RURAL ELECTRIFICATION IN INDIA: THE ACHIEVEMENTS AND THE SHORTCOMINGS

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ABSTRACT

This paper briefly summarizes some of the achievements and highlights some of the shortcomings of India's rural electrification programme. There are socio-economic problems as well technical problems associated with this programme. In this paper mainly the technical problems which are also pertinent to other developing countries are discussed.

Key Words: Rural electrification, T&D loss, Alternative sources.

1. INTRODUCTION

Less than 3000 out of 0.56 million villages in India had electricity when the British left India in 1947. The total installed capacity in the entire country at that time was about 2300 MW which has increased more than 25 times since then. The number of villages electrified has exceeded 0.4 million and more than 6.5 million irrigation pumpsets have been energized. Figs. 1 and 2 indicate the rates of growth of electrification of villages and energization of pumpsets over the last few decades. The growth was initially slow but has been increasing exponentially during the last decade.

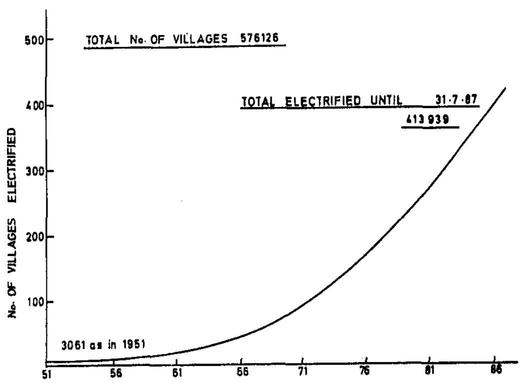


Fig. 1

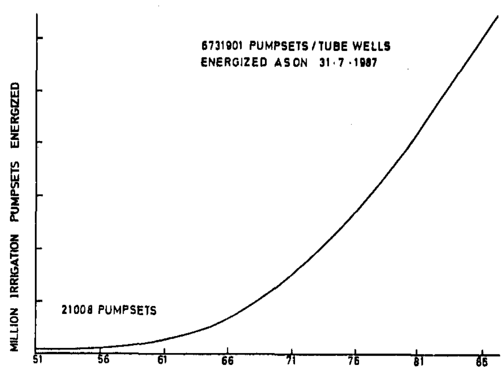


Fig. 2

This has brought about a significant change in India's agricultural sector. The high yielding varieties of food grain combined with increasing availability of ground water from artificial irrigation, has turned India from a deficit to food surplus country. The severe draught in Rajasthan and Karnataka State for four consecutive years would have led to famine in earlier years. India could however, tide over this crisis without having to import food. This achievement may be partly ascribed to the extensive electrification carried out in the country.

Street lighting in the rural areas has spread fairly extensively. The growth of agro-industries has however, been limited despite extensive electrification and it has been shown [1] that other infrastructural facilities are essential for agro-industrial development and electrification alone cannot bring about the anticipated growth. In some areas, electricity has been utilized by the rich farmers to replace human service by installing coffee crushers and paddy hullers and similar agro-machineries.

Unfortunately, rural electrification has not directly benefited 80% of the rural population although indirect benefits of improved agricultural production have percolated down to various levels and helped to alleviate general poverty to some extent. It was suggested [1] that unmetered electric connection be provided, free of cost, to the houses of the rural poor and a flat rate charged every month for a 60W bulb. Karnataka State Government took up the suggestion and instituted the 'Bhagyajyothi Scheme' which has provided domestic light to a large number of rural homes. The Central Government recently started the 'Kutirjyothi' plan to provide domestic lighting to poor homes.

Many problems associated with rural electrification are socio-economic in nature and do not have simple solutions. There are however, a number of technical problems which have arisen from an unplanned growth. In this paper two technical problems are discussed in some depth.

1. Rural electrification in India has been almost entirely carried out by extending the grid. Rarely have local resources been utilized for generating power.
2. The distribution networks have grown in a haphazard fashion. As a result, distribution losses are very large and often the terminal voltages are poor.

2. ALTERNATIVE ENERGY SOURCES FOR RURAL ELECTRIFICATION

The growth of electrification in India has been almost frantic in recent years. Desperate efforts have been made to meet targets. There was no master plan. The method followed by the State Electricity Boards (SEB) has been "to connect a village to be electrified to the nearest village that has been electrified". This has given rise to an inefficient distribution network as will be examined in the following section. Alternative energy sources have hardly been explored. It is only in a few inaccessible places that small hydel units have been installed. But it seems essential that local sources should be utilized to the extent possible.

Various alternative sources have been suggested in the literature [2]. Of these:
a) Small hydro power (SHP), (b) Wind energy, (c) Solar power, and (d) Bio energy have received considerable attention. Decentralized generation using diesel generation is used in some areas but is not recommended because it drains scarce oil resources. In fact the proliferation of diesel generating units in Industries to make up for inadequate power supply has been causing a considerable drainage of diesel oil. Solar cells installed by the Department of Non-renewable Energy Sources (DNES) of the Government of India for street lights in a few villages are still prohibitively expensive. The DNES has also installed wind farms on an experimental basis in some areas, but the cost effectiveness of these installations need to be examined. Besides, wind power ordinarily demands the presence of a grid.

Biogas plants for producing electrical energy have been tried in isolated experiments. Biomass is also being tried on an experimental basis for generating producer gas to run an engine and generate power.

Of the four alternatives as decentralized energy sources mentioned above, SHP is the oldest and has been extensively used in China where 7 GW of small hydropower has been installed and is in operation. The growth of SHP in India has been very limited, the total installed capacity being less than 300 MW.

The potential of mini hydel plants in India, particularly in the Himalayan region and their cost effectiveness have been discussed in reference [3]. It is generally believed that small hydel power is expensive and the cost of operation and maintenance is prohibitively high. Figs. 3 and 4 indicate the relative costs of installation and costs of operation and maintenance respectively of hydro-generators of various ratings. The use of local manpower and materials sharply bring down the costs of SHP.

The relative costs of minihydel generation and grid extension have been frequently discussed. In considering the cost-effectiveness of an alternative energy source, it is a frequent practice to compare an alternative source with the cost of grid extension. Fig. 5 presents relative costs of mini hydel generation and grid extension as a function of the distance of a village from the nearest grid.

It may however, be pointed out that alternative sources should not necessarily be considered as alternatives but as supplements to grid extension. Large losses occur when power generated from large generators, transmitted at various voltage levels over long distances finally makes its way to remote villages at relatively low voltage. Besides, there is a deficit of power and energy in the country and it has been mentioned earlier that industries have been supplementing for this deficit at a high cost. In Haryana, Punjab, Tamil Nadu, electrical energy used in the rural areas is over 30% of the total electrical energy consumed in the State. This has often caused deficits in other sectors. It is imperative that local sources be harnessed to meet local requirements to the extent possible and the generated power fed into the grid if it meets the necessary technical requirements. The Planning Commission of India has started an Integrated Rural Energy development programme which is given high priority in the eighth plan.

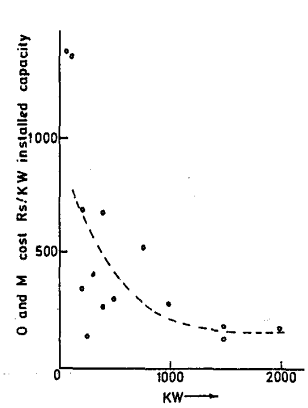
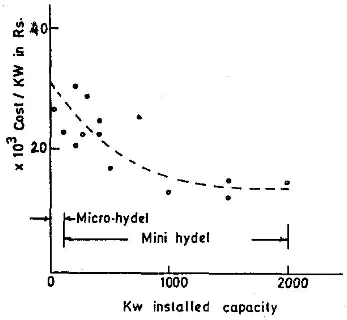


Fig. 3



Microhydel
< 100 kW
Minihydel
100 kW – 2000 kW

Fig. 4

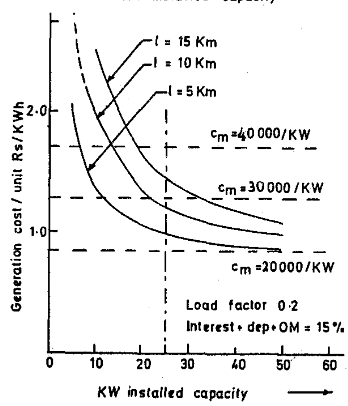


Fig. 5

3. LOSSES IN DISTRIBUTION NETWORK

Transmission and distribution losses in India are extremely high, exceeding 22%. The percentage losses are the highest in the 11 kV and 440-V distribution networks. Apart from the fact that the lines meander along tortuous routes, linking one village to another, the conductor sections are often inappropriate and the transformers are grossly overloaded. It may be added in this context that the utilization of electrical power in the rural areas is highly inefficient. The irrigation pumps are inefficient and the motors are overrated.

A typical example of a 11-kV rural network is shown in Fig. 6. Voltages were actually measured at the tail ends of a number of 11-kV feeders on the LT side during peak load. Table 1 gives the measured value of voltage in Devanahalli, a sub-district (Taluk) near Bangalore in Karnataka State. It may be seen that at peak load condition the line to line voltage is as low as 265 volts instead of 415 volts. Induction motors driving pumps frequently burn out when the voltage drops to such low values.

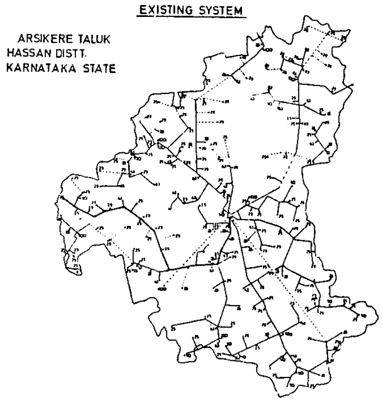


Fig. 6

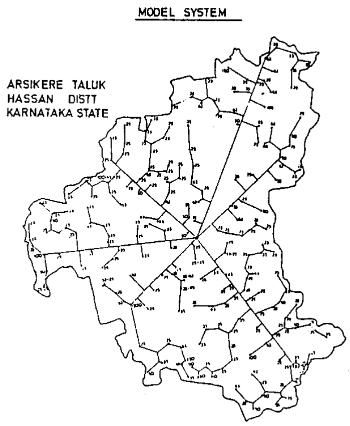


Fig. 7

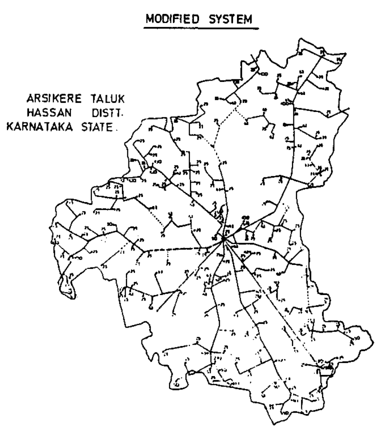


Fig. 8

Table 1
Measured voltages at selected points in Devanahalli Taluk (Karnataka State, India)

	Av. 7am - 8am	Evening	Worst reading Morng.	Eveng.
Budigere	277	296	264	258
Maralankute	277	326	266	305
Balepura	381	410	260	324
Allur Doddahally	377	410	286	364

3.1 Remedies Adopted by the SEBs

The remedies adopted by State Electricity Boards to improve tail end voltages have been as arbitrary as the original laying of the distribution networks. Express feeders, (feeders linking the substation directly to a bulk load without any intermediate tappings) are laid primarily to satisfy rich farmers demanding better voltages. Sometimes new substations are set up for improving terminal voltages. These are extremely ad-hoc and costly solutions and cannot be taken up as a general solution for the entire country.

There is also a growing tendency in different electricity boards to replace transformers of relatively larger ratings (200 kVA) by smaller transformers so that, LT lines can be increasingly replaced by 11-kV lines and copper loss in distribution lines may be reduced.

Gujarat Electricity Board (GEB) on the other hand are of the view that proliferation of transformers will significantly increase iron loss which takes place all the time unlike copper loss.

The solution lies in ascertaining the load density and load factor as to whether the multiplicity of low-rating transformers with short LT lines is going to be less lossy than a single transformer with proliferation of LT lines. A suitable decision can be reached only when computer analysis is undertaken.

4. A COMPUTER-AIDED COST -EFFECTIVE SOLUTION FOR LOSS MINIMIZATION

A computer program has been developed for improving the existing distribution networks using interactive graphics facilities. A large number of papers have been published for designing optimum distribution systems [4,5,6]. Normally these algorithms assume that the network is being laid in areas which have not been electrified and constraints of terrain and the right of the way are seldom included in these studies. An optimization programme can seldom take a proper decision as to where to stop and continues on the basis of the errors specified initially in the programme. It is necessary to use heuristics. The experience of an engineer familiar with the area and the local constraints is most suitable in deciding on the 'optimum' solution.

A fast solution of a network using Kirchhoff's current law and diakoptics is stored in the computer. The program has to be fast in order not to tax the patience of the operator interacting with the computer. The load is represented as a combination of fixed impedance load (lighting) and a variable load (motors) at each node. The data including the route map is entered through a "digitizer" and the network is

37.5.3

displayed in colour. The losses are computed and displayed. The voltage along a feeder progressively drops and reaches the 10-kV limit at a point. The colour of the feeder from the substation to this point is changed providing a visual indication of the 10-kV boundary. The feeders that demand attention can be detected immediately and remedial actions are proposed step by step.

In the first step, loads are redistributed and attempts made to 'strengthen' a feeder as much as possible within the constraints of the terrain. An ideal solution may be seen in Fig. 7 where the distribution network resembles the vein structure of a lotus leaf.

For every modification, the computer calculates the losses and the 10 kV boundary. What is most important is to calculate the cost of the proposed modification and the payback period. If the cost is acceptable, the next move is to project the load (with an assumed growth rate) upto 7-10 years to check whether the modification carried out now will still do when the load grows.

If reallocation of loads and straightening the feeder do not give satisfactory results for the present and the future, conductor size is altered in the section which is heavily loaded and the losses and voltage drops recalculated.

The solutions are carried out in the following sequence:

a) Redistribute loads and straighten feeders
b) Change conductor size
c) Instal feeders in parallel in overloaded sections
d) Instal new feeders
e) Change distribution transformers
f) Use switched shunt capacitors
g) Instal a new substation.

The effects of the proposed changes are studied at every step. If the results seem to be satisfactory for the existing load, they are recomputed for future loads as stated before.

Finally the future projections still give satisfactory percentage loss and acceptable voltage profile within reasonable expenses, retain the solution and proceed with other feeders. If a new substation has to be set up, layout of all feeders has to be taken up together.

It may be noted here that installation of a substation should be the last choice and shunt capacitors have not been found to be very effective in LT networks.

Fig. 6 has been modified to Fig. 8 and the feeder in thick line showed that reallocation of loads and straightening of the feeders reduced the losses considerably and gave 10 kV at the tail end in most feeders. Table 2 represents the aggregate results modifying the network in Devanahalli Taluk (see Table 1).

Table 2

Before modification				After modification			
Worst tail end voltage kV		Power loss kW		Worst tail end voltage		Power loss kW	
year 0	year 7	year 0	year 7	year 0	year 7	year 0	year 7
7.0	6.0	1667	3400	9.7	9.0	815	1965

	Year 0	Year 7
Power saving in kW	853	1435
Value of energy saving per annum in million rupees (LLF = 0.12, cost per unit Rs. 0.60)	0.54	0.9
Cost of peak load saved in million rupees at Rs. 25,000/kW*	21	36

Total cost of modification = Rs.0.53 million
Payback period = 1 year

* Costs at 1986 prices [Rs. 14 $ 1].

The results presented in Table 2 represent a typical study and similar studies have been carried out in a large number of places all over India. The improvements are dramatic and the payback period computed on the basis of energy saving alone is from 1-2 years depending largely on the terrain. It is necessary to consider that the power that is being saved is the power which does not have to be generated and the saving on that account is very high indeed.

5. CONCLUSIONS

Rural electrification in India has rapidly increased during recent years. A large number of developing countries have also been moving ahead with their rural electrification programme, having realized its all round benefit. There is however, every possibility that the grid extension pattern may continue as it has done before and modifications may be carried out in an equally ad-hoc manner.

It is imperative that computers are used at every level to design new systems and modify old systems, calculating the cost effectiveness at every stage of computation. With limited resources, developing countries face very large constraints and as such cost effectiveness has to be of prime concern.

Alternative sources have to be utilized wherever feasible, not necessarily as alternatives but as supplements in an integrated rural energy programme.

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