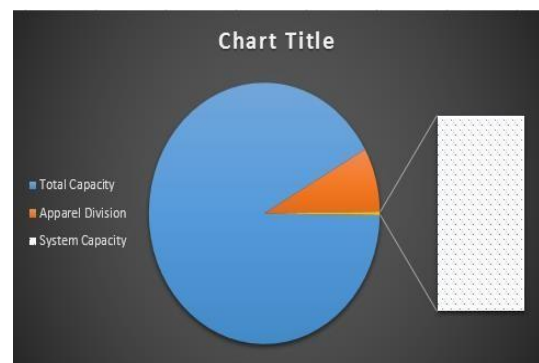

Fig 2 Portion of load covered by the System

Table 1 Price and rating of the components are given below as a tabular form.

Component Name	Capacity	Price
PV modules	93 kW	$47,451
Diesel Generator	30kW	$2,100
Converter	52kW	$2,600

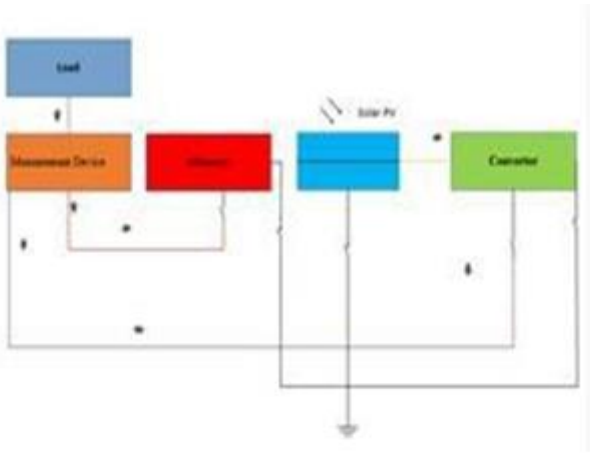The figure shown below represents the block diagram of the system.

Fig.3. System Block Diagram

It features five components: Alternator, Converter, PV modules, measurement device and respective loads. Current is going from alternator to measurement device directly. Output of solar PV first transfers to converter. Converter converts it into useful ac current for typical ac load. The relay connected to the alternator, PV modules and converter will bypass the excess current during overflow. Arrow sign shows the direction of current. The system provides switching mechanism that can make contact between load and generating device to provide constant supply.

III. ENERGY RESOURCES AND LOAD PROFILE

A. Load Profile and Collected Data

A distinctive load profile has been made according to the data which was collected. To supply the load of apparel division of the garment industry, a power supply of 369 kWh/day on average with a peak demand of 55.94kW is required. The load factor is 0.27. Load factor is the division of average load by peak value. The load operates for 9 hours (working hours). 2 hours are specially considered for overtime workers. The work load is maximum between 10 A.M- 12 P.M. Variation in load is not so high because the load type is industrial. The value is almost constant
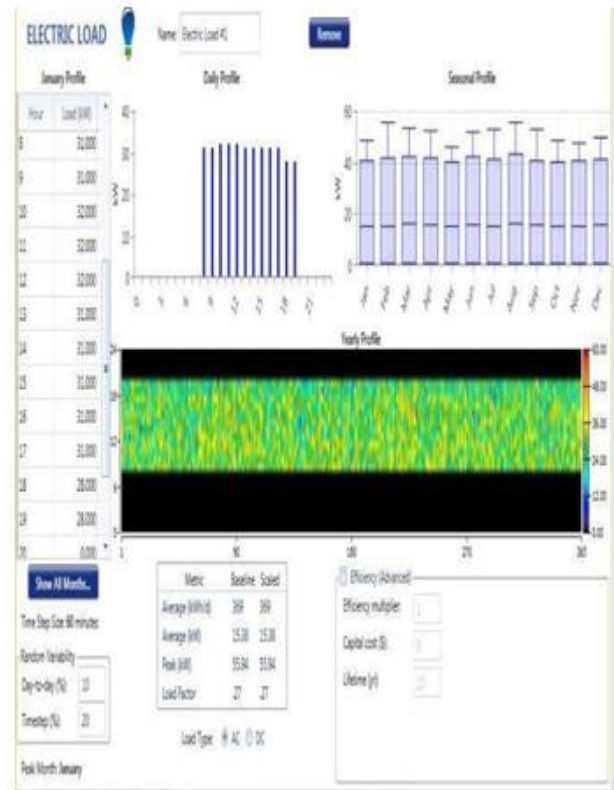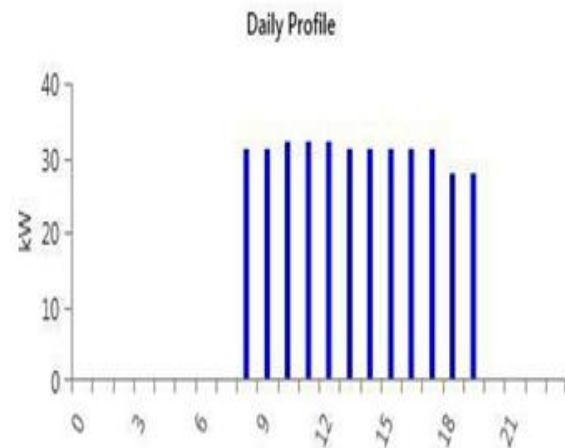

Fig 4 Electric Load Profile

Fig.5. Daily Load Profile

B. PV System Sizing

Actual geographical coordinates of that industry is 23º 39´ 0n North, 90º 31´ 0n South. The value of solar radiation (kWh/m²/ day) are computed by HOMER Pro software via internet. Space required by solar panel is quite higher compared to other power generating system. So this fact

should be considered before implementation of Solar PV. According to plant capacity, each kW PV requires 107 sq. feet of area. By considering the solar radiation photovoltaic system size are chosen between a ranges of 80-93kW capacity with a derating factor of 90%. Lifetime of the photovoltaic system is 25 years. Total capital cost of the system is $47,451. The replacement and O&M cost is considered $0, because the project lifetime is equal to the lifespan of solar PV.
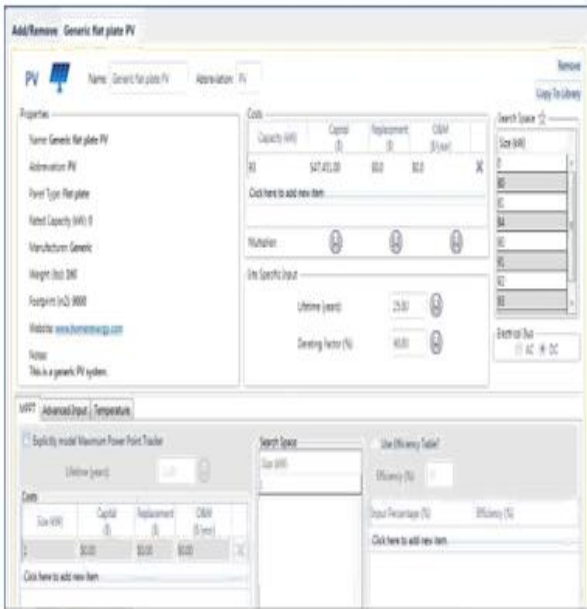

Fig.6. PV profile

C. Generator Sizing

Generator with a 30 kW capacity is required to make the system feasible. Generator is provided in such a way, so that it can jointly operate with PV to supply the load. Generator capacity is chosen 30kW. Value of the generator is $700 (10kW). Operation and maintenance cost is chosen $0.030. Generator sizes are specified in search space. Price of fuel is considered $0.837/L. Total operating hours of generator 219,000.
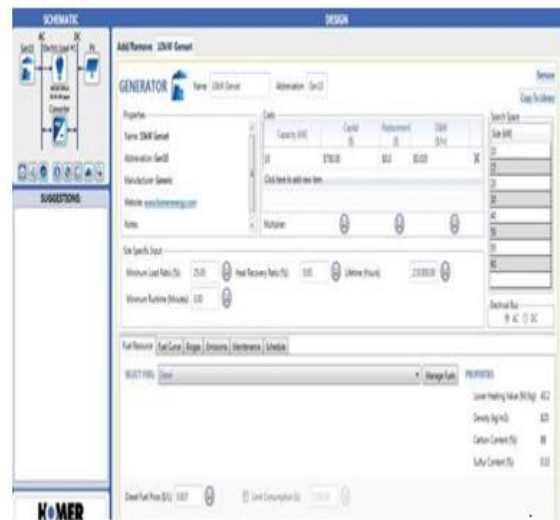

Fig 7: Generator Profile

D. Converter SizingDesign

Fig 8 Converter Profile

Converter configuration is shown in above figure. Capacity of converter is chosen 54kW with an efficiency of 95%. Initial cost of the converter is $2700.

IV.   SIMULATION AND OUTPUT

A. Simulation Result

By providing necessary data including the component cost and monthly data's of resources in HOMER simulation tool, simulation were initiated. The objective of this simulation is to find the optimal size of the system. The exact size and

combination of the system was showed by HOMER Pro, after the simulation was completed. Results are given below.

Fig 9 Simulation Output

From the figure, we can see that the cost of electricity (COE) which is the minimum cost of electricity is $0.129 (10.21 BDT; 1 USD = 79.21 BDT). Total NPC is $2, 48,047. Operating cost is considered $13,569. System is not totally noiseless and uncontaminated. This value is given by renewable fraction part of the system which is 68% in our case. Operating hours of generators are 2,502 with a production of 43,182 kWh. Total amount of fuel is 15,953 L. Production of PV modules are 190,050 kWh. Values regarding the expense of PV, generator and converter are given below in tabular form

Table 2 Cost of the system

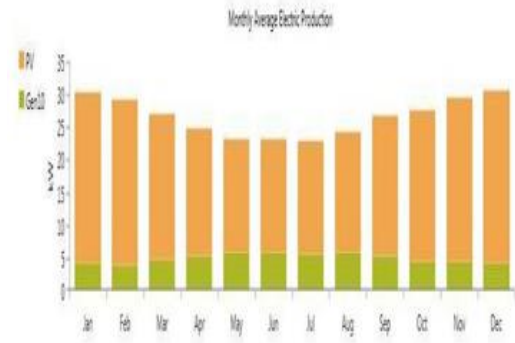| Component	Cost	O&M	Fuel	Salvage
Diesel Generator	$2,100	$3,249	$1,92,759	($117)
Converter	$2,700	$0	$0	$0
PV profile	$47,451	$0	$0	$0
System	$52,151	$3,249	$1,92,759	($117)

B. Electrical Output

Fig.10. Monthly average Electrical Production

Above figure shows the electrical output on monthly basis. Upper portion represents the output from PV modules and the lower portion is the output of diesel generator. Electrical production from different resources and consumption percentage of different loads are shown below as table format.

Table 3 Production of the System

Production	kWh/year	percentage
PV panel	1,90,050	81.49%
Generator	43,182	18.51%
Total	233,232	100%

Table 4 Energy Consumptions of Load

Consumption	kWh/year	Percentage
AC primary Load	132,892	100%
DC primary Load	0	0%
Total	132,892	100%

C. Cash Flow

Fig.11. Cash Flow

Above figure shows the cash flow bar chart of the system. First bar represents the initial capital (installment cost). The other bars show the fuel cost to purchase the fuel. As it is showing that the fuel cost is almost constant during its period. This values are represented as a line graph below.
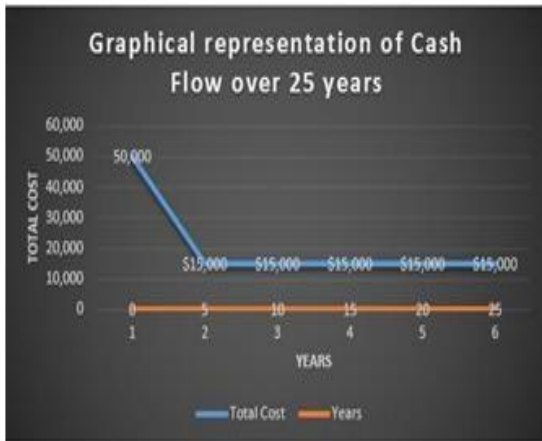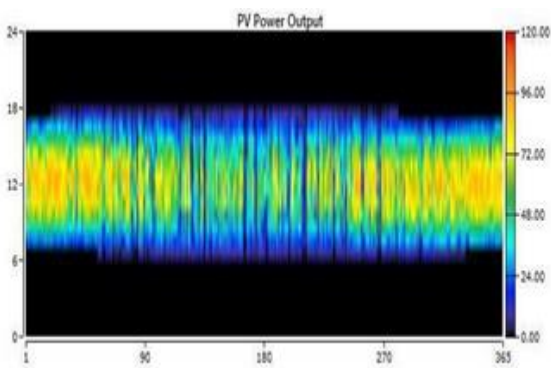

Fig.12. Cash Flow

D. Power Output

Fig.13. PV Power Output

Above figure shows the DMap of PV power output for 24 years and 365 days. The mean output is 520.68 kWh/day with a capacity factor of 23.33%. Total production is 190,050 kWh/year with a levelized cost of 0.0173 $/ kWh.
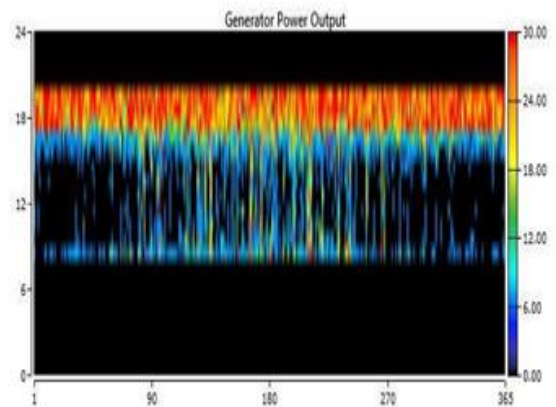

Fig.14. Generator Power Output

Same goes for generator. Maximum output of generator is 30 kW with a capacity factor of 16.4%. Total electrical production is 43,182 kWh/year with a marginal generation cost 0.239 $/kWh. Mean electrical efficiency is 27.51%.
Finally the curve we found for AC primary load is shown below.
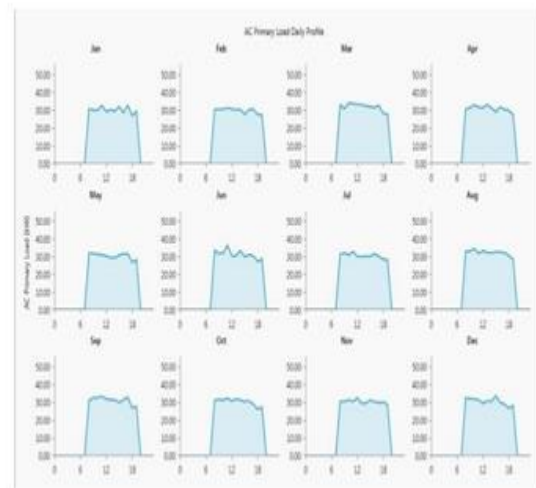

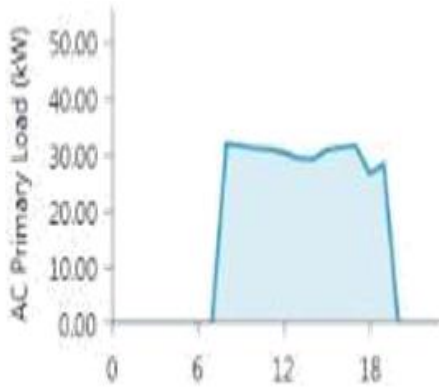Fig.15 AC load for a Particular month

Fig.16. AC load for a Particular month

Therefore, considering the availability of potential resources economic feasibility of the system: 93kW PV modules and 30 kW generator can be considered as follows

Total cost of the system = $2, 48,047

Maintenance cost of the generator = $3,249

Operating years = 25 years

No. of sunshine hours = 6 hours.

Assuming PV array generates 90% of their rated capacity

So per day generation of the PV system = 93*6*0.90 = 502.2 units

Per unit cost (for PV) = $47,451 / (25*365*502) = $0.010

Fuel cost of generator = $13,352

Generator cost = $2,100

Total cost = $13352+ $2,100+$3,249 = $18,701

Generation of the generator = 30*0.90 = 27 units

Per unit cost (for generator) = $18,701/ (365*25*27) = $0.07

V. LIMITATION

Main problem of the system is that it's not entirely renewable resource based. So the operation of the system is not noiseless and pollution free. Besides the system couldn't manage the entire load of the industry. It only covers some particular loads of apparel division only. Another problem of the system is that there are some excess electricity due to oversizing of the system. But this problem can be solved by connecting them to some other loads, except the counted one.

VI. RECOMMENDATION

In this study importance is given on the design of hybrid system. In most cases, industrial loads are supplied by captive stations, where natural gas is used as fuel. Due to enormous use of load for production purpose, the load consume very high energy. So there are many things that's need to be considered before designing a system for industrial load. Since the energy consumption is very compared to household appliances, the system should be designed in such a way, so that it can supply the load without any interruption in production. This system is able to supply sufficient energy required for suitable operation of load. Lifetime of the system is considered 20 years. The maintenance cost includes only the maintenance cost of generator. The mounting structure of the PV panels will be set on the rooftop of the building. The PV arrays will be arranged to their requirements. Spacing is important between two adjacent solar panels to ensure air circulation among them to reduce the amount of heating. Generator will be placed in a shaded area to prevent heat. Since the load will be used roughly throughout the year, the panels should be tilted at latitude.

VII. CONCLUSION

Energy is the basic criterion for the upward spiral of the continuous prosperity of a country. Access of electricity is essential for communication, development, employment, healthcare, education etc. Like other developing countries, Bangladesh is switching from its traditional agro- based economy to industrialization process. Our govt. is offering various scheme and opportunities to continue this revolution. To ensure the incrimination of productivity- maintaining the standard of products, preservation of specific products and power processing equipment etc. are important. Power supply from a reliable source is an important catalyst for serving this purpose. This causes a burden on power plants and available fuel resources of our country. To solve the scarcity of power crisis of our country, there is no other alternative but accessing renewable resources of our country. The research objective was to design a hybrid power system (solar-diesel generator) for a garment industry (Knit Concern's Ltd.), as the garments are the main source of employment and economy of the country. Details investigation was done on load consumption, location, available resources, feasibility etc. before designing the system. The system includes field data of specific site, cost analysis, proper components, operational lifetime, cost of servicing, spare parts availability etc. Despite of some limitation our system is able to supply energy to the load without any disruption. Though the system is not entirely renewable operated, still this could be a milestone for further work on this topic.

VIII.   REFERENCES

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