ELECTRIFICATION PROGRAMME WITH SOLAR ENERGY IN REMOTE REGION: A CASE STUDY FOR A REMOTE VILLAGE IN TURKEY

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ABSTRACT

The study presents a comparative economic analysis of electricity generation using photovoltaic (PV) cells, diesel generator (DG) and conventional grid. A sensitivity analysis was carried out on capital cost, conversion efficiency and interest rate. Its found that unit cost of PV electricity is comparable with DG generated electricity and grid system in some conditions.

I. INTRODUCTION

The supply of electricity to the rural communities of developing countries continues to be a major problem. The main objective of the present study, is to examine the feasibility of a centralized photovoltaic (PV) system as a source of guaranteed supply of power in a remote village in Turkey. The supply of power to a remote village is not economically viable because, of the exorbitantly high cost of distribution and associated transmission loss. As other alternatives, one may think of diesel generators or PV systems. The present paper aims economic benefits of solar energy as a source of supply of electricity in such a remote region in Turkey.

Also it's known that world reserves of oil and gas will run out in a little over 40 years at the current rate of consumption. The world needs a smooth transition period to shift from oil to alternative sources of energy. The solar photovoltaic (PV) cell is the most ideal energy conversion system.

II. ECONOMIC ASPECT

If the economic viability is concerned, one has to look at the cost structure of the production of solar energy and compare it with those of major conventional sources, by taking into account both the direct and indirect costs incurred at different stages of production and distribution. The cost of energy in the thermal or hydraulic based centralized power stations consists of the generation, transmission and distribution costs, whereas in the decentralized power generating system energy cost is primarily the generation cost.

The distributing power through medium / low voltage line in rural areas and in places located far away from the center is not economically viable. The high distribution cost is associated with high line lost which increases with the distance from the grid point and with low capacity utilization due to the lack of demand for power. The per unit cost of generation of power produced from decentralized diesel and PV based systems for different distances have been estimated and presented in Table 1 for a comparative study.

Table 1. Cost of generation of power through diesel and PV systems.

Generation System	Diesel	Solar
Average Cost/kW	509	7203
Annual Capital Cost/kW	142.5	795
Annual O & M Cost/kW	12.72	180
Annual Gen. at Bus [kWh]	1818	2691
Annual Fuel Cost [$]	121.1	0
Total Cost [$]	276	975
Cost of Generation [cent]	15.20	36.23

Notes:

(1) Annualized capital cost is based on capital recovery factor using
  (a) Interest rate at 12 per cent and discount rate has been neglected
  (b) System life as 15 000 hours for diesel generator, 25 years for PV panels, 7 years for batteries, 10 years for inverters
  (c) Annual O & M cost is 2.5 per cent of capital investment.

(2) Average capital cost of 1 kW capacity diesel generator has been estimated from a generator of 25 kW.

(3) Fuel price has been taken as 5.26 [$/MBTU] and consumption rate as 12.800 [BTU/kWh].
(4) PLF (load factor) has been taken as 20.7 per cent for diesel based system, 29 per cent for PV system
(a) Assuming peak demand / transformer rating to be 50 kW and 30 per cent load factor.
(b) Consideration of 30 per cent load factor as average demand, which is difficult to be realized in remote rural areas.

Also to compare the per unit costs of the different systems, we have to obtain the average energy production cost of the national electricity company. So, the information below has been collected from national electricity company of Turkey.

Table 2. Cost of generation of power through diesel, PV systems have been estimated and the average energy production cost has been obtained from the national electricity company of Turkey.

Generating System	Cost of Generation [$/kWh]
Conventional System	1.95
Diesel System	15.20
Solar System	36.23

The result shows that centralized power systems produces power at the lowest cost compared to the other systems. The result of that is the size resulting in scale, economy and greater efficiency in generation which is not possible in a locally installed plant of a smaller size adjusted according to the local demand. The cost of generation of diesel generator is comparatively high due to its high operational and maintenance cost, shorter system life and high fuel cost. This cost is the highest in the PV plant primarily due to its high capital cost. The cost incurred for the distribution of power from a centralized conventional system to distant areas from the 33 kV grid point, presented in Table 3, is quite high compared to its generation cost (which is zero in case of the decentralized PV and diesel system).

Table 3. Cost of distribution line by distance [km] from 33 kV grid point, including transformer cost.

Item of Expenditure	5 km	10 km	15 km	20 km	25 km	50 km
Capital Cost [$ x 1000]	36.13	69.76	103.39	137.02	170.65	338.80
Annual Capital Cost [$ x 1000]	4.69	9.06	13.43	17.81	22.18	44.04
O & M Cost [$ x 1000]	0.91	1.74	2.58	3.42	4.26	8.47
Total Cost [$ x 1000]	5.60	10.80	16.01	21.23	26.44	52.51
Cost/ kWh [$ x 0.1]	4.10	7.92	11.73	15.56	19.38	38.49

Notes:
(1) Cost km^{-1} of distribution line (11 kV) from the 33 kV grid point is approximately 6720 $.
(2) Rate of interest has been assumed as 12 percent, discount rate has been neglected and O & M cost has assumed as 2.5 per cent of capital cost.
(3) Life of distribution line has been taken as 20 years.
(4) Peak load has been taken as 50 kW where as the average load has been assumed as 30 per cent of the peak load.

The cost of distribution network depends on the length of the 11 kV line, transformer and the energy demand of the area. The cost of energy increases further due to heavy line losses at the time of transmission and distribution. The distribution cost of the power inside the village will be neglected for both of the three systems. The line losses have gone up steadily in Turkey. The national average of the loss is now 20 per cent of the production whereas in the rural areas it may gone up to 60 per cent of the production. So when the line loss percentage has been considered for the calculation of the national energy production cost, then the new energy cost without distribution and transformer costs occurs as 3.12 cents for these kinds of remote regions.

The increase in the distance from the centralized supply point, can be seen in the unit energy costs. So the distance of the remote village plays a very important role in the unit energy costs. The unit cost of establishing an energy distribution line for 5 km distance is much more expansive than to produce 1 kWh energy in a conventional thermal or hydraulic plant. This can be examined from the Table 4.

Table 4. Cost of delivered power in a remote village for Turkey.

Generation System	5 km	10 km	15 km	20 km	25 km	50 km
Conventional Grid [$ x 0,1]	7.22	11.04	14.83	18.68	22.51	41.61
Diesel Generator [$ x 0,1]	15.74	16.25	16.75	17.26	17.76	20.29
Solar PV [$ x 0.1]	36.23	36.23	36.23	36.23	36.23	36.23

Notes:
Cost of delivered power is the sum of generation cost of power supplied at bus and distribution cost including cost for line cost, transformer cost and line loss.
The line loss as a percentage of production has been taken as 60 for Turkish grid system, 0 for diesel and PV system. Also an extra fuel cost for the transportation of fuel of diesel system has been considered as [138 $/km] for the distance in a remote region.

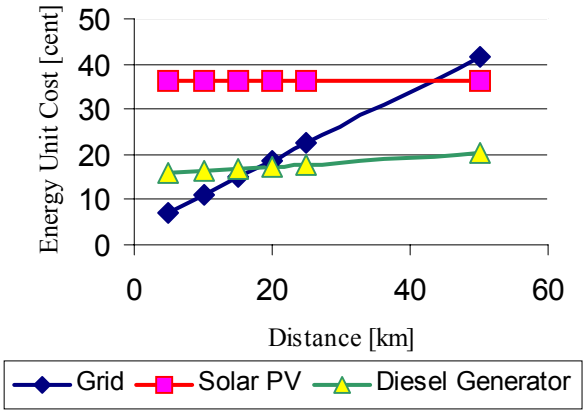

Fig. 1. Energy unit costs of the different systems as a function of distance.

III. CONCLUSION

The UN conference in Rio-de-Janeiro held in June 1992, addressed itself to the challenge of achieving worldwide sustainable development and it was felt that it cannot be achieved without major changes in the world's energy system. In countries like Turkey, dependent mostly in the import fuel, has increased the cost of generation of electricity significantly over the years. On the other hand, the cost of PV cells is declining progressively over time as a result of Research and Development (R & D). So a time would come when the per unit energy cost from the PV plants would be comparable with that of the centralized system at all levels for a rural electrification programme. Also it has to be emphasized that PV systems are an environment friendly source of energy and this also must be considered.

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