POWERING OF A REMOTE AREA THROUGH RENEWABLE ENERGY SOURCES

A DISSERTATION

Submitted in partial fulfillment of the requirements for the award of the degree of

MASTER OF TECHNOLOGY

in

ALTERNATE HYDRO ENERGY SYSTEMS

By

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CANDIDATE'S DECLARATION

I hereby declare that the work presented in the dissertation entitled **"POWERING OF A REMOTE AREA THROUGH RENEWABLE ENERGY SOURCES"** submitted in partial fulfillment of the requirements for the award of degree of **Master of Technology** in **Alternate Hydro Energy Systems** in the Department of Alternate Hydro Energy Centre, Indian Institute of Technology Roorkee, is an authentic record of my own work carried out from July 2006 to June 2007 under the guidance and supervision of **Dr.M.P.Sharma,** Associate Professor, Alternate Hydro Energy Centre & **Dr.R.P Saini,** Associate Professor, Alternate Hydro Energy Centre.

I have not submitted the matter embodied in the report for award of any other degree or diploma.

Date: June 29 2007

Place: Roorkee

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This is to certify that the above statement made by the candidate is true to the best of my knowledge and belief.

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ABSTRACT

Energy plays an important role in our day to day life. Electric power is a key driver of economic growth and prosperity. Due to the adverse affects of using conventional energy sources for power generation and due to their depleting nature, the world is shifting towards non conventional energy sources. Renewables are indigenous, non-depleting, modular and environment-friendly. They can meet a broad spectrum of energy demand. India is blessed with huge potential of renewable energy which can be used to power remote unelectrified areas.

India has been pursuing renewable energy sources of energy for various applications for a long time now. Currently, renewable energy sources of energy make up for about 5% of grid electricity produced in the country. Despite the increasing contribution of renewables to the total national power, about 21% villages still remain in dark and not all the households of the electrified villages have power. There are still a number of villages which do not have even a single light in their households. Because of the technical and economical problems associated with extending electricity services from the regional grid to these villages, they were left unelectrified. Renewable energy sources that are available in those villages can be used for meeting power demands of such villages. Among the various options available for generating and distributing power from renewable energy sources, Decentralized Generation and distribution is best suited for remote unelectrified areas which are located far away from the Grid and whose connection to the grid is technically and economically unfeasible.

Twelve unelectrified villages of Jaunpur block of Tehri Garhwal district of Uttarakhand were selected for study. The villages are rich in renewable energy sources and possess a total power potential of 50.8kW which is proposed to be generated from Micro Hydro Power, Biomass, Solar Photo Voltaic and Wind Energy Conversion technologies. The total power demand of the cluster of villages under the study area is 47.0418kW. Various options available for distributing the power to among the villages are studied and a cost comparison of the same was done. The cost optimized distribution system was arrived at with a total cost of Rs 3,84,614/km.

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CHAPTER 1

INTRODUCTION AND LITERATURE REVIEW

1.1 INTRODUCTION

Energy is the key theme for future world development. The energy demand worldwide is increasing rapidly, especially in the developing countries which seek to catch up with the economic development attained by industrialized countries during the last century. The world energy trends are changing day by day. Though the alternate energy sources are getting the required importance in many of the countries, the dominance of the conventional energy sources is in a continuous growth. For most of their power and energy needs, people in rural areas remain dependent on conventional sources such as firewood for cooking and kerosene for lighting. Even in villages that are electrified, supplies are erratic and of extremely poor quality. In this kind of power scenario, renewable energy sources that are locally available can be made of good use in order to meet the power needs of the rural people.

1.2 WORLD ENERGY SCENARIO

The world energy scenario shows that the usage of conventional energy sources is very much higher than the use of non conventional energy sources. The main concern about the use of conventional energy sources is the environmental impacts they pose. Climate change is a global problem faced due to the use of conventional energy sources for energy generation. Moreover, the conventional sources of energy are exhaustible and not environment friendly. All these lead to choose the non conventional energy sources for energy generation. There are a lot of advantages with non-conventional or renewable energy sources when compared to the non-renewable energy sources. They are in line with an overall strategy of sustainable development. They help reduce dependence on energy imports or do not create a dependence on energy imports in countries that will have increased energy demands in the future, thereby ensuring a sustainable security of supply.

Renewable energy technologies are suitable for off-grid services, serving those in remote areas of the world without having to build or extend expensive and complicated grid infrastructure. Combined with the improvement of energy efficiency and the rational use of energy, renewable energy can provide everything fossil fuels currently offer in terms of energy services. Though humans have been tapping most renewable energy sources for thousands of years, so far only a tiny fraction of the technical and economical potential of renewable energy has been captured and exploited. Yet, with existing and proven technologies, renewable energy offers safe, reliable, clean, local and increasingly cost-effective alternatives for all our energy needs. Renewable energy sources, due to their inherent decentralized nature can contribute significantly to overcome poverty in developing countries. Table 1.1 gives the exploitable power capacity of renewable energy. However, to achieve an economically attractive growth of renewable energy sources, a balanced and timely mobilization of all renewable energy technologies is of great importance.

Table 1.1 Existing Renewable Electric Power Capacity in GW

Energy Sources	**World Total**	**Developing Countries**
Small Hydro Power	66	44
Wind Power	59	6.3
Biomass Power	44	24
Geothermal Power	9.3	4.7
Solar Photovoltaic grid	3.1	~0
Solar Thermal Electric	0.4	0
Ocean (tidal) Power	0.3	0
Total Renewable Power Capacity(excluding Large Hydro)	182	79
For comparison		
Large Hydropower	750	340
Total Electric Power Capacity	**4,100**	**1,500**

Source: Global Energy [R]evolution – A Sustainable India Energy Outlook

1.2.1 Technically Accessible Renewable Energy Sources

The amount of energy that can be accessed with current technologies supplies a total of 5.9 times the global energy. Though a lot of renewable energy potential is available, only some part of it is accessible due to the technical constraints. Table 1.2 gives an idea of the technically accessible renewable energy today.

Table 1.2 Technically Accessible Renewable Energy

Energy Source	**Energy Intensity**
Sun	3.8 times
Geothermal Heat	1 time
Wind	0.5 times
Biomass	0.4 times
Hydrodynamic Power	0.15 times
Ocean Power	0.05 times

Source: Global Energy [R]evolution – A Sustainable India Energy Outlook

1.3 INDIAN ENERGY SCENARIO

As a rapidly developing country, India's energy needs are likely to increase over the coming decades. Already India is the world's sixth-largest consumer of energy. Most estimates suggest that to sustain its current average annual growth rate it will need to increase its energy consumption by about 4% annually. Currently, domestically mined coal meets close to 70 % of India's total energy needs. After China and the United States, India is the world's third-largest producer of hard coal. Oil supplies about another 30% of the country's energy. Currently, India imports more than 60% of its annual oil needs, or slightly more than 1.4 million barrels of oil per day. At current rates of economic growth this figure is likely to rise to as much as 5 million barrels per day by the year 2020. Unless India obtains or develops alternative sources of energy in 15 years, it will have to import close to 90% of its petroleum needs.

The Indian economy continues to show impressive economic growth. The country's GDP grew at an impressive rate of 9.1% during the first half of fiscal year 2006. India is now the eleventh largest economy in the world, fourth in terms of purchasing power.

It has also become a significant consumer of energy resources. According to Energy Information Administration estimates, India was the fifth largest consumer of oil in the world during 2006. India has a cumulative generation capacity 124,000MW, generating a total of 633 billion units. The generation is mainly based on coal, thermal and hydro. The Per capita energy consumption is 529 kgoe, which is 30% of the world average and about 80% of total rural energy consumption comes from non-conventional energy. Table 3.2 gives the energy resources and their installed capacity in the country.

Table 1.3 Resources and Installed capacity in India

Source	Potential(GW)	% Contribution
Coal	70682	53.5
Gas	13,691	10.4
Oil	1,201	0.9
Total Thermal	85,575	64.7
Hydro	34,653	26.2
Nuclear	4,120	3.1
Renewable	7760	5.9
Total	**1,32,110**	

Source: http://powermin.nic.in/JSP_SERVLETS/internal.jsp

1.3.1 Renewable energy sources of India

From table 1.3, it is clear that the share of renewables (mainly wind, solar and biomass) is almost double that of nuclear power and is growing steadily. Wind power contributes to nearly half the power from renewable sources. The rest is from solar, biomass, cogeneration and small hydro. India has the fifth largest wind power capacity in the world and India has a vast supply of renewable energy resources, and offers one of the largest programs in the world for deploying renewable energy products and systems. Indeed, it is the only country in the world to have an exclusive ministry for renewable energy development, the Ministry of Non- Conventional Energy Sources (MNES), now Ministry of new and Renewable Energy (MNRE). Since its formation, the Ministry has launched one of the world's largest and most ambitious programs on renewable energy.

Specifically, 3,700 MW are currently powered by renewable energy sources (3.5% of total installed capacity. This is projected to be 10,000MW from renewable energy by 2012. Table 1.4 gives the renewable energy sources available and achievements in India.

Table 1.4 Renewable Energy Resource Potential and achievements in India

S.no	Sources/Systems	Estimated Potential(MW)	Cumulative achievements as on 31.03.2007
I	Power from Renewables		
A	Grid-Interactive renewable		
1	Bio Power(Agro residues)	61,000	524.80 MW
2	Wind power	45,000	7092.00 MW
3	Small Hydro Power	15,000	1975.60 MW
4	Cogeneration- bagasse	5,000	615.83 MW
5	Waste to energy	7,000	43.45 MW
	Sub total	1,33,000	10,251.68 MW
B	CHP/Distributed renewable		
6	Solar Power	50,000	2.92 MW
7	Biomass/Cogen(non- bagasse)		45.80 MW
8	Biomass Gasifier	-	86.53 MW
9	Energy recovery from waste	-	19.76 MW
	Total	50,000	155.01 MW
	Total(A+B)	1,83,000	10,406.69 MW
10	Remote Village Electrification		2821/ 830 (villages/ hamlets)
II	Decentralized Energy Systems		
11	Family type Biogas Plants	120 lakhs	38.90 lakhs
12	Solar Photovoltaic	20 MW/sqkm	
	i.Solar Street lighting	-	61,321 nos
	ii. Home Lighting System	-	3,13,859 nos
	iii Solar Lantern	-	5,65,658nos
	iv. Solar Power Plants	-	1870.00 kWp
13	Solar Thermal Programme	-	
	i. Solar Water Heating	140 million sq.m	1.90 million sq.m collector
	ii. Solar cookers	-	6.03 lakhs
14	Wind Pumps	-	1180 nos
15	Aero-generator/Hybrid	-	608.27 kW
16	Solar Photovoltaic Pumps	-	7068 nos

Source: Ministry of New and Renewable Energy Annual Report 2007

MW = Megawatt kW = Kilowatt, kWp = kilowatt peak, sq.m. = square metre, CHP = Combined Heat & Power.

The key factors of the growth of power generation through renewable energy sources are: i) The demand- supply gap, especially as the population increases ii) Large untapped potential available iii) Concern for the environment iv)The need to strengthen India's energy security v)Pressure on high-emission industry sectors from their shareholders And vi) A viable solution for rural electrification.

The key driver for any kind of energy development is the technology that is available to exploit it. Table 1.5 shows India's position in the world with respect to renewable energy technology.

Table 1.5 India's position in Renewable Energy Technology

S.No	Component	Global	India
1	Commercial Solar cell efficiency	14-16%	13-15%
2	Commercial wind turbine size(maximum)	5MW	1.65MW
3	High Pressure Bagasse cogeneration Technology	Upto 105 bars	Upto 105 bars

Source: Global Energy [R]evolution – A Sustainable India Energy Outlook

1.4 RURAL ELECTRIFICATION

Currently, more than half of the world population lives in rural areas including almost 90 %(approximately 2.5 billion) in developing countries. A major part of these people has no access to modern energy resources such as grid electricity. The rural electrification in developing countries is fundamentally different from developed countries. An analysis of consumers needs (residential, commercial and micro- industrial) in rural and sub-urban areas indicates that the daily consumption would be much lower than the developed countries. In rural areas of developing countries, electricity is regarded as powerful factor of socio-economic development. Electricity contributes to the life quality improvement.

1.4.1 Energy Scenario in Rural India

India has made considerable progress in electricity generation. Installed capacities have grown many times, mainly through conventional sources of power generation like thermal power plants and large hydro plants. Even then, the demand for power continues to overtake supply, as the economy is growing. The result is substantial peak and energy shortages all over the country. In addition to it, India has a large transmission and distribution losses upto 40%. So, electricity to all remains a dream for most Indians, especially in rural areas. Though nearly 80% of villages have been electrified, only about 44% of households have access to electricity.

Rural Electrification Corporation (REC) looks after the rural electrification of remote areas. It was incorporated on July 25, 1969 under the Companies Act 1956. Rural Electrification Act 2003 had been passed by the Parliament. According to the act,
Rural electrification policy aims to provide access to electricity to all households by the year 2009, Supply quality and reliable power supply at reasonable rates, minimize lifeline consumption of one unit per household per day by the year 2012. For villages /habitations where grid connectivity would not be feasible or not cost effective, off-grid solutions based on stand-alone systems will be taken up for supply of electricity so that every household gets access to electricity. Where neither standalone systems nor grid connectivity is feasible and if only alternative is to use isolated lighting technologies like solar photovoltaic, may be adopted and decentralized distributed generation facilities together with local distribution network based either on conventional or non-conventional methods of electricity generation whichever is more suitable and economical will be provided.

The Ministry of Power has the responsibility of providing electricity to the remaining 1,25,000 villages through the programme Rajiv Gandhi Gramin Vidyutikaran Yojana(RGGVY). In addition, it will also provide electricity to 23 million households of remote rural areas. At least one Distribution Transformer of appropriate capacity is to be put up in each habitation of every village or hamlet as village electrification infrastructure, Stand-alone grid with generation where grid supply is not feasible. These Stand-alone grids would be setup in partnership with the Ministry of Non- conventional Energy also.

As per the act, a village is assumed to be electrified if the following conditions are met:

- "Basic infrastructure such as distribution transformer and distribution lines is provided in the inhabited locality as well as a minimum of one hamlet where it exists.
- "Electricity is provided to public places like schools, panchayat offices, health centers, dispensaries, community centers etc".
- "Number of households electrified should be at least 10% of the total number of households in the village".

Rural Electrification Corporation, a Government of India enterprise under the Ministry of Power, is the nodal agency for implementation. The management of rural distribution will be users Associations, individual entrepreneurs, Cooperatives, non-Governmental Organizations, Panchayat Institutions and Public sector units like National Thermal Power Corporation, Power Grid Corporation of India Limited, National Hydroelectric Power Corporation limited and Damodar Valley Corporation.

1.4.2 Financial Resources

90% capital subsidy will be provided overall cost of the projects under the scheme. The capital subsidy for eligible projects under the scheme will be through the Rural Electrification Corporation limited which will be the nodal agency. Electrification of unelectrified below-poverty line households will be financed with 100% capital subsidy as per the norms of *Kutir Jyoti programme* at Rs.1500 per connection in all rural habitations. Others will be paying for the connections at prescribed connection charges and no subsidy will be made available.

All States in India are active in achieving the targets of rural electrification. Table 1.6 shows the number of villages electrified under the projects financed by Rural Electrification Corporation.

Table 1.6 Status of Rural electrification in India

S.No	State	Cumulative upto 31-03-06 (Number)
1	Andhra Pradesh	14907
2	Arunachal Pradesh	1316
3	Assam	16363
4	Bihar	32490
5	Delhi	0
6	Goa	0
7	Gujarat	7712
8	Haryana	90
9	Himachal Pradesh	11143
10	Jammu & Kashmir	4416
11	Karnataka	8907
12	Kerala	151
13	Madya Pradesh	54411
14	Maharashtra	13322
15	Manipur	1720
16	Meghalaya	2321
17	Mizoram	531
18	Nagaland	793
19	Orissa	26648
20	Punjab	3908
21	Rajasthan	26477
22	Sikkim	277
23	Tamil Nadu	807
24	Tripura	3223
25	Uttar Pradesh	49881
26	Uttarkhand	469
27	West Bengal	23727
Total		**306010**

Source: http://recindia.nic.in/download/ar2005-06.pdf

The following tables give a brief idea about the status of rural electrification in Uttarakhand state. Table 1.7 gives a brief idea about rural electrification status in uttarakhand state as a whole. Table 1.8 and Table 1.9 give a brief idea about the status of rural electrification in Garhwal zone and Kumaon zone of Uttarakhand, respectively

Table 1.7 Rural Electrification in Uttarakhand

	Scheme Outlay	**Initial Target**	**Revised Target**	**Progress**
Number of Unelectrified Villages	787	634	397	318
Number of De-Electrified Villages	682	513	183	263
Total	1469	1147	580	581
Number of Hamlets	20381	9645	2074	1989
Number of Below Poverty Line Households	2,81,615	76034	20000	21539

Source: Uttaranchal Power Corporation Ltd

Table 1.8 Rural Electrification in Garhwal Zone of Uttarakhand

S.No.	**District**	**Target**		**Progress**		**Under Electrification**		**Balance**	
		Village	**Hamlets**	**Electrified Villages**	**Electrified Hamlets**	**Village**	**Hamlets**	**Village**	**Hamlets**
				Garhwal Zone					
1	Dehradun	40	1937	40	318	0	107	0	1512
2	Uttarkashi	173	975	173	235	0	105	0	635
3	Pauri	360	1549	209	157	75	140	76	1252
4	Tehri	248	3486	82	139	27	184	139	3163
5	Chamoli	102	815	46	97	4	101	52	617
6	Rudraprayag	48	886	37	193	5	48	6	645
7	Haridwar	4	97	5	103	0	18	0	0
Total Garhwal Zone		**975**	**9745**	**592**	**1242**	**111**	**703**	**273**	**7824**

Source: Uttaranchal Power Corporation Ltd

Table 1.9 Rural Electrification in Kumaon Zone of Uttarkhand

S.No	District	Target		Progress		Under Electrification		Balance	
		Village	Hamlets	Electrified Villages	Electrified Hamlets	Village	Hamlets	Village	Hamlets
Kumaon Zone									
1	Nianital	32	1785	20	421	2	105	10	1259
2	U.S.Nagar	6	448	0	163	0	75	6	210
3	Almora	200	2999	45	121	18	54	137	2813
4	Bageshwar	39	1091	47	431	0	49	0	610
5	Pitoragarh	126	2933	96	306	10	120	20	2507
6	Champaat	91	1380	85	374	6	21	0	985
Total Kumaon Zone		**494**	**10636**	**293**	**1816**	**36**	**424**	**173**	**8384**
Total Uttaranchal		**1469**	**20381**	**885**	**3058**	**147**	**1127**	**446**	**16208**

Source: Uttaranchal Power Corporation Ltd

Table 1.10 shows the zone-wise progress of rural electrification programme in Uttarakhand.

Table 1.10 Progress of Rural Electrification in Uttarakhand

S.No	Name of District	Total Villages as per Census-01	Total Electrified Villages Till 03/07	Total Electrified Villages by Grid	Electrified by UREDA	Total Electrified Villages	Balance Villages for Electrification
Garhwal Zone							
1	Dehradun	738	11	757	8	765	0
2	Uttarkashi	682	17	646	33	679	3
3	Pauri	3151	538	2914	122	3036	115
4	Tehri	1801	182	1675	39	1714	87
5	Chamoli	1166	199	1036	55	1091	75
6	Rudraprayag	658	202	625	19	644	14
7	Haridwar	510	64	484	4	488	22
Total		**8706**	**1213**	**8137**	**280**	**8417**	**289**
Kumaon Zone							
1	Nainital	1091	54	1068	14	1082	9
2	U.S.Nagar	674	-	653	1	654	20
3	Almora	2172	284	2044	42	2086	86
4	Bageshwar	883	179	813	54	867	16
5	Pitoragarh	1579	197	1353	87	1440	139
6	Champawat	656	173	595	58	653	3
Total Kumaon Zone		**7055**	**887**	**6526**	**256**	**6782**	**273**
Total Uttaranchal		**15761**	**2100**	**14663**	**536**	**15199**	**562**

Source: Uttaranchal Power Corporation Ltd

1.5 LITERATURE REVIEW

The optimal planning of a distribution system is important to decrease the cost of installation with regard to construction, materials and equipment of the system. Distribution systems planning is a complex procedure since a large number of variables are involved and also the mathematical modeling is quite a difficult task considering many requirements and restrictions imposed by the configuration of the system. The optimal planning of an electric power distribution system has been frequently described by the minimization of a single objective function representing the system planning economic costs, for a single or multiple stages, including the optimal size and/or location of the feeders and/or substations of the power system. On the other hand, Evolutionary algorithms have been applied to industrial optimization problems in recent years, achieving good results and showing also excellent optimization characteristics in operation and control of distribution systems.

Ramirez Rosado proposed two evolutionary algorithms for the multi objective optimal planning of distribution systems that allows for optimizing 'n' objectives simultaneously, under a multi objective planning approach. Particularly it has been applied to the optimization of two objectives: an objective function of the distribution system economic costs, including the fixed costs and the true nonlinear variable costs and other objective function related to the distribution network reliability

The main planning approaches of the distribution systems consists of the following methods,

i) The alternative policy method which compares a number of alternative policies and selects the best.

ii) The decomposition approach in which a large optimization problem is divided into several smaller sub problems and each one is solved separately.

iii) The linear programming and integer programming methods where the constraint conditions are linearized.

iv) The dynamics programming method.

Egill Benedikt Hreinsson , 2006 discussed the application of an activity based distribution cost model, APOWER to rural distribution system. The model was tested on an actual rural distribution system in Iceland. Fawzi et al, 1982 discussed about the routing optimization of primary rural distribution feeders. They discussed the problem of selecting the optimal route for a primary distribution feeder radiating from a rural substation at a given location and feeding a number of loads with known demands and locations. Nahman et al, 1997 suggested an optimal planning of rural medium voltage distribution networks. The model was suggested for selection of main initial parameters to meet the increasing load demands with minimum total present worth cost. Eloy Diaz Dorado et al, 2003 suggested a method for planning large rural low voltage networks using evolutionary strategies. Kersting et al, 1992 developed an analysis program called radial distribution analysis program(RDAP), for a personal computer. Monteiro et al ,2004 discussed about the influence of the decentralized generation in the harmonic pollution in an electric power system.Dussart ,1997 discussed about the problems encountered with connecting decentralized generating plants to the distribution networks.Tani et al ,1994 presented a case study on a village Kiribati. The authors made a comparative study of the grid extension and the use of PV for the electrification of the area. Owen, 1998 further explained about the different methods of obtaining electric power from traditional methods since decades.Dasuki et al, 1994 elaborated the status of Solar Home Systems in Indonesia. Karki et al, 2004 presented a simple method of controlling the cost of rural electrification in one and at the same time, improving the benefit for the utility. Wallace et al, 1997 explained in detail about the use of PV for rural electrification. Diniz et al, 2006 explained Brazils' photovoltaic rural school electrification. The authors provide a detailed explanation that PV is the effective complement to the Grid-Based power for a remote area. Sebitosi et al, 2003 considered the concept of very advanced technologies to solve the rural electrification problems in the developing world. A technology called white LED, with minimum power requirements is considered for general lighting, as a solution to African Rural Electrification. Dwolatzky et al, 1998 developed a novel design approach based on integrated software tool CART which minimizes the repetitive and time-consuming tasks for the designer.

Dedman et al, 1990 presented a survey report on the URD cable failure rates in rural electrification schemes. Soler at al, 2003 presented a planning method implemented in LAPER.They also compared the extension of MV grid with the installation of individual PV systems. Tapanlis et al 2003 presented a comparative study of PVP+ SHS and Hybrid schemes for rural electrification for a same area. Caamano-Martin et al, 2000 presented a simplified Characterization procedure for crystalline Silicon PV modules, which can be used for quality control processes in PV-RE programs. Thiel et al, 1996 introduced a power electronic converter solution that is capable of providing rural electrification at a fraction of the current electrification cost. Sen Gupta, 1989 briefly summarized some of the achievements and highlights and the shortcomings of India's rural electrification Programme. The important technical problems that are faced by the programme are highlighted. Chambers et al, 2006 developed a software tool for application in the design of suitable power generation systems for small isolated rural loads based on stand-alone wind-diesel hybrid systems. The proposed software applies dynamic programming techniques to arrive at a suitable selection of diesel generators and corresponding annual operating cost for given load and renewable resource profiles. Bellar et al, 2004 presented a comparative analysis of single-phase to three-phase converters based on simulation results using PSCAD and EMTDC. The purpose was to develop electronic converters suitable to supply consumers in rural or remote areas. Siyambalapitiya et al, 1991 presented the application of conventional economic analytical techniques to evaluate proposed rural distribution systems in an oil-importing developing country. Sabharwal, 1990 proposed a procedure that incorporates the transmission and distribution costs in the electricity supply cost to the rural load centers. A new method was suggested that determines the contribution of rural loads to the system peak demand. Holland, 1989 explained various methods of power generation for the remote areas where grid connection is technically and economically not feasible. Govender, 2001 described the automated creation of load polygons in randomly distributed rural communities, which is an important stage in the planning process. Intergraph's geomedia software was used as the GIS platform and a benefit points system was used to display the consumer distribution density by means of thematic map. The work presented an engineering tool to automatically determine the members of a load polygon.

Stone et al, 2000 detailed the impact of the three-hundred photovoltaic-powered solar home lighting systems (HS) that have been operated in the sunderbans region of West Bengal since 1997. Ijumba et al, 1999 discussed the development of a computer programme for determining the most cost effective energy source to supply the required load at any given time of the day. Douglas et al, 1998 developed a six-switch split capacitor topology for low cost single phase to three-phase conversion and evaluated against other technologies. The new topology has a reduced number of power electronic devices, which reduces the overall cost and size of the system. Mbogho et al, 1996 proved that for the same load factor and units generated, the unit cost for Hybrid power system is lower than for supply by grid extension due to the long distance from the existing grid termination to the village site. The plant capital costs were also proved to be lower for the Hybrid power system than for Supply by grid extension, for the same installed capacity. As a case study, the authors have taken a remote village in Kenya. Mather et al, 2000 presented model for a PV-Utility interface for remote rural application. The developed unit displays a topology involving few power conditioning stages, simplicity, fault tolerance, versatile power-sizing possibilities. It also includes a highly integrate d low cost embedded micro controller. Ijumba, 1996 made a comparison between the costs associated with the grid extension and the powering through the mix of alternate energy systems. Kagarakis et al, 1989 outlined some of the main problems of design and assessment connected with the practical applications of photovoltaic generation and discusses the major points of controversy concerning different choices of technologies available. Martins et al, 2005 performed a technical and economic feasibility analysis on a hybrid photovoltaic diesel system is presented for a typical remote Brazilian village.Anantha, 1990 discussed all the features of the solar photovoltaic system, its cost comparison with other sources, its merits and demerits, R&D efforts in India and strategies for commercialization. Sebitosi, 2003 made a brief revisit to the electricity distribution systems of the 19th century. Then a new proposed 42V dc automotive system can be applied with advantage to rural electrification. Thirault et al, 2003 presented a new tool named "ecoelectrify" for the economic design of electric distribution system for rural areas in developing countries.

A four-wire single-phase to three-phase static converters for rural distribution system was developed by Bellar et al, 2004. Monteiro et al, 2004 discussed about the influence of the decentralized generation in the harmonic pollution in an electric power system. Dussart, 1997 explained in detail about the Problems encountered with connecting decentralized generating plants to the distribution networks. A significant number of studies have been devoted to the optimization of distribution systems using computational methods. A dynamic programming method was utilized by Oldfield and Lang, 1998 and later by Adams and Laughton, 1974 to make a compromise between the difficulties due to the large number of variables, the complexity of the design process, and the computational advantage to be gained by searching for optimality. Oldfield and Lang, 1965 suggested a two-stage planning method in which the processes of design and optimization are applied consecutively rather than simultaneously. Crawford and Holt,1975 employed a linear programming approach utilizing the transportation algorithm to optimize substation service areas by minimizing the products of demand and the distances from the substation. This technique minimizes distribution feeder losses but it does not necessarily arrive at the optimal expansion plan since it does not minimize the present value of costs associated with expansion. The model developed by Masud ,1974 consists of a zero-one integer programming approach to optimize substation transformer capacity and a linear programming approach to optimize the load transfers. The procedure involves first minimizing substation transformer capacities for each year and then optimizing the load transfers. However, it does not minimize the present value of the expansion costs. Gonen and Foote,1981 developed a mathematical model and utilized mixed integer programming to determine the optimal design of distribution systems. The interesting aspect of their approach is that they linearized the nonlinear cost curve by using piecewise linear equations at the expense of increasing the number of variables. Carson and Cornfield, 1973 utilized a heuristic approach in which the discrete cost function is converted into a continuous one. They developed their method to determine the near optimal design of radial networks. The branch and bound algorithm of the linear programming method have been employed by Hindi and Brammeller,1976 to find an optimal solution to the design problem.

The model is concerned with the optimal locations of transformer substation sites and cable routes. Ponnavaikko and Rao, 1987 utilized the Quadratic Mixed Integer Programming method. Their model includes the substation fixed cost, cost of transformation losses and the cost of feeder losses. In this approach, the problem is solved in two steps, first, using the simplex method and second the quadratic mixed integer programming algorithm. Hsu and Chen, 1990 developed a knowledge-based expert system for distribution system planning.

1.6 OBJECTIVE OF THE WORK

Main objective of the present study has been to design a cost optimized power distribution system for the selected cluster of villages. The reason for selecting this topic is the growing importance of the rural electrification. Distribution system design plays a crucial role in a power system designing process, as the distribution system is the one which is directly connected to the end-user i.e. the costumers. Any discrepancies in the design of distribution system will lead to the dissatisfaction of the costumers. As cost plays an important role in the selection of a technology, the work is aimed at optimizing the cost of the distribution system for the selected cluster of unelectrified villages. In the work, a cost optimized distribution system was developed for the selected cluster of villages. As the area is very far off from the grid and the extension of electric supply from the grid is both technically and economically unfeasible, the rich renewable energy resources available are planned to be used for energy generation.

1.7 OVERVIEW OF THE WORK

The present work is organized in 5 chapters. The section below gives a brief idea of the same.

Chapter 1 gives an introduction to the energy trends and scenarios present in the world and India. The main stress is laid upon renewable energy sources. This chapter also gives a brief idea about the literature review done as a part of the work.

Chapter 2 gives profile of the study area. The demographic data and the energy details of twelve villages under the study are briefly explained in this chapter.

Chapter 3 explains in brief about the decentralized distribution systems. It gives a brief idea about different schemes of distribution systems that are available. Decentralized generation technologies are also discussed in brief. The rural distribution systems are also dealt with in this chapter with a small introduction to the steps involved in distribution planning process and the costs involved in designing a distribution system.

Chapter 4 deals with techno economic analysis of the distribution system design for the study area. A comparison was made between different schemes of distribution available for the study area and the cost optimized distribution scheme was arrived at.

Chapter 5 concludes the work with the results obtained from the work.

The area selected for study is Jaunpur block of Tehri Garhwal district of Uttaranchal. The selected area has got a total annual energy potential of 4, 44,930kWh/yr and a total annual energy demand of 4,12,086 kWhr/yr. A total of 12 unelectrified villages have been considered for study. Among the 12 villages, only 3 villages have surplus of energy and the rest of them have deficit. The villages are rich in biomass resource which could be the major source for energization of the area. The optimized generation model for the same shows that about 94% of the total demand can be met from biomass alone. MHP takes the next place by providing 19% of the total demand, followed by SPV providing 3% and wind energy system providing 2%. Only one village has got potential for Solar Photovoltaic and only one village was found feasible for setting up wind energy conversion system. The cost of energy generation is variable i.e. Rs 20.50/ kWh in the case of SPV, Rs 7.18/ kWh for wind, Rs 3.68/ kWh for BES and Rs 2.53/ kWh for MHP on the individual resource basis. The cost of Energy (COE) considering different hybrid optimized models is Rs 4.10 considering a hybrid system with MHP-WES-BES and Rs 4.15 considering MHP-SPV-WES-BES.

All the twelve villages are located within a distance of 2km, the maximum distance being 1.9km from village V9 to V1. It was also observed that the surplus power from the villages V8 and V12 is sufficient to meet the deficit of villages V1, V2, V3, V4, V5, V6, V7, V10 and V12 hence, power can be supplied by using three phase LT lines without using distribution transformers. A second scheme was also developed in which the excess power from village V8 after supplying to villages V2,V3,V5 and V6 and the surplus power from village V9 are sent to a common busbar emanating at V9.

In this case, it was observed that three distribution transformers are required to distribute the power to villages V1 and V12, which are at distances 1.9km and 1.4 km respectively, from V9.

It was also observed that except for villages V1 and V12, for every other village, weasel conductor was sufficient to distribute the power. Total costs of the two schemes are compared after taking into account the costs of accessories and contingencies, in addition to the conductor laying costs. The scheme without common busbar came out to be the one with minimum cost as it does not have the requirement that distribution transformers are to be installed for power distribution.

CHAPTER 2

JAUNPUR BLOCK OF TEHRI GARHWAL DISTRICT OF UTTARAKHAND: THE STUDY AREA

2.1 INTRODUCTION

The area selected for study is Jaunpur block of Tehri Garhwal district of Uttarakhand state. The state which was earlier a part of Uttar Pradesh was formed in the year 2000.The state consists of 88% hilly and only 12% plain area. Since most of the area is remote and without grid electricity and hence there is a strong need for generating energy through renewable energy resources. The state is very rich in renewable energy resources, especially small hydro. The hilly terrain has usually restricted population density in the state. Most of the people here are farmers or farm laborers and live in villages. Table 2.1 shows the main features of Uttarakhand state.

Table 2.1 Main features of Uttarakhand state

Feature	
Area Under Forests	.8%
Agricultural Land	7,92,000 hectares
Irrigated Land	40.66%
Permanent Grasslands	4.25%
Economy	Agriculture Based
Energy Production	1035MW
Total Energy Capacity	29,000MW
Major Rivers	Kali Ganga, Yamuna, Tons, Kosi, Song, Alaknanda, Sarayu, Bhagirathi
Major Industries	Electronics Industries, Paper Industries, Furniture, Woolen Clothes, Handloom, Food Preservation and Sugar

Source: http://gov.ua.nic.in

The states economy is based on agriculture. It possesses a rich agricultural land with a total of 7,92,000 hectares. It is also rich in natural resources and it is blessed with a good amount of water resources. The major industries include woolen clothes, handloom and electronics industries to mention a few.

2.2 GEOGRAPHICAL & DEMOGRAPHIC DETAILS OF THE STUDY AREA

The features of Tehri Garhwal district in which the study area is located are as follows:The district of Tehri Garhwal stretches from the snow clad Himalayan peaks of Thalaiya Sagar, Jonli and the Gangotri group all the way to the foothills near Rishikesh. Tehri Garhwal is the western most district of the Uttarakhand State (Former Uttar Pradesh) located on the outer ranges of the mid Himalayas which comprise low line peaks rising contiguously with the planes of the northern India. The district lies between the parallels of 30.3` and 30.53` north latitude and 77.56` and 79.04` east longitude. Uttarkashi from the north, Rudraprayag from the east, Pauri Garhwal from the south and Dehradun from the west are bounding the districts. On the western front Yamuna river separates it from Jaunsar Pragana of the Dehradun district while Bhagirathi rising from the north of the Gangotri in the district Uttarkashi touches the district near village Nagun .Total area of the district is 4421 sq. kms (Census 1991). The district headquarter is located at New Tehri Town since 1.4.1989, Earlier Narendranagar was the district head quarter. A major portion of the district is having hilly tract. The plain area is more fertile than the plateau area. Bulk of the area of the district is under forest which occupies a place of importance not only in the ecology but also in the economy of the district. These forests are rich in vegetations. Wood of commercial value is produced. These forests are also famous for production of herbs and plants of medicinal value. There has been a denudation of forests in the past, resulting in impoverishment of forests wealth. Under five year plans efforts have been made to plant trees under forestations programmed.

2.2.1 Details of the study area

Fig. 2.1 shows the location of Tehri Garhwal, the district in which Jaunpur block, the study area is located. The district lies close to Dehradun, the state capital. Fig 2.2 shows the location of Jaupur block in Tehri Garhwal district of Uttarakhand. Arrow shows the exact location of the study area.

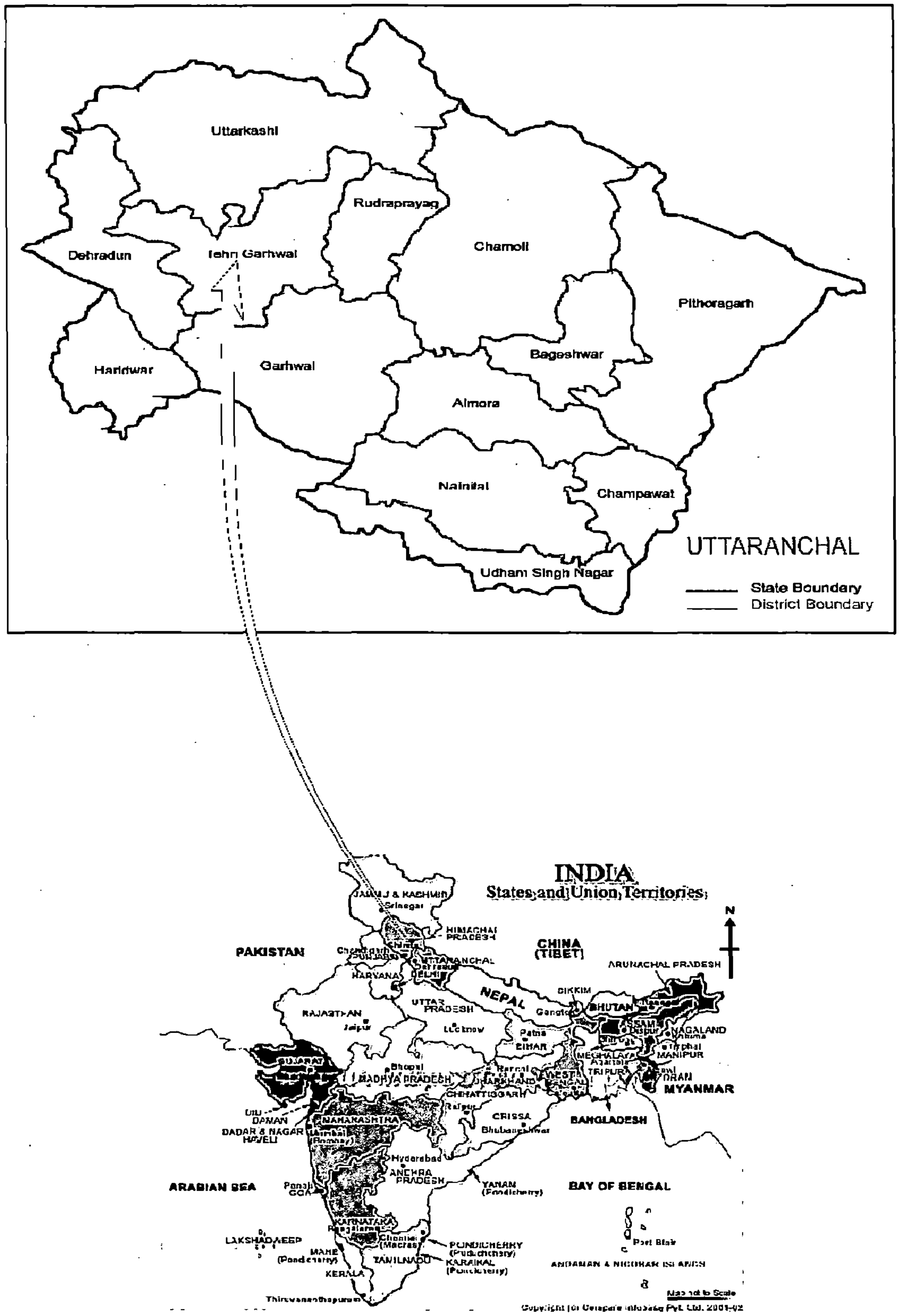


Fig 2.1 Location of Tehri Garhwal in Uttarakhand

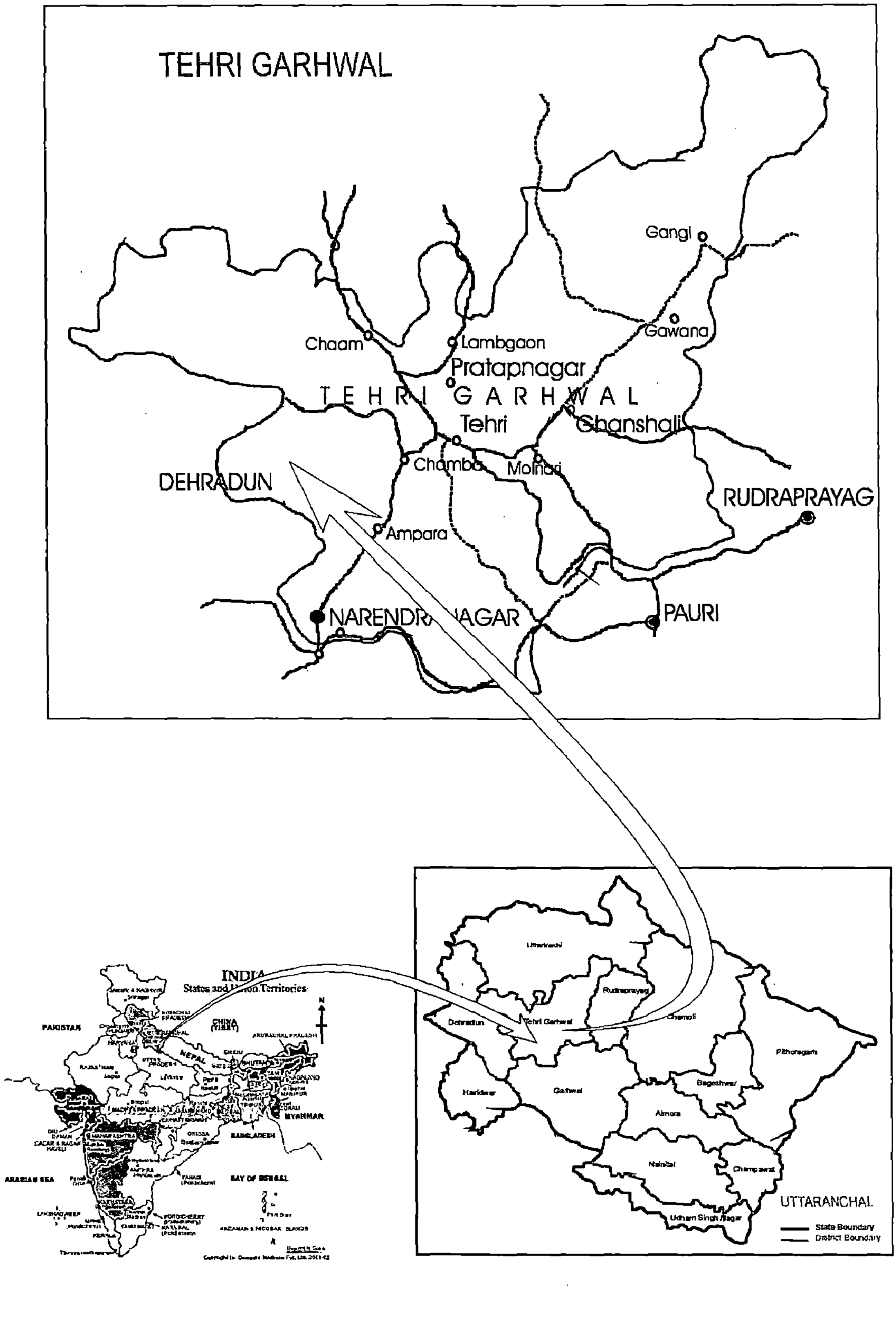


Fig 2.2 Geographical map of Tehri Garhwal District

Table 2.2 Demographic data of Jaunpur Block

Feature	Quantity
Area (in sq. km.)	485
Number of inhabited villages	252
Total Population	50,636
Number of Households	8,291
Population density (persons/sq. km)	104
Total Literacy (%)	38.9
Male Literacy (%)	61.46
Female Literacy (%)	15.36
Number of government primary schools	126

Source : http://gov.ua.nic.in/

Table 2.2 gives the demographic details of Jaunpur block in which twelve unelectrified villages are chosen for study. Table 2.3 shows the salient features of Jaunpur block of Tehri Garhwal. It shows that the richly available water resources are being made use of for satisfying the energy demands of the study area, by installing water wheels.

Table 2.3 Salient Features of Jaunpur Block

Feature	Total
Number of Villages	259
Number of Un-electrified Villages(by UREDA)	24
Number of water mills(Gharat) installed	52
Number of Springs available	30
Number of Falls Available	8
Number of Reserved Forest(RF)	22

Source: http://gov.ua.nic.in/

Fig 2.3 shows the geographical location of zone 4 from which twelve unelectrified villages have been chosen for study, in Jaunpur block.

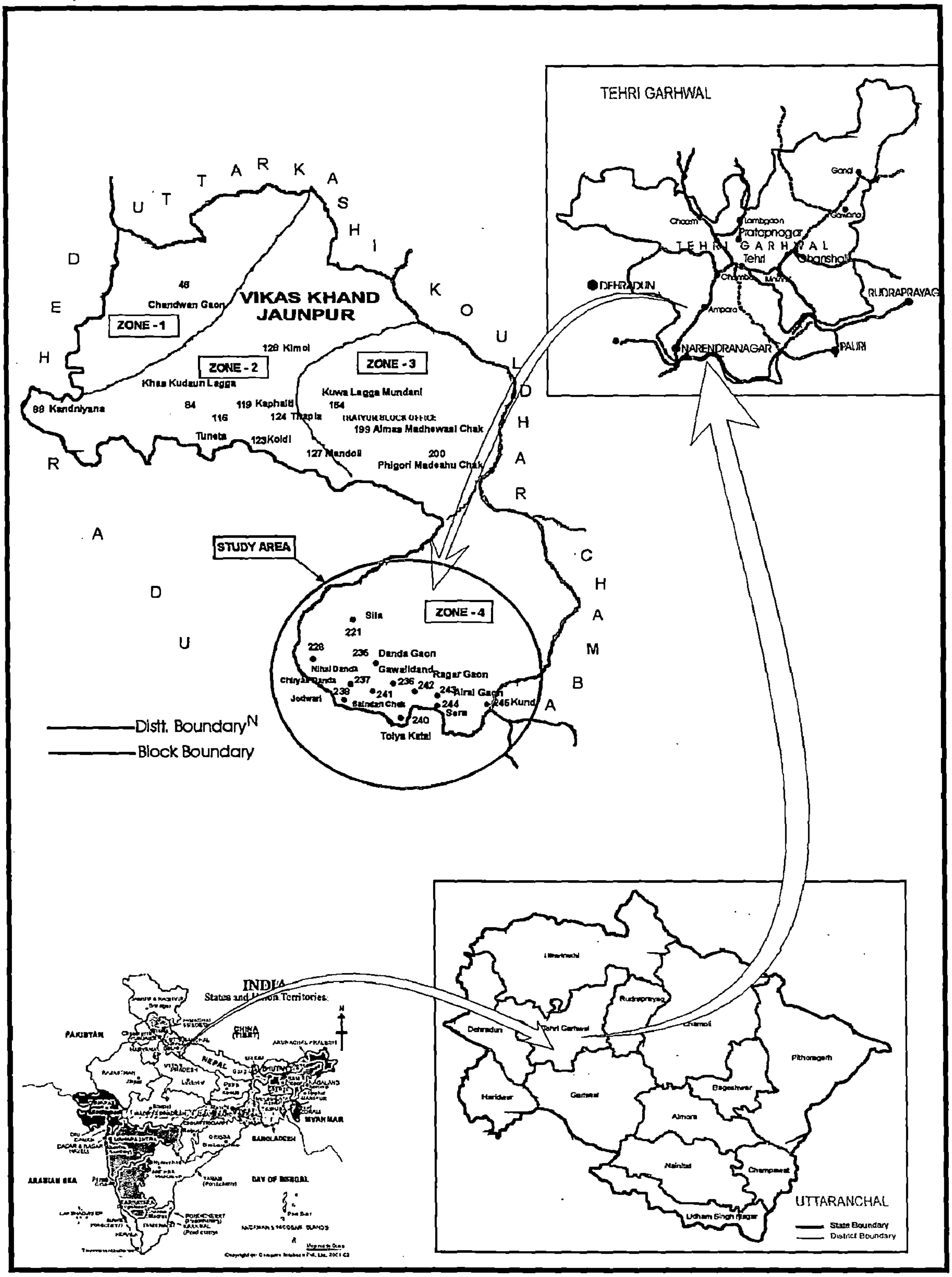


Fig. 2.3: Geographical Location of the Study Area

2.3 DATA COLLECTION

The necessary data, required to be known for the twelve unelectrified villages in order to design a distribution system had been taken from "Modelling of Integrated Renewable Energy System", a Ph.D Thesis by Mr.Ashok kumar Akella. According to the data collected, main features of the twelve unelectrified villages chosen for study are given in table 2.4. It is evident that most of the villagers are agricultural labor and are under below poverty line. It also shows that there is large number of non workers. The villages are less populated with the maximum population in a village being 40.

Table 2.4 Features of Zone 4 of Jaunpur Block

Village	Area(sq.km)	No.of Households	Total population	Cultivators	Agricultural laborers	Marginal Workers	Non Workers
V1	15.82	40	188	80	0	0	71
V2	1.91	7	35	22	0	0	13
V3	6.79	7	40	6	0	6	26
V4	14.08	6	50	11	7	12	45
V5	4.31	8	50	5	0	13	27
V6	7.83	10	70	7	0	16	28
V7	9.88	14	75	9	5	16	43
V8	2.32	14	100	8	0	10	28
V9	19.86	45	225	85	0	0	117
V10	15.66	15	120	26	0	20	41
V11	8.21	40	300	59	0	0	56
V12	28.22	35	150	70	0	2	87

Source: Modelling of Integrated Renewable Energy System", a Ph.D Thesis by Mr.Ashok kumar Akella

2.4 ENERGY POTENTIAL ASSESSMENT

The amount of energy potential available and the energy demand in the 12 unelectrified villages are given below.

2.4.1 Energy Available

The selected area of study is rich in renewable energy resources, especially in micro hydro power and biomass. Details of the same are given in table 2.5.

Table 2.5 Energy potential of study area

Village	Micro Hydro Potential (kWh/yr)	Biomass (kWh/yr)	Wind (kWh/m^2/yr)	SPV (kWh/m^2/yr)	Total (kWh/yr)
V1	5271	918	0	0	**6189**
V2	0	0	0	1800	**1800**
V3	0	106	3600	0	**3706**
V4	0	35	0	0	**35**
V5	2678	166	0	0	**2844**
V6	0	164	0	0	**164**
V7	0	0	0	0	**0**
V8	28908	6783	0	0	**35691**
V9	134028	175661	0	0	**309689**
V10	0	549	0	0	**549**
V11	15768	14472	0	0	**30240**
V12	49352	4671	0	0	**54023**
TOTAL	**236005**	**203525**	**3600**	**1800**	**444930**

It can be observed from the tables above that the villages are rich in biomass. 94% of the total demand of the villages can be met from biomass alone using gasifier engine system of suitable capacities. The next abundantly available source is MHP which can be used to meet 19% of the total demand, followed by SPV which supplies 3% and wind which supplies 2%. It is also evident from the table 2.5 that only one village is suitable for Solar photovoltaic and only one village is suitable for setting up a wind energy conversion system. The surplus energy is available at villages V8, V9 and V11. It can also be observed that in all the three villages with surplus, the surplus energy comes either from biomass or micro hydro power. The total available energy potential is 4,44,930 kWhr/yr.

2.4.2 Energy Demand

The energy demand has been estimated by considering the domestic load, agriculture and Motive/Industry Power.

Table 2.6 Energy Demand of the study area

Village	No. of Households	Lighting load (kWh/yr)	TV load (kWh/yr)	Fan Load (kWh/yr)	Crop Threshing (kWh/yr)	Rice Hullers (kWh/yr)	Flour Mills (kWh/yr)	Total Load (kWh/yr)
V1	40	58108	6950	9292	0	0	725	**75075**
V2	7	6716	613	1093	0	0	0	**8422**
V3	7	3650	766	586	0	0	0	**5002**
V4	6	3650	639	586	0	0	0	**4875**
V5	8	3942	1073	644	0	0	456	**6115**
V6	10	6570	1378	1054	0	0	0	**9004**
V7	14	6716	1226	1093	0	0	0	**9035**
V8	14	11315	1533	1806	0	0	0	**14654**
V9	45	108040	19418	13664	135	298	18429	**159984**
V10	15	6351	1993	996	0	0	0	**9340**
V11	40	18433	4344	2928	0	0	0	**25705**
V12	35	57487	11497	9223	0	0	6668	**84875**
TOTAL	**241**	**290978**	**51432**	**42965**	**135**	**298**	**26278**	**412086**

It can be observed from the table 2.6 that energy demand for domestic purposes is more when compared to the agricultural and industrial demands. The total energy demand of all the twelve villages is 4,12,086 kWhr/yr

2.4.3 Surplus or Deficit of Energy Potential

Three villages have got surplus of potential available and every other village have got a deficit of potential with V12 having the most deficit potential. One more important feature of the selected villages is that the villages which have got surplus amount of energy are getting the surplus energy from MHP and Biomass only. Table 2.7 shows the deficit and surplus in the twelve unelectrified villages.

Table 2.7 Surplus/Deficit of Energy in the village

Village Name	Village Number	Total Supply(kWh/yr)	Demand (kWh/yr)	Surplus (kWh/yr)	Deficit (kWh/yr)
Silla	V1	6189	75075	NA	-68886
Nihaldanda	V2	1800	8422	NA	-6622
Dandagaon	V3	3706	5002	NA	-1296
Gawalidanda	V4	35	4875	NA	-4840
Chifalli	V5	2844	6115	NA	-3271
Jaintwari	V6	164	9004	NA	-8840
Talyakaral	V7	NA	9035	NA	-9035
Sandnalaga	V8	35691	14654	21037	NA
Ragargaon	V9	309689	159984	149705	NA
Airalgaon	V10	549	9340	NA	-8791
Sera	V11	30240	25705	4535	NA
Kund	V12	54023	84875	NA	-30852
	TOTAL	**44930**	**412086**	**1,75,277**	**1,42,433**

The distribution of villages as per source is given in table 2.8. It shows that maximum number of villages have got biomass and micro hydro power. Four villages are there with availability of only one among the four renewable energy sources considered. There is one village with no source at all. No village has got all the four renewable sources of energy that are considered for study area.

Table 2.8 Energy Particulars of Study Area

Particulars	**Number**	**Village codes**
Villages with no source at all	1	V7
Villages with only one source	4	V2, V4, V6, V10
Villages which have got MHP	6	V1, V5, V8, V9, V11, and V12
Villages which have got SPV	1	V2
Villages which have got Wind Energy	1	V3
Villages which have got Biomass	10	V1,V3, V4, V5, V6,V8,V9,V10,V11,V12

2.4.4 Sizing of Integrated Renewable Energy System

The following plant sizes for the different resources are preferred from the previous study. Based on the previous work done on integrated renewable energy system modeling for the selected area, the following system sizes have been proposed for the selected area.

Micro Hydro Power (MHP)

It was found out that six villages have MHP potential. Considering water availability for 10 months and a utilization factor of 0.6, the energy was determined.

Biomass Energy System (BES)

The number of gasifier systems and the biogas plants was estimated on the basis of total potential of biomass available in the villages. Table 2.9 shows the details of sizes of gasifier and biogas plants.

Table 2.9 Village wise sizes of gasifier and Biogas plants

Village	Size of Gasifier(kW)	Number of Gasifiers	Size of Plants(m^3/day)	No. of Plants
V1	1	1	10	4
V3	1	1	3	2
V4	1	1	4	1
V5	1	1	4	2
V6	1	1	4	2
V8	1	1	4	3
V9	38	1	4	4
V10	4	1	8	2
V11	4	1	10	4
V12	1	1	6	5
V2	NA	NA	3	2
V7	NA	NA	4	3
Total	45	5	222	34

Wind Energy Systems

Based on the wind speed data, a wind energy conversion system of 3m rotor diameter of three blade propeller type wind turbine having a power coefficient 0.45 had been proposed. With an average wind speed of 5.5m/s about 300 W of power had been determined. Ten numbers of such systems have been proposed for the study area with a total potential of 3600kWh/year, considering 1440 operating hours per year.

Solar Photovoltaic (SPV)

A stand alone SPV system of 1000W capacity had been proposed. The sunshine was assumed to be available for 6 hours per day and 300 days in a year giving a potential of 1800 kWh per year.

2.4.5 Cost of Energy

The unit cost of energy generated was obtained by considering the capital recovery cost and operation and maintenance cost.

The following expression was used to calculate the same.

$$C = \left[r(1+r)^n / (1+r)^n - 1 \right] \left[P/87.6k \right] + [O\&M]$$

Where C= cost of energy

k= Annual capacity factor

n= Amortization period (in years)

O & M = Operation and Maintenance cost

P = Capital Cost

R= Fixed Annual interest.

In case of biomass gasification, the cost of biomass and diesel fuel was added as $(0.3413f/\eta)$

$$C = \left[r(1+r)^n / (1+r)^n - 1 \right] \left[P/87.6k \right] + [O\&M] + (0.3413f/\eta)$$

Where f= fuel cost in Rs per million Btu at the generation site

H = Overall efficiency of the plant

Table 2.10 shows the parameters considered for estimation of unit cost of energy for the sized systems.

Table 2.10 Parameters for Cost of Energy

Parameter	Resource				
	BES	**Biogas**	**MHP**	**SPV**	**WES**
Energy Generation(kWh/yr)	203525	332206	236005	1800	3600
System Rating(kW)	45	155	59	1	3
System Operating Hours(hrs/yr)	4600	2200	4380	1800	1200
Amortization Period(yr)	12	20	25	30	20
Capital Cost(Rs/ kW)	20000	4500	85000	330000	70000
O & M cost (%)	2	2	2	1	2
Annual Interest (%)	11	11	11	11	11
Fuel Cost (Rs/kWh)	2.90	3.00	NA	NA	NA

Based upon these parameters, the cost of energy calculated from each source is given in table 2.11

Table 2.11 Cost of Energy

Source	Cost of Energy(Rs/kWhr)
MHP	2.53
BES	3.68
Bio	3.15
WES	7.18
SPV	20.50

2.3.6 Distribution System

In general, power supply to a remote area is either done from grid or by providing an isolated power system. In case of the study area, the grid is very far off and hence stand alone power system was chosen. The power from the villages with surplus energy will be distributed to those nearby villages with deficit. The total energy potential of the twelve villages upon considering the energy available from the four renewable energy resources, i.e. micro hydro power, solar photovoltaic, biomass and wind energy conversion systems is 4,44,930 kWhr/yr. the total energy demand after considering the domestic, agricultural and industrial loads is 4,12,086 kWhr/yr. Domestic load included lighting load, fan load and TV load. Agricultural demand included crop treshing and rice hullers and industrial demand included flour mills. Table 2.12 summarizes the energy potential available in all the twelve villages, their energy demand and the cost of energy.

Table 2.12 Total Energy potential, system rating and cost of energy for twelve villages

Source	**Potential(kWhr/yr)**	**System Rating(kW)**	**Cost of Energy(Rs/kWhr)**
Biomass	203525	45	3.15
MHP	236005	59	2.53
WES	3600	3	7.18
SPV	1800	1	20.50

From the above table, it is obvious that the cost of energy for SPV is the highest among all the sources. Cost of energy for wind energy system is the second highest, followed by biomass and micro hydro power. It was assumed that the biomass energy system operates for 4600 hours/ year, micro hydro power system operates for 4380 hours/year, solar photovoltaic system operates for 1800 hours/ year and wind energy systems operate for 1200 hours/year.

The total power available at all the twelve villages is 50.79kW and their total power demand is 47.04 kW. It is proposed that the surplus power from villages will be used to supply the deficit of the remaining villages. The potential available in all the villages will be utilized first to meet is their local demands and the deficit will be met by the power from villages with surplus. The total power that is to be distributed decentrally is 16.26 kW.

CHAPTER 3

DECENTRALIZED DISTRIBUTION SYSTEMS

3.1 GENERAL

Distribution system is the electrical system which is used to transfer electric energy from the low voltage (LV) side of the substation transformers to the customer's metering points. The distribution system in general context is part of the system between transmission and the consumer service point. It contains the following components:

- Sub transmission circuits which deliver energy to distribution substations.
- The distribution substation which converts the energy to lower primary system voltage for local distribution and usually improves the facilities for voltage regulation of primary voltage.
- Primary circuits of feeders supplying the load in well-defined geographical area, usually operating in the range of 4.16 to 34.5 kV
- Distribution transformers of ratings ranging from 10 to 2500kVA, usually installed on poles or on pads or near the consumers' sites which transform the primary voltage to the secondary voltage, usually 240/415 v
- Secondary circuits at service voltage which carry energy from the distribution transformers along the streets etc.
- Service lines or drops which deliver the energy from secondary circuits to the consumer premises at declared voltage of 400/230 V ± 6%.

In case of Decentralized generation, distribution includes all parts of an Electric Utility System between power sources and the consumers' service entrance equipments.

The planning and design of the distribution systems is an important task that is to be given utmost care because of the following facts:

i) About 75% of the total power system losses occur during distribution

ii) More than 90% of system faults are in distribution area

iii) Officially recorded transmission and distribution losses(T & D) are 22 to 23%

iv) Nearly 95% of all power system network length lies in distribution

v) Realistically distribution losses should be 9%

vi) Efficiency of distribution system including consumer end is 20%

3.2 CLASSIFICATIONS OF DISTRIBUTION SYSTEMS

3.2.1 Classification based on Current

i) DC distribution systems

ii) AC distribution systems

3.2.2 Classification based on number of Conductors

i) Single phase distribution systems

ii) Three phase distribution systems

3.2.3 Classification based on type of Construction

i) Overhead distribution system

ii) Underground distribution system

3.2.4 Classification based on scheme of Connection

i) Radial distribution systems

ii) Parallel distribution systems

iii) Ring distribution systems

iv) Interconnected distribution systems

v) Closely interconnected distribution systems

3.3 COMPARISON BETWEEN DIFFERENT TYPES OF DISTRIBUTION SYSTEMS

3.3.1 Merits & Demerits of overhead distribution system over underground distribution system

3.3.1.1 Merits

i) Overhead facilities can be adapted easily to changing conditions.

ii) Repairing of overhead distribution systems is easy when compared to underground distribution systems.

iii) In case of overhead lines, if the volute of the line needs to be changed, (in order to accommodate the increase in power requirements) this can be accomplished by changing the insulators on the cross arms and transformers on the poles.

iv) Overhead lines are more reliable

v) In case of overhead lines, the land required is less i.e. only for a pole or a pole and a guy anchor.

vi) Replacing overhead cables is easy.

vii) Faults in overhead lines can be detected easily and quickly as compared to underground cable.

viii) Due to enhanced spacing of the conductor, the charging current is less in overhead system than that in the underground cable.

ix) Jointing in underground cable is difficult and precise as compared to overhead conductors

3.3.1.2 Demerits

i) Maintenance cost of overhead system is more is more as there are more faults in overhead lines.

ii) Also, reaching to heights for maintenance involves more time and labor

iii) Overhead system produces a shabby appearance

iv) Underground cables are buried in the ground and therefore are safer to the public

v) Lighting and thunderstorm produces effect on overhead system, whereas these do not produce any effect on underground cables

vi) Overhead system is disturbed by surges, whereas in underground system, the surges are absorbed by the metallic sheath of underground cable and as such produce no damaging effect

vii) There can be accidents with overhead lines whereas chances of accidents are remote in underground system

viii) The inductance in an overhead line is more because of larger spacing of conductors, therefore more voltage drop is there in an overhead line for the same distance

ix) The overhead lines may interfere with the nearby telecommunication lines, trees etc, whereas underground cables do not have any effect on them

3.3.2 Merits and demerits of AC distribution systems over DC distribution systems

3.3.2.1 Merits

i) The voltage in case of AC system is very high with the results that the transmission of electrical energy at distances is possible with less copper losses

3.3.2.2 Demerits

i) For the same working voltage, the potential stress across the insulator terminals is $\sqrt{2}$ times less in AC system than in DC system. This necessitates more spacing among the insulators to avoid corona loss and to provide insulation. This increases the cost of cross arms.

ii) In AC system, one has to take into consideration the effect of inductance and capacitance while designing the AC system line, whereas there is no such problem in DC system. Due to capacitance, there is continuous loss of electrical energy caused by charging current and even if there is no load on the line, the loss will take place continuously.

iii) Due to skin effect, the resistance of the same line is more in AC system than in DC system. This will cause more copper losses in AC system for the same amount of power transported at constant voltage.

iv) If the load and sending end voltage are same, the voltage regulation for DC transmission line is better.

v) If UG cables are used, dielectric losses due to potential stress will be more in AC system

vi) AC system is very complicated in comparison to DC system. More staff is therefore required to erect and maintain the AC system.

vii) Main disadvantage of AC distributor is that the initial cost of distributor is more in comparison to DC distributors where only three conductors are seen.

3.3.3 Comparison of the copper efficiencies for different configurations of AC and DC systems

The main factor that decides the selection of a conductor for carrying power is its kWkm capacity and the cost of the conductor which further depends on the copper efficiency of the conductor. Table 3.1 gives a comparison between copper efficiencies of AC and DC systems. θ is power factor of the system.

Table 3.1 Comparison between AC and DC systems

System	**Copper Efficiencies(Volume or weight of conductors)**	
	Maximum Voltage between one conductor and earth	**Maximum Voltage between two outgoing conductors**
1) DC system		
Two wire	1	1
Two wire with mid point earthed	0.25	1
Three wire system	0.3125	1.25
2) single phase AC system		
Two wire	$2/\cos^2\theta$	$2/\cos^2\theta$
Two wire with mid point earthed	$0.5/\cos^2\theta$	$2/\cos^2\theta$
Three wire system	$0.625/\cos^2\theta$	$2.5/\cos^2\theta$
3)Three phase AC system		
Three wire	$0.5/\cos^2\theta$	$1.5/\cos^2\theta$
Four wire	$0.583/\cos^2\theta$	$1.75/\cos^2\theta$

3.4 DISTRIBUTION SYSTEMS OF RURAL AREAS

Rural networks are constrained by space, have slower load densities, have smaller equipment ratings and commonly use overhead lines. In rural areas, long scattered 11kV lines and heavy peaks with predominant agriculture loads lead to the usual problem of bad voltage regulation, low power factor, heavy distribution losses and lower load factor ($0.2 \approx 0.4$) .The general performance of the induction motors commonly used for agricultural pumping and industrial loads are normally designed for a power factor of 0.8 or 0.85 at full load. But this factor falls appreciably if the motors operate in partial loads which in practice are often the case.

There are many factors because of which motors run at partial loads. A major one is the tendency to install a motor of a higher capacity than the one needed under given conditions. This may be due to lack of proper guidance in the selection of the motor pumping set or tendency of the farmer to go for higher capacity motors because of the fear that lower capacity motors may get burnt. Mostly power factor of the rural loads without compensation is about 0.7. As losses are inversely proportional to the square of the power factor, an increase in the power factor, say from 0.7 to 0.85(being the statutory value as stipulated in the Indian electricity rules), reduces the losses by as much as 22.5%.

During power shortage/ cut period, there is a tendency to use auto starters by tube well consumers, especially during paddy season. When feeder is switched on from sub station, one time start-run of the motors imposes a high in-rush current (about four to six times the motor ratings) on transformer, simultaneously with the transformer own switching in-rush current($\sim$ eight times the transformer rating). The net instant overloading on distribution transformer (11/0.433kV) can be 10 to 14 times, which can do mechanical shifting of the windings, as mechanical shock is proportional to square of peak current. This may lead to damage of the transformers. The problem of low voltage conditions due to long and over-loaded line is predominant. More than 50% consumers in the rural areas have unmetered supply in the domestic, commercial and agriculture sector. Most of them are charged a flat rate on a point in the installation or getting free electricity. Most consumers use misuse this facility and use extra appliances and hectares than what is permissible. Generally distribution networks are radial and R/X ratio is very high. The percentage losses are the highest in the 11kV and 440V 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.

In India, all the 11kV rural distribution feeders are radial and too long. The voltages at the far end of many such feeders are very low with very high voltage regulation. Because of this, distribution networks are ill-conditioned and conventional Newton-Raphson (NR) and fast decoupled load flow (FDLF) methods are inefficient at solving such networks.

The delivery of reliable power of sufficient quality to consumers requires, among other things, that the voltage levels at the remotest consumer from the power source satisfy the minimum appliance specifications. This is often constrained by the cost of infrastructure. Quite often, rural networks are over designed, resulting in under utilization and, therefore, costly overheads. One reason often cited for the over- specification is anticipation of load growth.

The impedance of a distribution network is proportional to its total length. So, by Ohm's law, line voltage drops and network losses should increase with network length. It would, therefore, be reasonable to anticipate that by designing a distribution network topology that minimizes path length from a power source to a given number of consumers, one would minimize the losses. Moreover, a more compact network would require less material and, hence be less expensive to construct. Real rural consumer areas range from planned, like community structures, to amorphous and scattered structures and, therefore, are difficult to model mathematically.

Features of a typical Rural Electrification Network:

An electrical network to feed and distribute a rural area may be classified into one of the three major categories, depending on its electrical components. They are as follows:

- Consist of a transformer and low voltage distribution lines
- Are extensions to the existing low voltage distribution lines in the area.

Some of the major challenges that are faced during the implementation of the rural energy services are given as:

- The rural population is dispersed in remote areas. Due to this, providing centralized services may be difficult and costly.
- The relatively higher costs of decentralized technologies
- The transaction costs of providing services to rural areas is high resulting in higher prices
- The poor affordability as many people live in poverty.

3.5 DISTRIBUTION SYSTEM PLANNING

Distribution of electricity is a complex process involving many interconnected networks operating at a variety of voltage levels. The goal of modern power distribution planning is to satisfy the growing and changing system load demand during the planning period and within operational constraints, economically, reliably and safely, by making optimized decisions on the following: voltage levels of the distribution network, locations, sizes, servicing areas, loads and buildings or expanding schedules of the substations; routes, conductor types, loads and building schedules of the sub transmission lines and feeders.

Many optimization and solution models and solution methods have been proposed as detailed in Chapter 1 under literature review. The different methods of distribution system planning, the various works done are discussed in Chapter 1, introduction and Literature Review.

A few of the more common problems in distribution systems are outlined below:

1) Overloaded feeders- when the load current exceeds the current carrying capacity of (ampacity) of the conductor.

2) Overloaded station banks – when the distribution load exceeds the thermal rating of the station transformer, reducing its expected life.

3) Low voltages – when the voltage at the costumer's transformer is below a pre-determined minimum. These are a common occurrence in rural areas.

4) Feeder load unbalance- when load is not evenly distributed among the phases of a two or three – phase section of feeder. The result of unbalance is reduced ability to add three-phase loads without causing overloads on a segment.

The general problem in the planning of LV distribution networks is essentially to search for a radial network with low overall cost by taking into account : MV/LV substations(size and location) , LV lines (routes and capacities) to supply a given spatial distribution of forecast loads, thermal limits(lines and substations) and voltage level.

.The requirements of the optimal network planning include:

- Minimization of the capital investment, annual operational cost and annual cost of power losses.

- Consideration of all important technical constraints, such as security of supply and reliability of supply
- Consideration of the degrees of freedom, for example equipment types, laying multi-feeder in the same trench, and network structures
- The solution must be optimal or at least close to optimum
- Optimization time for the planning of real distribution systems must be acceptable

3.5.1 Factors affecting DSP

The factors that affect DSP decision-making can be divided into two categories:

Direct factors: Which the DSP planner can control and indirect factors with no DSP planner control. Direct factors are: equipment sizing and siting, operating voltage level, and permissible voltage drop.

Indirect factors: Which the planner cannot control. Indirect factors are: duration and frequency of outages cost of equipment and labor, fuel market price fluctuations, economic variations and changes in the government regulations.

The fig3.1 gives a brief detail about the main components in planning a distribution system. Distribution system planning is a process which involves the decisions to be taken regarding the optimal location and allocation of many components of the power system. The optimum selection can be either for an individual component or the system as a whole.

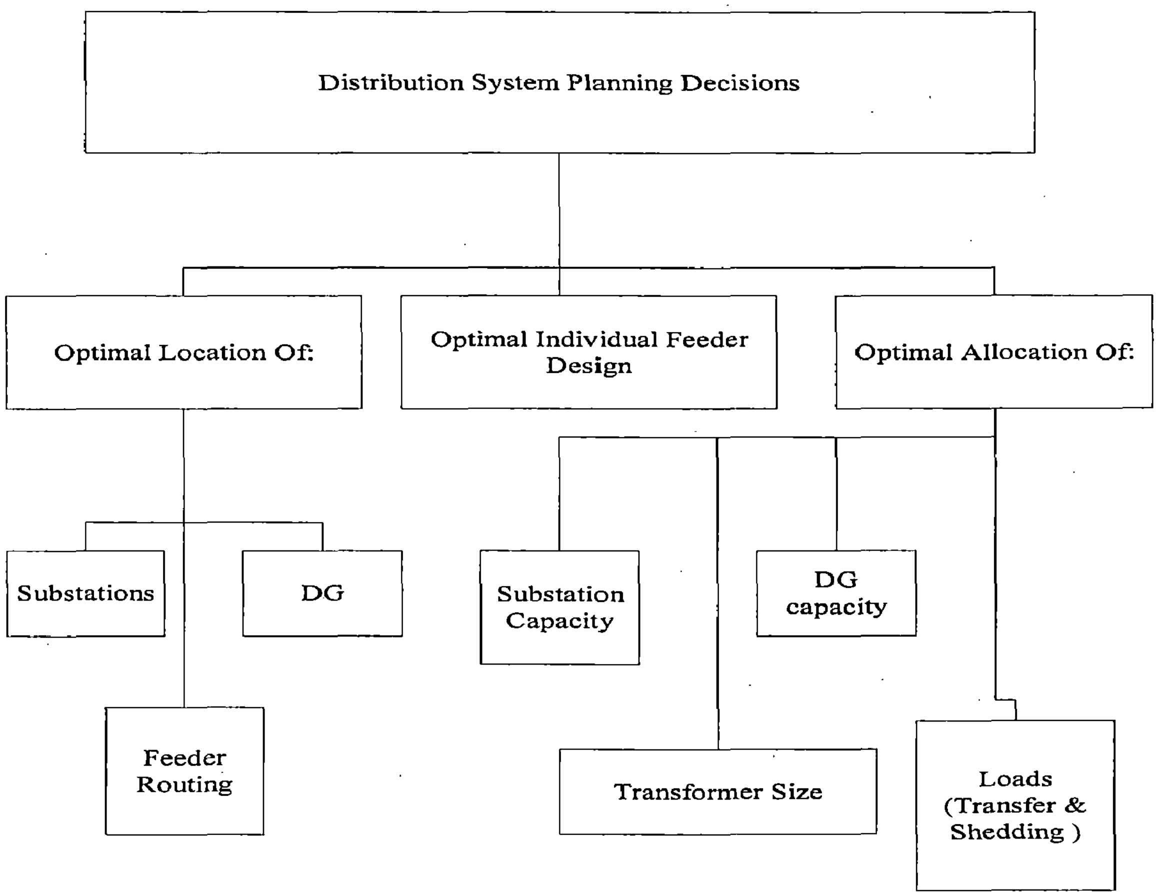


Fig 3.1 Steps in Planning Distribution Systems

3.6 ECONOMIC ASPECTS OF A DISTRIBUTION SYSTEM

Cost of rural electrification includes the capacity costs, consisting of investment in the generating facility, investments in distribution network, connection costs and the cost of energy, consisting cost of operating generators and accounting for the losses in distribution system.

3.6.1 Cost Elements

The cost elements that need to be considered when planning a distribution system are given below:

Installation cost: It includes the cost of purchasing the equipment, together with any civil and electrical works required to install the equipment. These installation costs are often site specific.

Planning Cost: For certain decentralized technologies, there will be an additional planning cost, including the development of any designs, consultation and the submission of planning application. Additionally, surveys including structural surveys may also be required.

Grid Connection Cost: It will be necessary to install the necessary metering and distribution technology with an associated grid connection cost so that the excess amount of power, if any can be sold out to an electricity supply company.

Operation and maintenance costs: Ongoing operation and maintenance costs will vary from one technology to the next. In case of micro CHP and biomass energy systems, it is important to include fuel costs in the calculations. A critical assumption in the investment decision is the projected fuel prices. The lower the fuel price, the better the economics. If the upfront capital costs were financed through borrowing, then it is important to include the cost associated with loan repayment at a suitable rate.

Table 3.2 gives the summary of cost elements associated with decentralized generation and distribution systems.

Table 3.2 Cost Elements in planning Decentralized Systems

Cost Elements	**Description**
Up-front Cost/Payment	
Planning Application	Relevant to most decentralized generation technologies, but most significant for MHP and to a lesser extent wind and SPV
Purchase of Equipment	Equipment cost will vary with supplier and with size of installation
Installation of equipment	Includes civil works, plus any structural surveys
Grid Connection cost	(Applicable in case of excess power availability) Metering and connection, including transaction costs
Annual Cost	
O & M Cost	Includes cleaning/servicing and average maintenance costs
Loan Repayments	If up-front costs funded through loan
Fuel Costs	For micro-CHP, natural gas or biomass will need to be purchased

The total cost of a power system is divided into two components. They are fixed costs and variable costs. Fixed costs are those which are also called as one time cost. They are incurred in the beginning, i.e. during the construction. Variable costs are those which appear when the system is under operation. They are not fixed.

Figure 3.2 shows various cost components to be taken care of while planning a cost optimized distribution system.

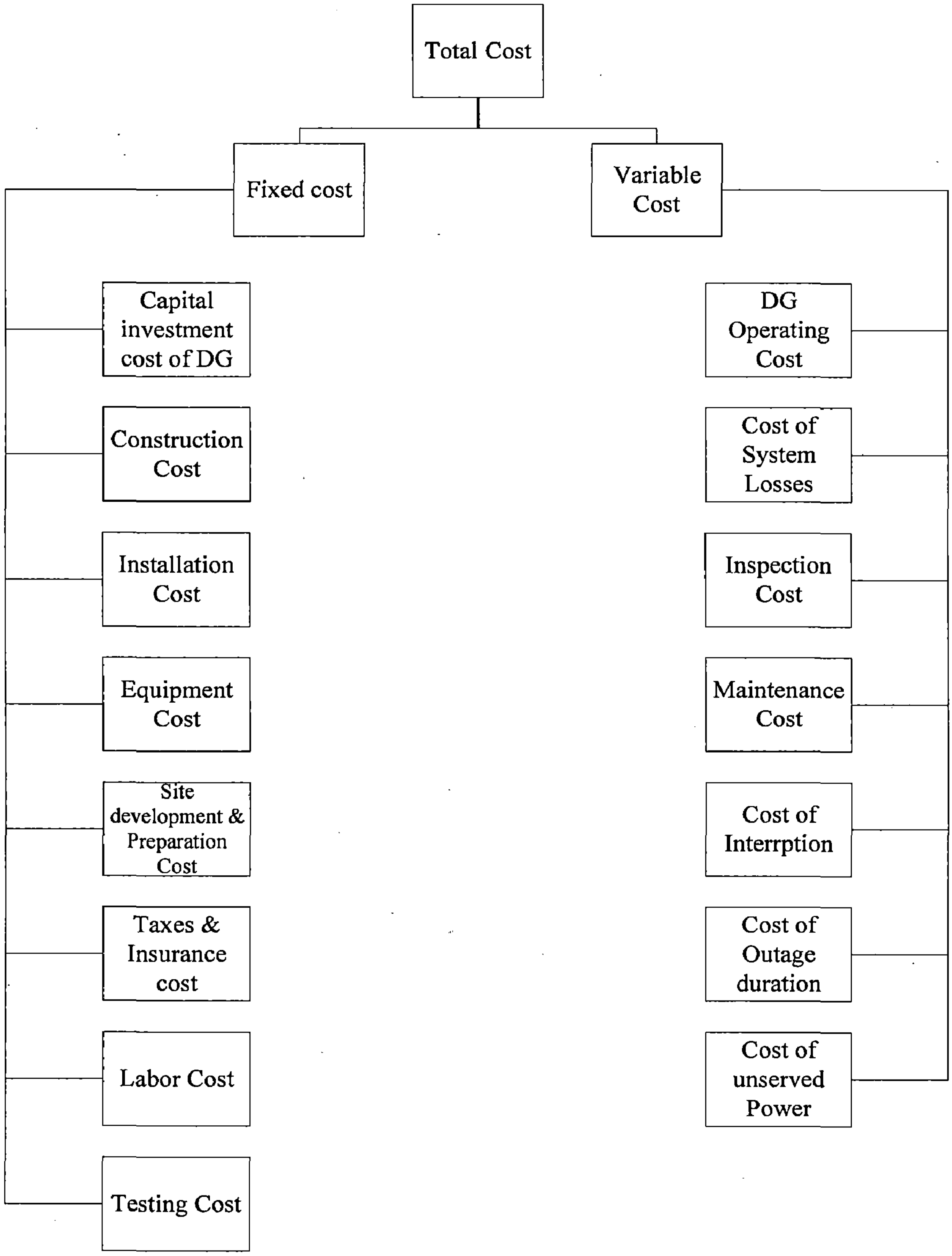


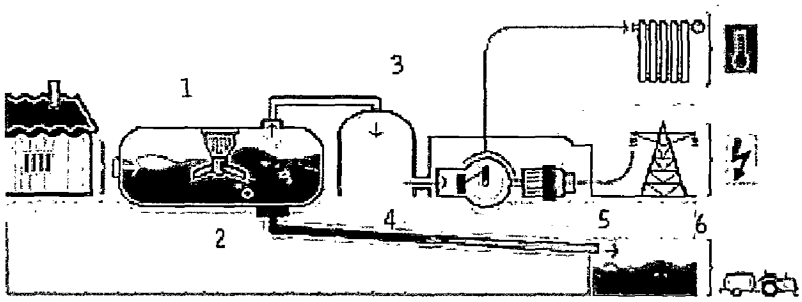
Fig 3.2 Cost Components of a Decentralized Distribution System

3.7 DECENTRALIZED POWER GENERATION TECHNOLOGIES

On an average, the energy in the sunshine that reaches the earth is about one kilowatt per square meter worldwide. According to the research association for solar power, power is gushing from renewable energy sources at a rate of 3,078 times more energy than is needed in the world today. In one day, the sunlight that reaches the earth produces enough energy to satisfy the world's current power requirements for eight years. Even though only a percentage of that potential is technically accessible, this is still enough to provide just under six times more energy than the world currently requires. In the context of electrifying villages, decentralized power has to be necessarily grid-independent. One of the reasons why electricity has not been able to reach villages is that they remain out of the grid and even if transmission lines pass through villages, they do not have sub stations, feeders and other infrastructure required for further distribution to rural households. In addition, economic viability of connecting villages to grid is also a major constraint. Under decentralized power generation and distribution, electricity needs of local people are met form a power station(mini-grid) located in the villages, based on locally available raw material i.e. biomass, solar, wind, micro and mini hydro. This locally generated power is distributed to the villagers through a village level distribution network. Villagers themselves run the entire system, without any involvement of state electricity utilities or other agencies. Technological options available for decentralized power generation are mainly mini hydro, biomass and solar.

3.7.1 Biomass based power

About 200 million tonnes of firewood and an equivalent amount of agricultural residues are burnt annually in India with low end-use efficiency. Biomass based power generation involves using firewood, agricultural residues such as bagasse, crop stalks, rice husk, coconut shells, animal dung and wastes generated from agro-based industries. These materials basically contain carbon, hydrogen and oxygen, besides moisture and ash. Their direct combustion is inefficient and leads to pollution. But if burnt at low oxygen supply and high temperature, biomass materials can be converted into a gaseous fuel known as producer gas, which comprises carbon monoxide, hydrogen, carbon dioxide, methane and nitrogen. This gas has a low calorific value compared to natural gas or liquefied petroleum gas, but can be burnt with high efficiency and without emitting smoke. Combustion takes place in a gasifier, which is a chemical reactor. The producer gas generated from combustion, after cleaning can be used to operate an IC engine. In India, gasifiers are available with capacities varying from 20 to 500kW for electrical appliances.



1. HEATED MIXER
2. CONTAINMENT FOR FERMENTATION
3. BIOGAS STORAGE
4. COMBUSTION ENGINE
5. GENERATOR
6. WASTE CONTAINMENT

Fig 3.3 Biomass Conversion Technology

3.7.2 Solar thermal and photovoltaic

Solar energy plays an important role in a village decentralized power system. The use of solar thermal energy for tasks like water heating, drying of agriculture products, cooking, desalination, refrigeration, pumping etc has been well established. In a country like India which has average 250-300 clear sunny days a year, such systems appear to be viable and cost effective.

While solar thermal systems use direct sunlight through convectors to generate heat, SPV systems are actually solar cells. SPV cells are small, square-shaped panel semiconductors manufactured in thin film layers from silicon. When sunlight strikes a PV cell, chemical reactions release electrons, generating electric current. The small currents from individual cells, which are installed in modules, can power homes and other buildings, or can be plugged into bulk electricity grid. Since the electric current generated by PV cells is direct current, or type of current used in batteries, it has to pass through an inverter where it is converted into alternating current, or the type of current that comes over power lines. From the inverter the electricity can be used by appliances in home or can go into a grid.

The power generated from PV systems can also be stored into batteries for use at night. Street lighting systems, solar lanterns and other such lighting systems are based on PV systems. Fig 3.4 shows the photovoltaic conversion technology.

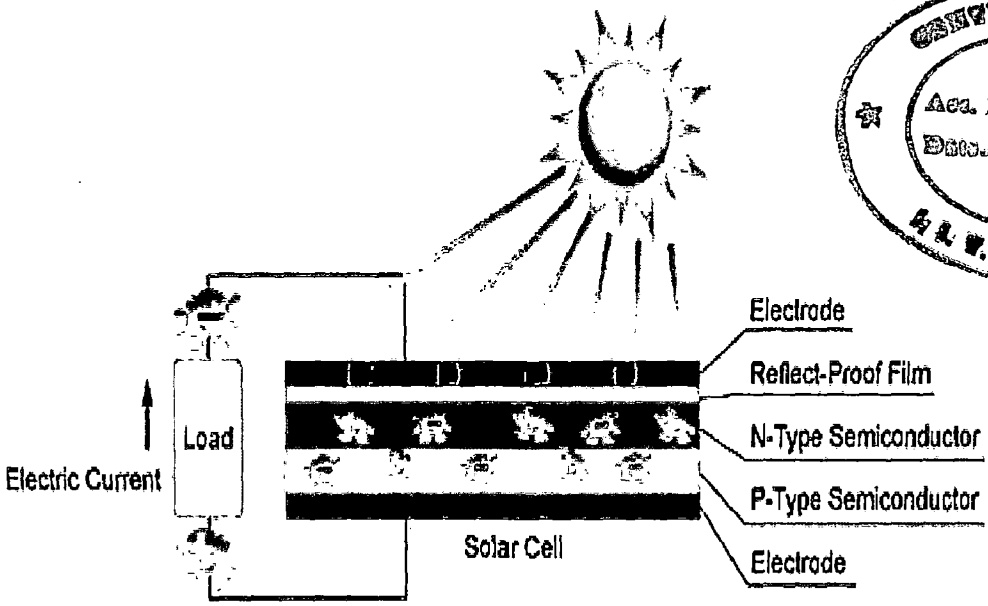


Fig 3.4 Solar Photovoltaic Technology

3.7.3 Wind energy systems

Over the last 20 years, wind energy has become the world's fastest growing energy source. Today's wind turbines are produced by a sophisticated mass production industry employing technology that is efficient, cost effective and quick to install. Turbine sizes range from a few kW to over 5,000 kW, with the largest turbines reaching more than 100m in height. One large wind turbine can produce enough electricity for about 5,000 households. The global wind resource is enormous, capable of generating more electricity than the world's total power demand. The wind resource at sea is even more productive than on land, encouraging the installation of off-shore wind parks with foundations embedded in the ocean floor. Smaller wind turbines can produce power efficiently in areas that otherwise have no access to electricity. This power can be used directly or stored in batteries.

Wind energy conversion system is divided into two types. i) Horizontal Axis Machines in which the axis of rotation is parallel to the air stream

ii) Vertical Axis Machines in which the axis of rotation is perpendicular to the air stream. Horizontal axis propeller type wind turbines are mostly used for power generation. The main components of a wind energy conversion system are i) Blades ii) Hub iii) Rotor Bearing iv) Gearing v) Generator vi) Tower vii) Storage

Fig 3.5 shows a typical wind energy conversion system.

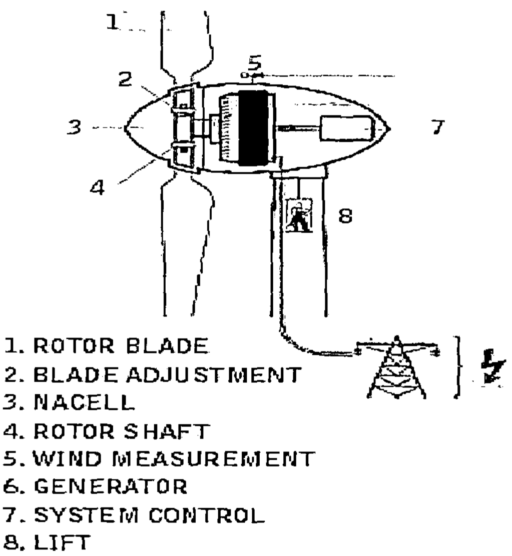


Fig 3.5 Wind Energy Conversion System

3.7.4 Micro hydro Power

Hydropower is mature technology that has long been used for economic generation of electricity. Water has been used to produce world's electricity for about a century. Today, around one fifth of the world's electricity is produced from hydro power. Large unsustainable hydroelectric power plants with concrete dams and extensive collecting lakes often have very negative effects on the environment, however, requiring the flooding habitable areas. Small run-of-the-river power stations, which are turbines powered by one section of running water in a river, can produce electricity in an environmentally friendly way. The main requirement for hydro power is to create an artificial head so that water, diverted through an intake channel or pipe into aa turbine, discharges back into the river downstream. Micro hydro power plants are those which have capacity in the range of few watts to 100kW. The electricity provided shall be in the form of 415/240 volt AC line. The main elements of a micro hydro scheme are:

i) Power Generation Equipment: This consists of a turbine, a drive system linking the turbine and a generator and/or mechanical devices, a generator, a turbine and generator controller, switchgear and transformer

ii) Power Distribution Systems: This involves distribution of electrical power by a line system. A line system normally comprises one or more main power distribution lines to central points, then by sub distribution lines and consumer service connections to consumption point. Fig 3.6 shows a micro hydro scheme.

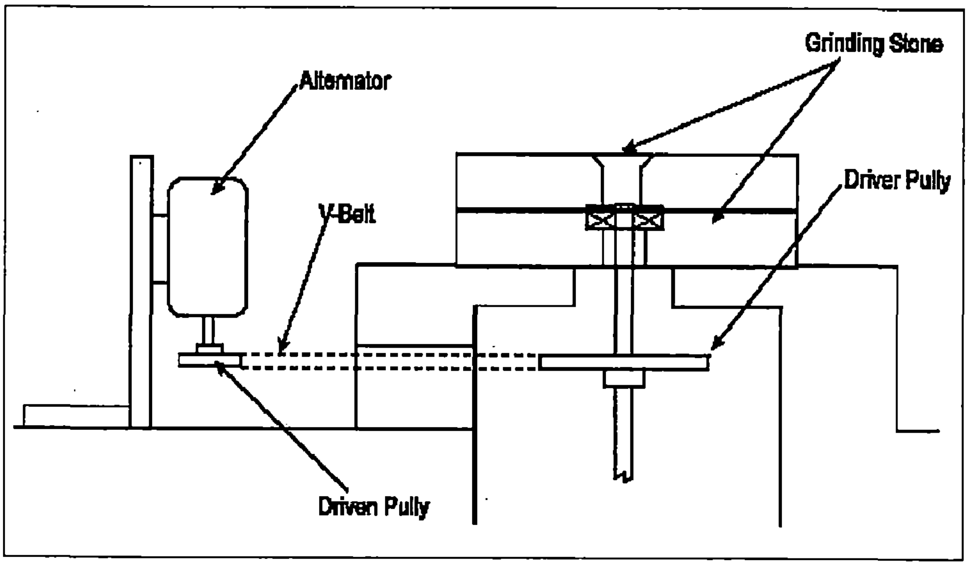


Fig 3.6 Vertical Shaft Water Mill

3.7.5 Advantages over grid-based rural electrification

- Dependence on fossil fuel will go down as decentralized systems are based on renewable energy sources.
- Transmission and distribution costs can be minimized to a greater extent.
- Green house gases will be controlled significantly.
- Since the system is to be run by people locally, it will lead to direct and indirect employment.

Such systems can efficiently provide energy for lighting, cooking, cooling or heating, mechanical power and communication infrastructure.

3.8 DECENTRALIZED DISTRIBUTION SYSTEMS

Decentralized power systems are characterized by the following:

- Generation capacity ranging from few kW to MW levels
- Generation at distribution voltages(11kV or below)

- Grid inter-connection at distribution line side for power import and / or export
- Inter-connected to a local grid or
- Totally off-grid, including captive

While it is found that the unit cost of such generation is likely to be on higher side due to reverse economies of scale and lower capacity factors, it is expected that on account of lower losses, the higher generating cost of such systems could be somewhat offset.

There are four different methods to distribute the power in a remote unelectrified area. They are as follows:

i) Central grid-based Rural Electricity Distribution Systems – as the one that is followed by Rural Electric Cooperative Societies in India.

ii) Central Grid-based Rural Electricity Generation – Sugar Co-generation in India

iii) Off-Grid Centralized Rural Electricity Supply Systems- as the one that is followed by Bengal State Government, WBREDA

iv) Off-Grid Decentralized Rural Electricity Supply

For the thousands of houses too far away from the electricity grid, independent electrical power is required. Even a mini grid may not be feasible in many cases. The only option then is to have individual systems and the options are limited to a battery-based system (where the battery has to be recharged few times per month), kerosene or diesel generator or a solar PV system. A solar PV system operates on 12 Volt Dc and has to use lamps and accessories that need DC power.

There are many possibilities for rural households to obtain electricity at the individual level. Technologically, it could be kerosene or a diesel generator, a battery based 12-Volt DC power system, a small wind generator, a biogas generator system or a micro hydro. However, the first step for a rural household in moving away form kerosene lighting is to invest in a battery based system as it is the cheapest and the easiest to obtain (though the regular recharging of the battery is an inconvenience) .The next most popular technology is the solar photovoltaic (PV) system. In addition to a few 12-Volt lamps, the SPV system has the added benefit of powering a small TV and a radio. A solar PV system, therefore, is a distinct unit that has to be installed to a technical standard.

A typical power system basically consists of four stages i) Generation ii) Transmission iii) Sub-transmission iv) Distribution.

The main difference between a centralized and decentralized distribution system is that there is no transmission stage in the decentralized distribution systems. The energy is used at or near the point of generation. A properly designed stand alone power system can be more reliable than grid power. Grid power in rural areas is supplied through hundreds of kilometers of overhead lines and subject to falling trees, storms and lightning strike as well as voltage sags and surges. By contrast, the technology used in stand alone power system is similar to that used for uninterrupted power supplies that provide power to critical computer electronics when grid power fails. A stand alone power system provides continuous energy, free from the interruptions often associated with mains supply. Furthermore, stand alone power systems support local employment as they encourage associated industries into the area.

As a result of low population density, difficult terrain and low consumption, rural electricity schemes are usually more costly to implement than urban schemes. In addition, low rural incomes can lead to problems of affordability. And the long distances mean greater electricity losses and more expensive customer support and equipment maintenance

There are two ways of distributing power to an area in general.

i) On –Grid

ii) Off-Grid

3.8.1 Control of decentralized distribution systems

Fully Automatic Remote control scheme:

Here devices are controlled by a computer located either at the area control room or at the primary substation. This computer gathers the information about fault location from data supplied from transducers at remote switching points.

Fully Automatic Local Control Scheme:

This scheme differs from the one above in that there is no requirement for a costly communication link (a computer). The remote device decides how and when to operate solely on information based received locally from pole top conditions of voltage and passage of current at specific tim-e.

As the area selected for study is very far off from the grid and as the connection to the grid is not technically and economically feasible, the second option, i.e. an Off- Grid distribution system was chosen for supplying the power. The only sources available for generation are the renewable energy resources i.e MHP, SPV, WES and BES.

Following tables give the details of power available and the power demand. Table 3.3 gives the power potential of all the twelve villages under study. A total of 50.8 kW power is available from twelve villages.

Table 3.3 Power Potential of study area

Village	Micro Hydro Potential(kW)	Biomass(kW)	Wind(kW)	SPV(kW)	Total (kW)
V1	0.6017	0.1048	0	0	**0.7065**
V2	0	0	0	0.2055	**0.2055**
V3	0	0.0121	0.4109	0	**0.423**
V4	0	3.995×10^{-3}	0	0	**3.995×10^{-3}**
V5	0.357	0.01894	0	0	**0.3247**
V6	0	0.01872	0	0	**0.0187**
V7	0	0	0	0	**0**
V8	3.3	0.7743	0	0	**4.0743**
V9	15.3	20.0526	0	0	**35.353**
V10	0	0.0627	0	0	**0.0627**
V11	1.8	1.652	0	0	**3.4521**
V12	5.6338	0.533	0	0	**6.1671**
Total	**26.94**	**23.23**	**0.4109**	**0.2055**	**50.7915**

Table 3.4 shows the total power demand of the twelve villages under the study area. A total power demand of 47.0418 kW exists after considering domestic loads which include fan load, light load and TV load, agricultural loads which include crop treshing and rice hullers and industrial load which comprises of flour mills.

Table 3.4 Power Demand of study area

Village	No. of Households	Lighting Load (kW)	TV load (kW)	Fan Load (kW)	Crop Threshing(kW)	Rice Hullers (kW)	Flour Mills (kW)	Total Load (kW)
V1	40	6.633	0.7934	1.0607	0	0	0.0828	**8.5702**
V2	7	0.7667	0.0699	0.1248	0	0	0	**0.9614**
V3	7	0.4167	0.087	0.0669	0	0	0	**0.571**
V4	6	0.4167	0.0729	0.0669	0	0	0	**0.5565**
V5	8	0.45	0.1225	0.0735	0	0	0.0521	**0.6981**
V6	10	0.75	0.1573	0.1203	0	0	0	**1.0279**
V7	14	0.7667	0.1399	0.1248	0	0	0	**1.0314**
V8	14	1.2197	0.175	0.206	0	0	0	**1.6728**
V9	45	12.333	2.2167	1.559	0.0154	0.034	2.104	**18.263**
V10	15	0.725	0.2275	0.1137	0	0	0	**1.0662**
V11	40	2.104	0.4959	0.3343	0	0	0	**2.9344**
V12	35	6.562	1.3124	1.053	0	0	0.7612	**9.6889**
Total	**241**	**33.217**	**5.871**	**4.905**	**0.0154**	**0.034**	**2.999**	**47.0418**

Based on the availability of surplus potential and the distances from the villages with deficit, from those with surplus, the following decisions have been made primarily

i) V8 will supply its surplus to villages V3, V5 and V6 apart from meeting its own demand.

ii) V9 will supply its surplus to villages V1, V2, V4, V7, V10 and V12

The basic criterion for conductor selection in order to distribute power is kWkm of the load. Distance through which power is required to be carried and the net power requirement determines the kWkm. Figure 3.7 shows the distances between the 12 unelectrified villages.

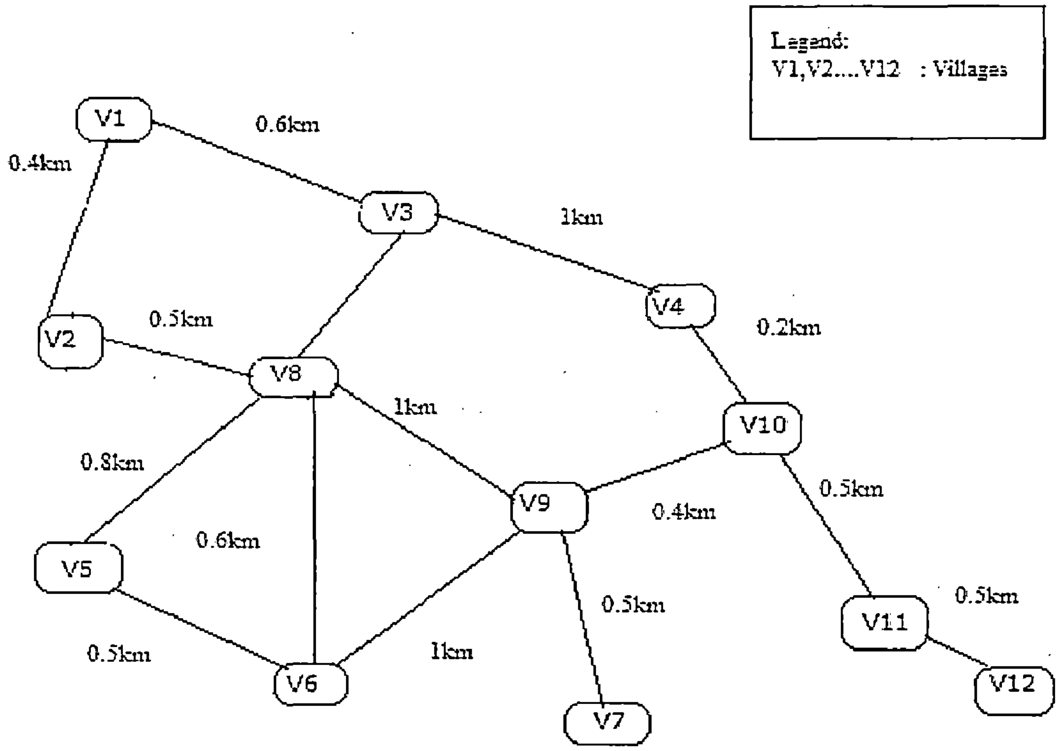


Fig 3.7 Distances between 12 Villages of Study Area

In order to select the suitable conductor for power distribution, it is necessary that we know the kWkm capacity of the distribution paths that are selected. It is also important to know the most economical voltage for the specific loads (villages here).

Table 3.5 shows net power requirement and the most economical voltage for all the 12 villages.

Table 3.5 Net Power Requirement and Most Economical Voltages of 12 villages

Source Village	Load Village	Distance between Source and Load(L in km)	Net Power Requirement P (kW)	kW-km	Most Economical Voltage(kV)	Standard Voltage(kV)
V8	V3	0.5	0.15	0.074	3.08	11
V8	V5	0.8	0.37	0.3	3.90	11
V8	V6	0.6	1.01	0.61	3.41	11
V9	V1	1.9	7.86	14.94	6.19	11
V9	V2	1.5	0.76	0.38	5.35	11
V9	V4	0.6	0.55	0.33	3.39	11
V9	V7	0.5	1.03	0.52	3.13	11
V9	V10	0.4	1.00	0.40	2.81	11
V9	V12	1.4	3.52	4.93	5.25	11
V8	V8	0	1.68	0	0.71	11
V9	V9	0	18.26	0	2.35	11
V11	V11	0	0.53	0	0.94	11

Most Economical Voltage = $5.5 \times [(L/1.6) + (P/100)]^{1/2}$ kV (3.1)

L= Distance over which the line is to be taken in km

P=Power Demand in kW

3.8 DESIGN CRITERIA OF DISTRIBUTION SYSTEMS

The steps involved in designing a decentralized distribution system are as follows:

Step1: Assess the potential and demand of the selected area

Step2: Based on the availability of resources and considering the necessary factors, size the individual systems, i.e. MHP, WES, SPV and BES.

Step 3: Assess daily loads for individual villages (or households if a single village is being considered)

Step 4: If there are villages with surplus and deficit, then plan for the transfer of power from surplus areas to deficit areas.

Step4: Take the shortest distances (or lengths) possible for initial layout plan of the distribution line, as lengthier lines will always lead to increased losses

(Line losses = I^2R kW (3.2)

$R = \rho L/ A$ (3.3)

Where

ρ is the resistivity of conductor material

L is the length of distribution line

A is the area of conductor

I is the conductor current

R is resistance of the conductor)

Step5: Calculate the kW- km for each village from the generating point.

Step6: Calculate the most economic voltage using the formula mentioned in section 3.7

Step7: Select the suitable conductor for the obtained kW-km, according to the REC specifications. After selecting the suitable conductor based on kW-km and power requirement, the following steps are followed for laying the 11kV distribution lines:

- Erection of supports
- Staying of supports
- Mounting cross arms, pins and insulators
- Stringing of line conductors
- Jointing of line conductor using jointing sleeves
- Sagging of line conductor
- Earthing of line conductor
- Testing and commissioning

These are the Material required for L.T lines

- Support steel tubular poles 410- SP with MS base plate and top cap
- Conductor- ACSR/ AAAC Weasel/ Rabbit
- L.T shackle insulators
- L.T Clamps and shackle straps
- Loop guards
- Loop insulator and split Insulator
- Jointing sleeves
- Barbed wire
- 16 mm Stay rod with G.I thimble
- 7/10 SWG G.S Stay Wire
- Stone pad (if necessary)

- Aluminum binding wire- 5mm dia and A1 tape 6.4 × 0.77mm
- Danger Board
- Earthing Pipe/ Rod
- Bolts & Nuts as required
- Brick Ballast, sand and cement for concreting of foundation, wherever required
- Clamps i) Stay clamps ii) Earth Wire Clamps iii) P.G Clamps
- G.I Wire No. 6 SWG, for Neutral –cum-earth wire(if required)
- G.I wire No.8 SWG for coil Earthing (if necessary), for pole earthing
- Rope and Sal –ballies of different size and lengths along with other T & P required for erection

Step8: Based on the power requirement if there is no conductor that can carry the required power, then use step up distribution transformers whose rating will be dependent on the net power requirement to carry power from the generating point to the load and again at the load, use a step down transformer and distribute the power

Step9: After selecting the necessary equipment to bring the power from generating point to the demand node (or village here), plan for the LT service connections and metering.

Fig 3.8 gives the flowchart of steps involved in designing a decentralized distribution system.

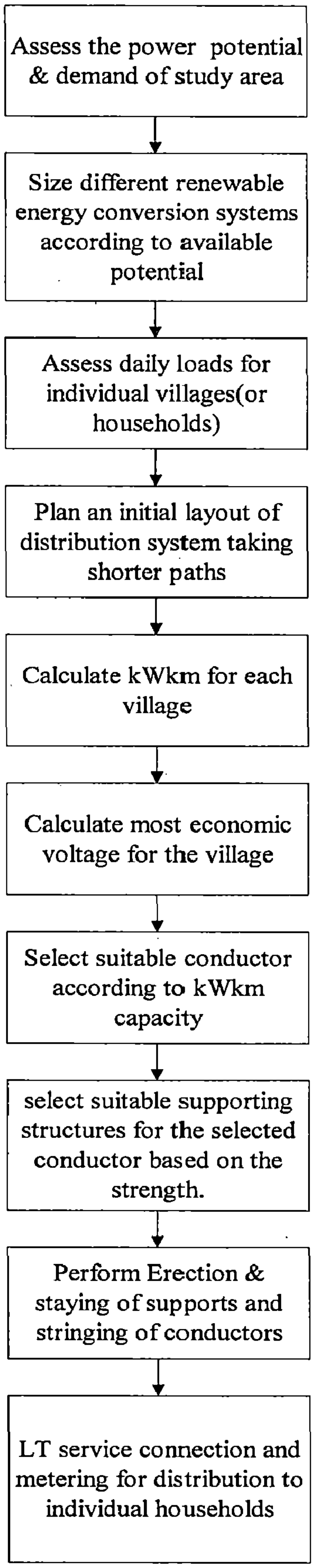


Fig 3.8 Steps Involved In Designing a Distribution System

CHAPTER 4
TECHNO-ECONOMICAL ANALYSIS

4.1 INTRODUCTION

One of the difficulties in the overall simulation and optimization of a power system is that the investment costs of system's components are not known beforehand. The investment costs are the function of project's component sizes. On the other hand, the component dimensions are the function of various site-specific factors (weather, geology, hydrology, socio-economic policy, etc) to mention a few. Obviously, the cost functions are highly non-linear.

4.1.1 Power system optimization

It includes mainly the economic and technical performance indices that may provide useful information to decision makers. Depending upon the nature of the project and the need of information for decision makers, the objective function may be to select only one or all of the following objectives:

- Minimize the life cycle cost
- Minimize the cost of energy
- Maximize the system efficiency
- Maximize the net present value(NPV)

In this work, the objective function is to minimize the total annual cost of the power system. Total annual cost is given by the following expression:

$$TAC = [r(1+r)^t / (1+r)^t - 1] \times [\sum_{K=1}^{n} (\sum_{i=1}^{j} I_i)_k \times (1+r)^k + (1/((1+r)^t) \times I_{rein,i}] + \sum_{i=1}^{j} I_{o\&m,i} \tag{4.1}$$

Where

$(\sum_{i=1}^{j} I_i)\, k$ = Total Investment on i^{th} systems components in year k in Rs

$\sum_{i=1}^{j} I_{o\&m,i}$ = Total annual O & M cost of i^{th} systems components in Rs

r = Discount rate in %

$I_{rein,i}$ = Reinvestment on i^{th} system's component in Rs

K= construction phase

t= Time variable in an economic life (t= 1,2,...T)

T = projects economic life

Total investment cost is determined as the sum of individual components of the power system. It is given by

$$(\sum_{i=1}^{j} I_i) = I_{HP} + I_{WP} + I_{PV} + I_{bio} + I_{BB} + I_{MG} + I_{DLI} + I_{DLII} \quad (4.2)$$

Where

I_{HP} Initial investment on hydropower facilities

I_{WP} Initial investment on wind power facilities

I_{PV} Initial investment on photovoltaic facilities

I_{bio} Initial investment on biomass energy facilities

I_{BB} Initial investment on battery bank/storage facilities

I_{MG} Initial investment on Mini grid facilities

I_{DLI} Initial investment on deferrable load type I

I_{DLII} Initial investment on deferrable load type II

Deferrable loads are those loads which could be connected selectively in order to utilize the excess power and energy available after satisfying the need of the primary loads.

Deferrable load type I is meant for charging batteries for those consumers who live beyond the mini grid reach

Deferrable load type II is the load which consumes both active and reactive power and energy. These include the devices such as water pumps for drinking water or irrigation, motors used for grinding cereals, water boilers, rice cookers and other mechanical power tools.

4.1.1.1 Decision Variables

Decision variables are the system sizes that must be selected in combination of others within the boundary conditions. The table 4.1 shows decision variables for optimization of an isolated power system.

Table 4.1 Decision Variables for designing an optimized decentralized power system

Power system component	Decision Variables	Dimension
MHP	-Percent of time rated flow equaled or exceeded - Canal freeboard safety factor - Flow control through turbine	%
BES	- Amount of biomass available -Size of biogas plant and gasifier	Kg/yr
SPV	- PV array size - Collector slope angle - Surface azimuth angle	m^2 Deg Deg
WES	- Wind rotor diameter -Turbine Hub height	m m
Energy Storage	- Size of Battery Bank	kWh
Deferrable Loads	-Size of deferrable load type I -Size of deferrable load type II	kW kW
Mini-Grid	-Distribution Voltage -Conductor size	kV mm^2

4.1.1.2 Boundary Conditions

They consist of the constraints imposed upon to participating system components. In fact, they are imposed in order to confine the search space for optimum configuration of the components. Boundary conditions are broadly classified as hard conditions and soft conditions. Hard boundary conditions are those which must be satisfied during the process of optimization. They are both necessary and important constraints. In fact, hard boundary conditions have been used to develop the power and energy balance algorithm. The table 4.2 gives a list of hard boundary conditions.

Table 4.2 Boundary conditions for designing an optimized decentralized power system

Boundary conditions		**Formula**	**Symbol**	**Predefined Value**
Storage balance	Minimum Battery state of charge	SOC_{min}	≥	Actual from battery type
	Maximum Battery state of charge	SOC_{max}	≥	Actual from battery type
Capacity and energy balance	Capacity Balance	$\sum_{i=1}^{n} P_{p,i} - \sum_{j=1}^{m} P_{C,j} - \Sigma P_{C,SL}$	≈	0
	Energy Balance	$\sum_{i=1}^{n} W_{p,i} - \sum_{j=1}^{m} W_{C,j} - \Sigma W_{C,SL}$	≈	0
Excess Power and Energy	Excess Power	P_{Ex}	≈	0
	Excess Energy	W_{Ex}	≈	0
Installed capacity	Max. System Power supply	$\sum_{i=1}^{n} P_{p,i}$	≤	Installed capacity
	Max. System Load	$\sum_{j=1}^{m} P_{C,j}$	≤	Installed capacity
Mini- Grid	Max. Voltage Drop	ΔV_{max}	≤	5%
	Max. Grid Power loss	$P_{C,GL}$	≤	5%
	Max. Grid energy loss	$W_{C,GL}$	≤	5%
	Current Carrying Capacity	I_{max}	≤	Actual for Conductor materials

Soft boundary conditions on the other hand, are required to check the simulated size of individual components. These are additional conditions imposed to the system.

They are important but not necessary conditions for the systems optimality. Their use increases the search space. Therefore, it is allowed that some of these conditions may be left without consideration in order to shorten the search process i.e. the soft boundary conditions refer to individual plant constraints. For instance, for MHP it they can be canal free board, minimum head loss etc. In case of SPV, they can be PV array size, collector slope angle and surface azimuth angle.

The table 4.3 gives a brief idea of the technical and economical parameters that are required for decision making.

Table 4.3 Technical and Economical Parameters for decision making

	Parameter	**Dimension**
Technical parameters	Daily Maximum load and power	kW
	Daily Minimum load and power	kW
	Daily average load or power	kW
	Daily energy demanded and supplied	kWh
	System Load ratio	-
	System Load factor	-
	System Utilization Factor	-
	System Performance index	-
	System Improvement ratio	-
	Energy index of reliability	-
	Mini-grid efficiency	%
	Annual Energy Production	kWh
Economic parameters	**Project Cost**	
	Initial Investment	Rs
	First year distribution	Rs

	Second year distribution	Rs
	Economic Indicators	
	Present value of cost	Rs
	Present value of benefit	Rs
	Net Present value	Rs
	Cumulative net cash flow	Rs
	Year to positive cash flow	Year
	Simple pay back period	Year
	Benefit- cost ratio	-
	Break-even energy value	Rs/ kWh
	Profitability index	-

4.2 MAIN COMPONENTS OF A DISTRIBUTION SYSTEM

The function of an electricity distribution network is to deliver electrical energy from the transmission sub stations or small generating stations to each consumer, transforming to a suitable voltage wherever is necessary. Generally, distribution of electricity in rural area is by means of overhead line with bare conductors. The length of LV lines is usually limited to about 500 m or less depending upon factors like voltage regulation (%VR), kW km limit of the conductor, conductor size, number of phases etc. As shown in the comparisons in previous chapter, when the same real power is being delivered, the losses in a single phase line are six times the losses in a balanced three phase line. While designing a system, we have to make economic considerations as well, in addition to considering losses. The losses in a rural distribution system where the line lengths are quite long can be minimized by using number of low capacity distribution transformers, instead of single layer capacity unit. For low-density rural areas with mainly lighting loads, REC strongly recommends the use of single phase distribution transformers. Due to their smaller size and availability in smaller ratings, these can be installed much closer to the load centre thus reducing L.T line length and hence the losses.

The main components in an electrical distribution system and the method of installation are explained below:

4.2.1 Conductor Sizing

Conductor size is decided such that it allows transfer of electric power to the consumer while confining to the permissible values of kVAkm and %VR for a given voltage level and power factor so that line losses will not increase. If these values are beyond permissible limit, then it is better to select a higher conductor size so as to keep these values within the allowable limits.

4.2.2 Different types of Conductors

Hard drawn copper and aluminium, cadmium copper and galvanized or aluminium steel wire conductors are available for overhead type distribution.

4.2.2.1 Hard Drawn copper Conductor

Copper is a superior conductor as compared to other three. It has highest conductivity, very good tensile strength, least resistance, and best weather resisting properties. Due to non- availability of enough copper indigenously and high cost, copper wire is no more being used for distribution.

4.2.2.2 Cadmium Copper

Tensile strength of copper can be doubled if 1% cadmium copper alloy is used. But in such a case, the conductivity will be reduced by 15%. ACSR conductor has now completely replaced it.

4.2.2.3 All Aluminium Conductor (AAC)

This is also called aluminum stranded conductor. Aluminium as a conductor is being used extensively in MV and LV circuits. For the same voltage drop, the area of conductor in case of aluminium conductor shall be 1.61 times that of copper conductor but due to low density the weight ratio is only 0.48 times. For equal diameter, current carrying capacity of aluminium is conductor is only 0.78 times less than that of copper. Due to less weight ratio for equal resistance, aluminium is being preferred. Aluminium conductor is less ductile due to which single strand conductor is seldom used. The total number of strands shall be either 7, 19, 37, 49 or 61. These are recommended to be used for shorter spans upto 35 m above which ACSR should be used.

4.2.2.4 ACSR conductor

The ultimate tensile strength of AAC is poor if it is to be used in spans above 35m. To save it from breaking, in case of use in higher pole spans, one of the conductors out of several strands is made of steel wire due to which the tensile strength is doubled. This combined conductor is known as ACSR conductor.

4.2.2.5 Aluminium Alloy Stranded conductor

Aluminium alloy conductors has got little less breaking strength than the equivalent size of ACSR conductor but far less weight.

4.2.2.6 Steel conductor

Galvanized steel wires are not supposed to carry currents normally but are used as earth wire in which current will flow only in case of leakage or short circuits. It is extensively used as earth wire, Guard wire, and telecommunication circuits and as reinforcement in ACSR conductor.

4.2.3 Supports for Overhead lines

The following types of supports are used generally for supporting the overhead conductors:

1) Wooden poles
2) Steel tubular poles
   a) Swaged type
   b)Stepped type
3) RCC and PCC poles
4) 4) Poles made of Rails and RSJ
5) Poles fabricated from GI/MS pipes
6) Lattice type structures.

4.2.3.1 Wooden poles

Such poles can be used in non-urban areas and for economic reasons, in areas where wood of particular category is available in abundance. Such poles are also used for temporary lines.

4.2.3.2 Steel tubular poles

These are of two types

a) Stepped diameter one piece (type T.P): These are manufactured in one piece seamless or welded design and are in three sections each having diameter reducing in steps.

b) Stepped diameter swaged (Type S.P): these are fabricated from three different steel tubes of different diameters swaged to each other to form a unit length of pole.

Each of the above is further divided into two categories according to their tensile strengths.

i) 410 mPa(42 kgf/mm^2) category

ii) 540 mPa(55 kgf/mm^2) category

Due to light weight, high strength to weight ratio, easy availability and transportation, they are in maximum use among all types of poles.

4.2.3.3 RCC Poles

RCC poles are cheaper than steel tubular poles. They have a very long life as they are free from corrosion but these are very bulky in sizes. RCC poles have an extremely long life but have shattering tendency when hit by an impact load like accident with vehicles. Such poles are extensively used for power distribution in urban areas and in remote and inaccessible places as they can be fabricated at site.

4.2.3.4 Rails and R.S.Js

As new rails and R.S.Js are very costly, old and used second hand rails and R.S.J (rolled Steel joints) are frequently used as supports for OH lines.

4.2.3.5 G.I pipes (Galvanized steel pipes) and black M.S pipes

These are used for street and compound lighting in internal roads with single fittings. It is also used as a mechanical protection for cables traveling along the pole.

4.2.3.6 Lattice type poles and towers

Lattice type poles are fabricated from narrow base steel structures and can be designed for working loads 800kg and above. They are light in weight and can be assembled at site.

4.2.4 Installation of LT and 11 kV lines

4.2.4.1 Foundation

All poles are positioned in the foundations so that the bigger section modulus of the pole is always transverse to the length of the line.

4.2.4.2 Pole fittings and cross arms

LT lines: The phase conductors in horizontal configuration should be run on pin or shackle insulators. The neutral conductors may be run on reel insulators. For vertical configuration, the insulators may be fixed on the pole by using D-type or other suitable clamps.

11kV lines: These lines are usually arranged in delta formation generally by placing one of the conductors on the top of pole and fixing it with an insulator mounted on a bracket type clamp and by placing the bottom conductors on a suitable cross arm. Bird guards may be provided in locations where birds are found in large numbers. In that case, V or U type cross arms are used. Annexures 1 to 6 shows the various accessories while laying a conductor.

4.2.4.3 Insulators

The following types of insulators are generally used for Overhead power lines.

Pin insulators

Disc insulators: For HV lines

Shackle insulators: For LV and MV lines

Stay insulators: For stay and guy wires

4.2.4.3.1 Fixing of insulators

The insulators are attached to the poles directly with the help of D type or other suitable clamps in case of vertical configuration or attached to the cross arms with the help of pins in case of horizontal configuration. Annexure 3 shows a 11kV pin insulator.

4.2.5 Stays and staying arrangements

Overhead lines supports at angles and terminal positions need to be well stayed with stay wire, stay rod etc.

4.2.5.1 Stay wires

Hard drawn galvanized steel should are used as stay wires. The minimum tensile strength of these wires is 70kgf/mm^2.

4.2.5.2 Stay Rods

Mild steel rods are used for stay rods. The minimum tensile strength of these rods is $42kgf/mm^2$

4.2.5.3 Stay Anchoring

Stays are anchored either by providing base plates of suitable dimensions or by providing angle iron or rail anchors.

4.2.5.4 Fixing of stay wires and rods

Stay wires and rods are connected to the pole with a porcelain guy insulator. Suitable clamps are used to connect stay wires and rods to its anchor.

4.2.5.5 Setting of stays

The inclination of stay relative to the ground is roughly determined before making the hole for excavation. The stay rods are securely fixed to the ground by means of a suitable anchor.

4.2.6 Installation of Conductors

The conductor is run out by putting the conductor drums over roller blocks. Sagging is done in sections from one tension point in the line to the other. While sagging the conductor, tension in it is kept uniform throughout the length of the section being sagged.

4.2.6.1 Attachments of conductor with insulators

The insulators are bound with the line conductors with the help of copper binding wire in case of copper conductors, galvanized iron binding wire fro galvanized iron conductors, and aluminium and steel enforced aluminium conductors. The minimum size of the binding wire is 2 sq.mm

4.2.6.2 Spacing of conductors

As a thumb rule, spacing between conductors is 1% of the maximum span. The lighter section conductor should have more spacing than the heavier section. This is due to inductive reactance.

4.2.6.3 Tapping Service connections

No service connection line should be tapped from OH line from any point midspan except at point of support. When service connection is taken overhead with bare conductor, it is provide with guard wires.

Annexure 9 shows the service connections for a typical pump house and Annexure 10 gives the service connections for a flat roofed house. Annexure 8 shows the service connections for a gabled roof.

4.3 DESIGN OF DISTRIBUTION SYSTEM FOR THE STUDY AREA

As discussed in the previous chapters out of 12 villages, two villages V8 and V9 have got surplus potential, one village V11 has got self sufficient potential. Accordingly, the distribution system layout was planned. As longer distribution lines will lead to more losses, the shortest distances between the villages are chosen as the distribution paths.

It is proposed that villages V8, V9 and V11 use the available power for fulfilling their local power demand and supply the available surplus power to the nearby villages with deficit. After making the primary consideration of taking minimum distance path, there exist two options for meeting the power deficit from the villages with surplus. One of the options is village V8 meeting the power deficit of villages V3, V5 and V6 and village V9 meeting the power deficit of villages V1, V2, V4, V7, V10 and V12. The second scheme is sending the surplus power from V8 to V2, V3, V5 and V6 and then sending the remaining surplus to a common busbar emanating from V9. V9 will supply its surplus to villages V1, V4, V7, V10 and V12.

The type of poles selected for supporting the conductors are Steel tubular poles(8.5 m long, 410-SP21).According to Rural electrification specifications, the recommended span for steel tubular poles is 50 -80 m. A span of 70 m is selected for the proposed distribution schemes. Therefore, 28 poles are required per km, for supporting the conductors.

Conductors are selected based on the kWkm capacity of the villages. Typical characteristics of different types of conductors are given in table 4.4.

Table 4.4 Conductor Specifications

Name of Conductor	Size (mm)	Equivalent Area of Aluminum (sq.mm)	Power Capacity (HPkm)	Power Capacity (kWkm)
Weasel	7/ 2.59	31.21	10.2	7.6
Rabbit	7/ 3.35	52.21	14.9	11.11
Raccoon	7/ 4.09	77.83	22.21	16.56
Dog	6/ 4.72 + 7/ 1.57	103.6	29.56	22.05

4.3.1 Distribution Scheme I

V8 supplies its surplus to V3, V5 and V6 and V9 supplies its surplus to V1, V2, V4, V7, V10, and V12. The surplus power from villages V8 and V9 will be supplied to the deficit villages using LT lines only. Here, no distribution transformers are required. Table 4.4 gives a brief idea of the power demand at the villages and the conductors selected for distribution of power in the scheme I. Fig 4.1 gives an outline of the proposed scheme discussed above.

Table 4.5 Conductors selected for Scheme I

Village with surplus(Source Village)	Village with deficit(Load Village)	Distance between Source village and load village(km)	Power Demand(kW) of Villages with deficit	kWkm	Conductor Selected
V8	V3	0.5	0.1479	0.074	Weasel
V8	V5	0.8	0.3734	0.299	Weasel
V8	V6	0.6	1.009	0.605	Weasel
V9	V1	1.9	7.8636	14.94	Raccoon
V9	V2	1.5	0.7559	1.134	Weasel
V9	V4	0.6	0.5525	0.332	Weasel
V9	V7	0.5	1.0314	0.5157	Weasel
V9	V10	0.4	1.0035	0.401	Weasel
V9	V12	1.4	3.5219	4.931	Weasel

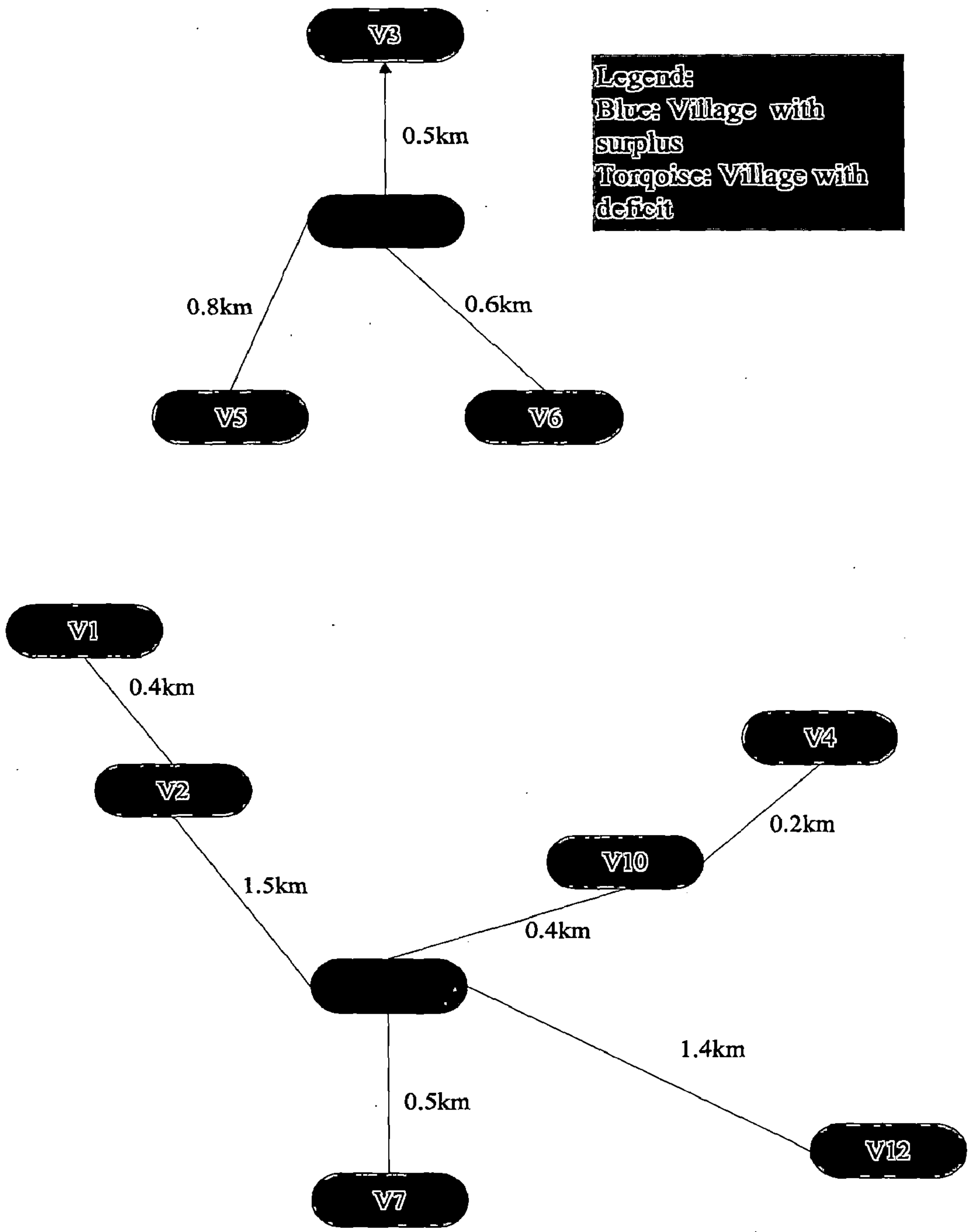


Fig 4.1 Proposed Distribution Scheme I

4.3.2 Scheme II

V8 Supplys its surplus to V2, V3, V5, V6 and the remaining surplus power is sent to the common busbar starting from V1, by using an LT line, and V9 supplies its surplus to V1, V4, V10, V7 and V12. V9 is proposed to supply its surplus to villages V4, V10, V7 using LT AAAC weasel conductors and at 11kV to villages V1 and V12 using a common busbar. In this scheme, step down transformers are required to be used at villages V1 and V12. Table 4.5 gives a brief idea of the type of conductors selected for distribution. Fig 4.2 shows an outline of this distribution scheme.

Table 4.6 Conductors selected for Scheme II

Village with surplus(Source Village)	**Village with deficit(Load Village)**	**Distance between Source village and load village(km)**	**Power Demand(kW) of Villages with deficit**	**kWkm**	**Conductor Selected**
V8	V2	0.5	0.7559	0.378	Weasel
V8	V3	0.5	0.1479	0.074	Weasel
V8	V5	0.8	0.3734	0.299	Weasel
V8	V6	0.6	1.009	0.6054	Weasel
V9	V1	1.9	7.8636	14.941	Raccoon
V9	V4	0.6	0.5525	0.3315	Weasel
V9	V7	0.5	1.0314	0.5157	Weasel
V9	V10	0.4	1.0035	0.4014	Weasel
V9	V12	1.4	3.5219	4.931	Weasel

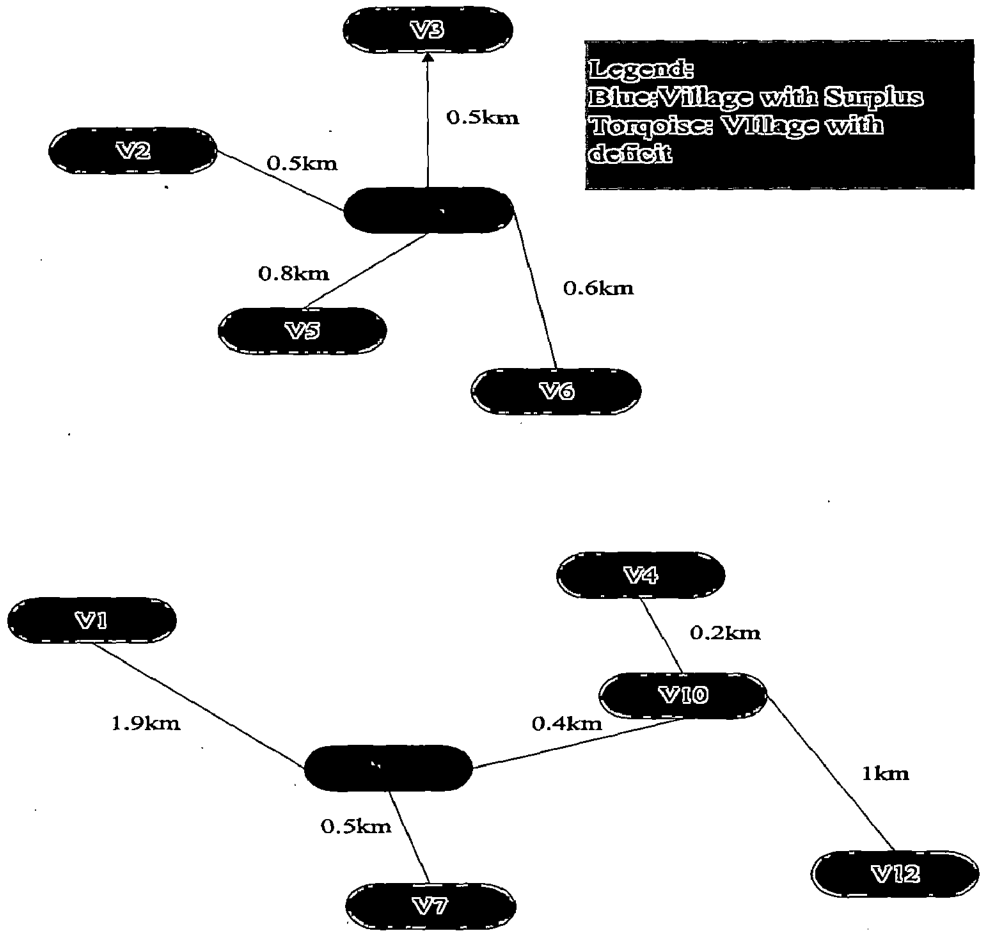


Fig 4.2 Proposed Distribution Scheme II

4.4 COST ANALYSIS

The laying of conductors comprise of different steps like erection of poles, etc with necessary accessories as described in section 3.9. Table 4.7 gives a brief idea about the accessories and their costs while laying a kilometer of three phase LT line.

Item	Quantity	Rate(Rs)	Total Cost
Stone Pads(500 ×100 × 75)	28	50	1400
LT clamps with bolts & nuts for ST poles	112	100	11,200
Earthwire clamps for ST poles with bolts & nuts	28	100	2800
LT shackle insulators	112	20	2240
Bolts & nuts for shackle insulators	112	50	5600
Loop Guards	56	40	2240
Spacer LT PVC	112	30	3360
Neutral cum earth wire 6 swg/5 sq.mm	77.8kg	50	3890
Al. Binding Wire 5mm	7.8kg	120	936
Jointing sleeve for weasel conductor	9 nos	150	1350
Extra for stays at angle & Terminal location	14 nos	1000	14,000
Earthing Complete	8 nos	300	2400
Concreting of ST pole	28 nos	500	14000
Total			**65,416 /-**

Table 4.7 Cost analysis of one kilometer of three-phase LT line for hills

In addition to the costs that are mentioned in table 4.7, contingencies @ 5%, Cartage Charges @ 5% and Erection charges @ 10% are to be considered.

Cost of Contingencies + Cartage Charges + Erection Charges

= (3271+3271+ 6542)

= Rs13,084/-

In addition to the cost of laying conductors and supports, the costs of service connections should be taken into account to know the total cost of the distribution system. Table 4.8 shows the cost of service connection for all the twelve villages, considering a cost of Rs200/- per household.

Village	Total Number of Households	Total Cost of service connections(Rs)
V1	40	8000
V2	7	1400
V3	7	1400
V4	6	1200
V5	8	1600
V6	10	2000
V7	14	2800
V8	14	2800
V9	45	9000
V10	15	3000
V11	40	8000
V12	35	7000
Total cost of service connection for 12 villages		48,200

Table 4.8 Cost of service connections

The bill of material/ price schedule for 1km 11kV three phase line in hills, for weasel and raccoon conductors are given in table 4.9 and table 4.10 respectively. The tables indicate the cost of accessories that are required for conductor laying for 11kV lines for weasel and raccoon conductors in hilly areas.

Table 4.9 Bill of material/Price schedule for 1km 11kV 3 Φ line - Weasel conductor

S.No	Description	Unit	Quantity	Rate in Rs	Amount
1	S.T Pole 8.5 m long 410 SP-23 with supply and erection including X arm. Insulators. Clamps, bolts & nuts -Single pole	Nos		9858	
2	AAAC 7/2.5 mm equivalent to weasel with supply and erection including earth wire	km	1	67459	
3	Extra for Stays at angle location	Nos	4	1000	4000
4	Earthing Complete	Nos	4	500	2000
5	Contingencies LS				10000
6	Total				**16000**

Table 4.10 Bill of material/Price schedule for 1km 11kV 3 Φ line- Raccoon conductor

S.No	Description	Unit	Quantity	Rate in Rs	Amount
1	S.T Pole 8.5 m long 410 SP-23 with supply and erection including X arm. Insulators. Clamps, bolts & nuts -Single pole	Nos		9858	
2	AAAC 7/2.5 mm equivalent to Raccoon with supply and erection including earth wire	km	1	1,48,409	
3	Extra for Stays at angle location	Nos	6	1000	6000
4	Earthing Complete	Nos	6	500	3000
5	Contingencies LS			10000	10000
6	Total				**19000**

4.4.1 Cost Analysis of scheme I

Table 4.11 gives the total cost of distribution systems for scheme I. The total cost of the Distribution system till the service connections are calculated based on the bill of materials as given in table 4.7 as in this scheme, all lines are LT lines only.

Table 4.11 Cost analysis of Distribution Scheme I

Village	Conductor	Total no. of poles	Cost(Rs)		Total cost of pole(Rs)	Cost of accessories and contingencies	Total(Rs)
			Per Pole	conductor			
V3	Weasel	14	6000	13,660	84,000	78,500	1,76,160
V5	Weasel	22	6000	13,660	1,32,000	78,500	2,24,160
V6	Weasel	17	6000	13,660	1,02,000	78,500	1,94,160
V1	Raccoon	53	6000	31,300	3,18,000	78,500	4,27,800
V2	Weasel	42	6000	13,660	2,52,000	78,500	3,44,100
V4	Weasel	17	6000	13,660	1,02,000	78,500	1,94,160
V7	Weasel	14	6000	13,660	84,000	78,500	1,76,160
V10	Weasel	11	6000	13,660	66,000	78,500	1,58,160
V12	Weasel	39	6000	13,660	2,34,000	78,500	3,26,160
Grand Total upto Service Connection							**22,21,020**

4.4.2 Cost Analysis of Scheme II

The total cost of distribution upto service connection and without considering transformers is calculated based on tables 4.9 and 4.10 i.e bill of materials for 11kv lines.

Table 4.12 Cost Analysis of Distribution Scheme II

Village	Conductor	Total no. of poles	Cost(Rs)		Total cost of pole(Rs)	Cost of accessories and contingencies	Total(Rs)
			Per Pole	conductor			
V2	Weasel	14	6000	13,660	84,000	78,500	1,76,160
V3	Weasel	14	6000	13,660	84,000	78,500	1,76,160
V5	Weasel	22	6000	13,660	1,32,000	78,500	2,24,160
V6	Weasel	17	6000	13,660	1,02,000	78,500	1,94,160
V1	Raccoon	53	9858	1,48,409	5,22,474	19,000	6,89,883
V4	Weasel	17	6000	13,660	1,02,000	78,500	1,94,160
V10	Weasel	11	6000	13,660	66,000	78,500	1,58,160
V7	Weasel	14	6000	13,660	84,000	78,500	1,76,160
V12	Weasel	39	9858	67,459	3,84,462	16,000	4,67,921
V8	Weasel	28	6000	13,660	1,68,000	78,500	2,60,160
Grand Total upto Service Connection (Rs)							**27,17,084**

Table 4.12 gives the cost of distribution system upto service connection for scheme II. In addition to the costs incurred in conductors, supports for conductors and other contingencies and accessories, the cost of distribution transformers and isolator are to be taken into account in scheme II. Considering the costs of three transformers required in scheme II,

The total cost of the distribution system will be as shown below:

Cost of laying conductors and supports = 27, 17,084 + (Cost of 16 kVA 0.415/11kV transformer + Cost of 16 kVA 11/0.415kV transformer + Cost of 16 kVA 11/0.415kV transformer)+ Cost of Isolator

= 27, 17,084 + (66,000 + 66,000 + 66,000) + 15,000

= Rs 29,30,084/-

4.4.3 Total Costs of Scheme I and Scheme II

The total costs of two schemes of distribution systems, including the service connections are as shown below.

Scheme I:

Total cost = Cost of laying conductors + Cost of Service connection

= 22,21,020 + 48,200

= **Rs 22,69,220 /-**

Cost per km:

Cost per km = Total Cost of the Distribution system/ Length through which power is to be distributed

= 22,69,220/ 5.9

= **Rs 3,84,613.6/km**

Scheme II

Total cost = Cost of laying conductors + Cost of Distribution Transformers+ Cost of isolator + Cost of Service connection

= 27,17,084 + (66,000 + 66,000 + 66,000) + 15,000 + 48,200

= **Rs 29,78,284/-**

Cost per km:

= Rs 29,78,284/ 7.4

= **Rs 4,02,470/km**

Therefore, upon looking at the cost analysis, it is obvious that scheme I is less costly than scheme II. i.e. scheme I is the cost optimized option among the two schemes that are available for distributing the power to villages with deficit of power. Therefore, instead of opting for a common busbar scheme, it is better to supply the surplus power to the nearby villages through LT lines, so that both the costs and losses are minimized to a greater extent. Following graphs show the variation of cost of distribution systems with respect to the variation in different components of the distribution system. Fig 4.3 shows that the cost of distribution system increases as the rating of the transformer increases. Fig 4.4 shows that the cost of distribution system increases with the increase in length of the conductor.

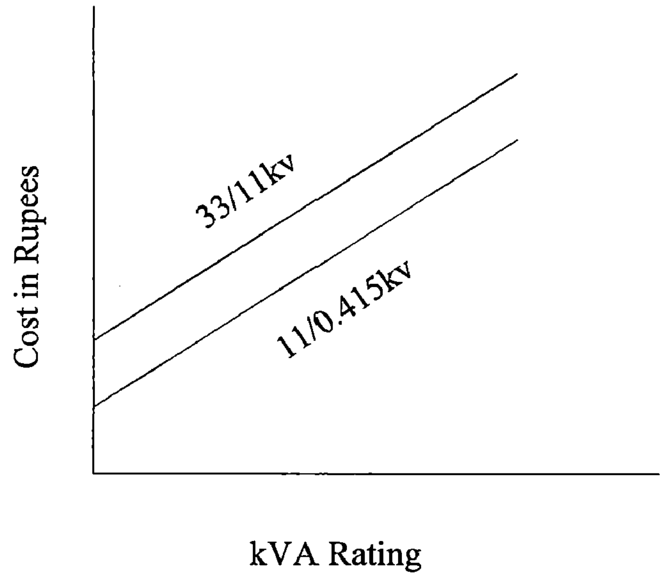


Fig 4.3 Cost of Transformer vs Rating of Transformer

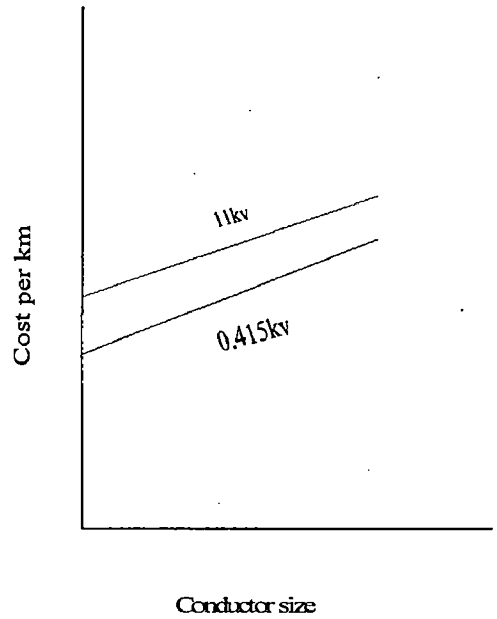


Fig 4.4 Cost per km of conductor vs conductor size for overhead distribution

Fig 4.5 shows the variation of cost of distribution system with the increase of voltage or current ratings of transformers and conductors. Fig 4.6 shows that the cost of distribution system increases as the loss level of the distribution system increases.

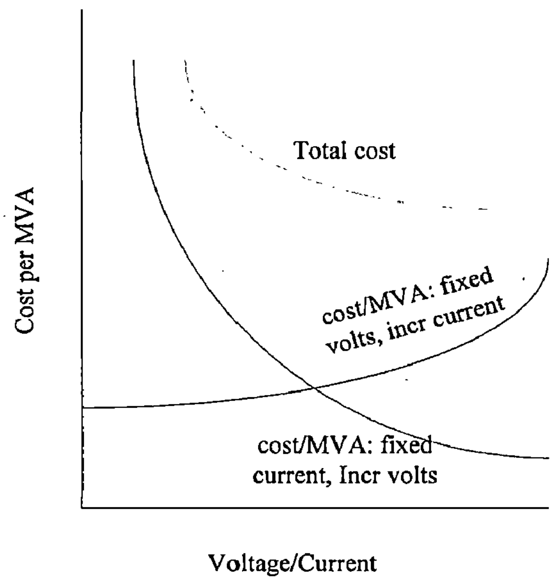


Fig 4.5 Cost vs current/voltage rating of conductors and transformers

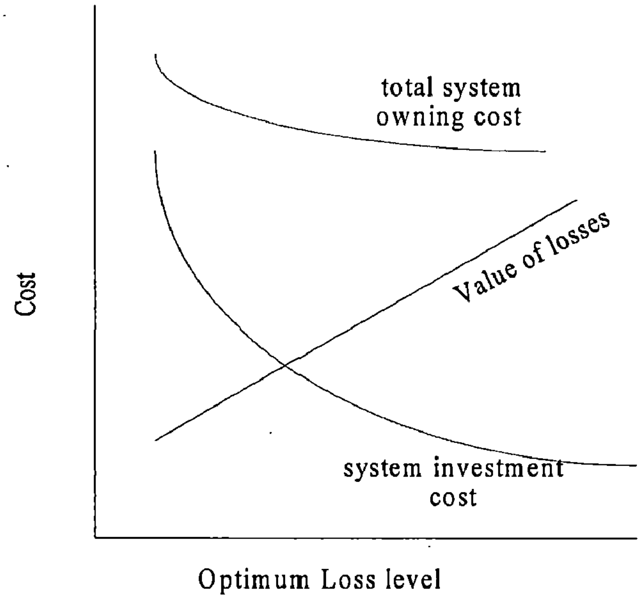


Fig 4.6 Optimum loss level

As the distance between the source point and the load increases, lengthier conductor is required which increases the losses and also the cost of conductor, cost of supports and accessories for supports. Moreover, as the distance increases, the kWkm of the load point increases, which most of the times cannot be met by the conductors alone. In that case, distribution transformers are needed to be installed, which in turn increases cost of the whole distribution system. Fig 4.7 indicates that the cost of distribution system will increase as the distance of distribution increases i.e. as the length of conductor increases.

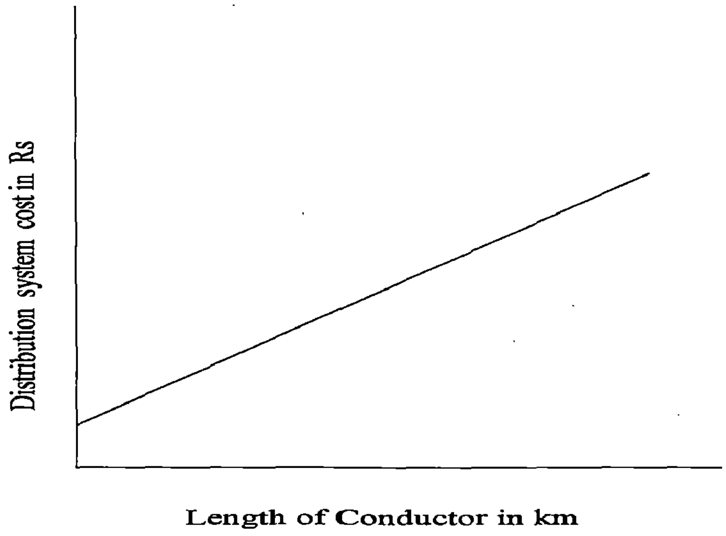


Fig 4.7 Distribution system cost vs Length of conductor in km

Since more amount of power to be carried requires a conductor with more kWkm capacity, which in turn increases the cost of the conductor, therefore total cost of the distribution system increases. Fig 4.8 shows that the cost of distribution system increases as the power that is to be distributed increases.

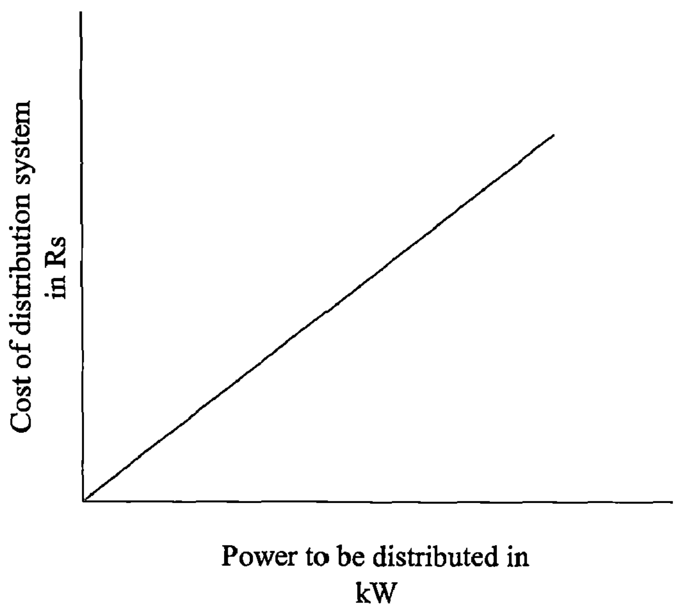


Fig 4.8 Distribution system cost vs Power to be distributed

4.5 Cost Function

The objective function to minimize is the sum of the total costs for the MV network, MV/LV substations and LV networks and a penalty function for unfeasible LV networks.

Let ψ be the cost function.

$$\Psi = C_{MV} + C_{LV} + C_{sub}$$

$$C_{MV} = K_{iMT} \times \sum_{(j,k) \in A_{min}} L_{jk}$$

$$C_{LV} = \sum_{(j,k) \in LV} (Ki_{j,k} + Km_{j,k} + Kp_{j,k} * I^2_{j,k}) \times L_{j,k}$$

$$Csub = \sum_{j \in sub} (Ki_j + Km_j + K_{Fej} + K_{Cuj} * P^2_j)$$

where

C_{MV}	Total cost of the MV network
K_{iMT}	Investment cost of MV network per unit length
L_{jk}	Length of the line (j,k)
A_{min}	Minimal distance
C_{LV}	Total cost of LV network
$Ki_{j,k}$	Investment cost of the line(j,k) per unit of length
$Km_{j,k}$	Maintenance cost of the line (j,k) per unit of length
$Kp_{j,k}$	Electrical losses cost of the line (j,k) per unit of length
$I_{j,k}$	Intensity of line(j,k)
Csub	Cost of mv/lv substations
Ki_j	Investment cost of the mv/lv substation at node j
Km_j	Maintenance cost of the mv/lv substation at node j
K_{Fej}	Iron losses cost of the mv/lv substation at node j
K_{Cuj}	Copper losses cost of the mv/lv substation at node j, per unit of power
P_j	Real power that flows through the MV/LV substation in node j

In the case of study area, there is no substation cost but there are transformer costs and isolator costs in place of the substation costs. The transformer itself can be treated as the substation.

After analyzing the costs of two available schemes of distribution systems for distributing power to the villages with deficit, it is obvious that, instead of bringing the surplus power to a common busbar and then distributing, it is economical to distribute the power from where it is available. Table 4.13 gives a brief idea about the total costs of two schemes that are considered for distributing power to the villages.

Table 4.13 Total Costs of Distribution Schemes I and II

Scheme	Total Cost(Rs)	Cost /km(Rs/km)
Scheme I	22,69,220 /-	3,84,614
Scheme II	29,78,284/-	4,02,470

Therefore, it is economical to send the power from villages with surplus power to the nearby villages with deficit from the villages directly instead of bringing the power to a common busbar and then supplying it. This is because, if the power is brought to a common busbar and then supplied the costs and losses of the whole distribution system will increase because of added components like distribution transformers and isolators. In addition to that, some part of the power is lost while bringing it to the common busbar in form of conductor losses. This accounts to a greater reduction in the total power being supplied to the villages with deficit as the power potential is very low.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

The concept of decentralized generation and distribution systems for electrifying remote unelectrified villages located far away from utility grid is gaining importance day by day as stipulated in the Rural Electrification Act 2003. The present work was carried out to design a cost optimized distribution system for 12 unelectrified villages of zone 4 of Jaunpur block of Tehri Garhwal district in Uttarakhand. Out of 12 unelectrified villages selected for study, only three villages have got surplus of energy (+1, 75,277 kWh/yr) and the remaining nine villages have deficit of energy, (– 1, 42,433kWh/yr).

Two power distribution options have been analyzed for meeting the power deficit in 9 villages. Distribution from the system placed at various locations and the common busbar scheme.. The one with minimum cost and able to meet all the technical constraints optimized was selected. Cost analysis of all the options available for supplying power to the villages with deficit had been done. The minimum cost option was obtained considering that the power supply to villages facing energy deficit, (V3, V5 and V6) is done by obtaining balance energy from village V8 which is having surplus power. The energy deficit of the villages V1, V2, V4, V7, V10 and V12 was met from the other village with surplus, i.e. village V9

It was clearly observed that

- Based upon the analysis of energy systems considered for the study, it was found that the cost of integrated renewable energy sources model has been found as Rs 14/kWh whereas the cost of energy considering individual system are as MHP at Rs 2.53/kWh, BES at Rs 3.68 /kWh, WECS at Rs 7.18/ kWh and SPV at Rs 20.50 /kWh. It is seen that the cost of energy of integrated renewable energy systems is lower than the individual cost of energy considering individual system, indicating the significance of integrated renewable energy systems for rural electrification.

- The cost of distribution system with common busbar scheme has been found much higher than the distribution system having energy from different locations, and therefore, the total system has been found to be cost effective.
- Three phase LT lines were sufficient to distribute the power to all the villages under the distribution system having energy from different locations. HT lines were required for two villages which are located at a distance more than 1km where common busbar scheme was considered.
- A total number of 229 Steel Tubular Poles were found to be required in both the cases.
- The total cost of distribution system was found to be Rs 22,69,220/- with Rs 3,84,613/km, for the distribution system having energy from different locations and Rs 29,78,284/- with Rs 4,02,470 /km for the common busbar scheme.

5.2 RECOMMENDATIONS

In present study, 12 unelectrified villages were supplied power from renewable energy systems. In view of the fact that so far, conventional methods have been used for distributing power to the twelve unelectrified villages of the study area. The following recommendations may be made

- Study on using Single wire earth return transformer instead of conventional distribution transformer
- Study using High Voltage Distribution Systems for distribution of power in decentralized manner.
- There is a need to classify and design criteria for different types of local/ medium / mini grid for supplying power in decentralized mode.

REFERENCES

[1] A.G.Ter Gazarain, N.Kagan, Design Mode for electric distribution systems considering renewable and Energy storage units,1992

[2] Alessandro Bertani, Clardio Boss, Bruno Defino, Norbert Lewald, Stefano Massuco, Elmar MEtten, Tim Meyer, Federico Silvestro, Irena Wasiak- Electrical Energy Distribution Networks: Actual Situation & Perspectives for Distributed generation: 17th International Conference on Electrical Distribution, 2003

[3] Amulya K.N.Reddy, Kirk R.Smith, Robert H William- World Energy Assessment: Energy the Challenge of sustainability: Chapter10; Rural Energy in developing countries,

[4] Anantha, A., Solar photovoltaic as an energy source for India, Volume 4, 27 July-1 Aug. 1997 Page(s):2328 - 2333 vol.4

[5] Bellar, M.D.; Aredes, M.; Silva Neto, J.L.; Rolim, L.G.B.; Aquino, A.F.C.; Petersen, V.C., Single-phase static converters for rural distribution system, Industrial Electronics, 2004 IEEE International Symposium ,Volume 2, 4-7 May 2004 Page(s):1237 - 1242 vol. 2

[6] Bellar, M.D.; Aredes, M.; Silva Neto, J.L.; Rolim, L.G.B.; Aquino, F.C.; Petersen, V.C., Comparative analysis of single-phase to three-phase converters for rural electrification, Industrial Electronics, 2004 IEEE International Symposium, Volume 2, 4-7 May 2004 Page(s):1255 - 1260 vol. 2

[7] Best Practices in Sustainable Rural energy development: Five International Case Studies- March 2005 by PEMBINA institute for appropriate development

[8] B.P Statistical Review of World Energy June 2007

[9] Caamano-Martin, E.; Lorenzo, E.; Lastres, C. PV modules characterization in rural electrification action, Photovoltaic Specialists Conference, 2000. Conference Record of the Twenty-Eighth IEEE,15-22 Sept. 2000 Page(s):1472 - 1475

[10] Chambers, T.; Mutale, J.; Jenkins, N., Software tool for the Development of Small Rural Power Supplies with Renewable Resources, Transmission &

Distribution Conference and Exposition: Latin America, 2006. TDC '06. IEEE/PES, Aug. 2006 Page(s):1 - 5

[11] C.W.Hasselfield, P.Wilson, L.Penner, M.Lau, A.M.Gole- IEEE Transactions on Power delivery : Vol.5, No.2, April 1990- An automated method for least cost distribution system planning

[12] Diniz, A.S.A.C.; Franca, E.D.; Camara, C.F.; Morais, P.M.R.; Vilhena, L., The Important Contribution of Photovoltaics in a Rural School Electrification Program, Conference Record of the 2006 IEEE 4th World Conference on Photovoltaic Energy Conversion,Volume 2, May 2006 Page(s):2528 - 2531

[13] Dwolatzky, B.; Meyer, A. A software based distribution design methodology supporting rural electrification in South Africa , Rural Electric Power Conference, 1998. Papers Presented at the 42nd Annual Conference, 26-28 April 1998 Page(s):b1 - 1-4

[14] Dedman, J.C.; Bowles, H.L. A survey of URD cable installed on rural electric systems and failures of that cable , Rural Electric Power Conference, 1990. Papers Presented at the 34th Annual Conference, 29 April-1 May 1990 Page(s):D2/1 - D2/7

[15] Decentralized Energy Alternatives (DEAs), Columbia University

[16] W.E.L.Khattam, M.M.A.Salama, Dept of Electrical & Computer Engineering, University of Warterloo - Distribution System Planning Using Distributed Generation

[17] Decentralised Generation – Independent Analysis of the Potential Role of Small Scale Distributed Generation.

[18] Dasuki, A.S.; Djamin, M.- Fifty mega watt peak (50 MWp) photovoltaic rural electrification in Indonesia, Photovoltaic Energy Conversion, 1994., Conference Record of the Twenty Fourth ; IEEE Photovoltaic Specialists Conference - 1994, 1994 IEEE First World Conference on,Volume 2, 5-9 Dec. 1994 Page(s):2379 - 2382 vol.2

[19] Douglas, H.; Malengret, M., Symmetrical PWM with a split-capacitor single-phase to three-phase converter for rural electrification, Industrial Electronics,

1998. Proceedings. ISIE '98. IEEE International Symposium,Volume 1, 7-10 July 1998 Page(s):289 - 293 vol.1

[20] Dussart, M., Problems encountered with connecting decentralized generating plants to the distribution networks,**14th International Conference and Exhibition on Electricity Distribution (IEE Conf. Publ. No. 438,** Publication Date: 2-5 June 1997,Volume: 5, On page(s): 26/1- 26/5 vol.5

[21] Egill Benedikt Hreinsson, Cost Analysis in a rural power distribution system, IASTED international Conference on Power , Energy, And Applications(PEA 2006) Science and Technology for development in 21st century, 2006

[22] Eloy Diaz- Dorado, Jose Cidras Pidre, Edlemiro Miguez Garcia, Planning of Large Rural Low Voltage Networks Using Evolution Strategies, IEEE transactions on Power systems, Vol 18, no 4 November 2003

[23] Govender, K.M.; Meyer, A.S.; Dwolatzky, B., The automatic clustering of uniformly distributed loads for the use in rural electrification planning, Transmission and Distribution Conference and Exposition, 2001 IEEE/PES Volume 1, 28 Oct.-2 Nov. 2001 Page(s):450 - 455 vol.1

[24] Global Energy [R]evolution – A Sustainable India Energy Outlook

[25] Helio International: Sustainable Energy Watch 2005/2006 Energy & Sustainable Development in India

[26] Holland, R., Appropriate technology-rural electrification in developing countries, IEE Review, Volume 35, Issue 7, 13 July 1989 Page(s):251 - 254

[27] Ijumba, N.M.; Raphalalani, V.T.; Reddy, P., Optimized application of renewable energy sources in rural electrification, AFRICON, 1999 IEEE, Volume 2, 28 Sept.-1 Oct. 1999 Page(s):971 - 976 vol.2

[28] Ijumba, N.M.; Wekesah, C.W., Application potential of solar and mini-hydro energy sources in rural electrification, AFRICON, 1996., IEEE AFRICON, Volume 2, 24-27 Sept. 1996 Page(s):720 - 723 vol.2

[29] International Journal of Energy Research-1999

[30] J Nahman, J Spiric, Optimal Planning of rural medium voltage distribution networks, Electric Power & Energy Systems, Vol 19, No8. pp 549-556,1997

[31] Karki, N.R.; Reducing the cost of rural electrification: a key to improve the quality of life in rural areas in developing countries, Power System Technology, 2004. PowerCon 2004. 2004 International Conference ,Volume 1, 21-24 Nov. 2004 Page(s):447 - 452 Vol.1

[32] Kagarakis, C.A.; Avaritsiotis, J.N. ,Assessment of solar photovoltaic systems at the level of rural electrification, Electrotechnical Conference, 1989. Proceedings. 'Integrating Research, Industry and Education in Energy and Communication Engineering', MELECON '89., Mediterranean,11-13 April 1989 Page(s):31 - 33

[33] Low cost electrification for household energy-Boiling Point , Autumn 2000, number 45

[34] Mather, M.N.; Malengret, M.; Le Claire, J.C.- 110 W low cost, efficient PV-grid interface for rural electrification, Power Electronics and Variable Speed Drives, 2000. Eighth International Conference on (IEE Conf. Publ. No. 475),18-19 Sept. 2000 Page(s):136 – 139

[35] Mbogho, M.S.; Wekesa, C.; Murage, D.; Toyoda, J., Economic analysis of supplying an electro village using alternative electrical power sources, AFRICON, 1996., IEEE AFRICON, Volume 2, 24-27 Sept. 1996 Page(s):968 - 971 vol.2

[36] Monteiro M.F.C.; Pinto, J.A.D.; Moura, A.C.S.M.E., Influence of the decentralized generation in the harmonic pollution in an electric power system, Universities Power Engineering Conference, 2004. UPEC 2004. 39th International Publication Date: 6-8 Sept. 2004,Volume: 2, On page(s): 884- 887 vol. 1

[37] Manual for Decentralized Distribution and Generation Projects (Based on Community Approach), prepared by UREDA

[38] Martins, D.C.; Bazzo, E.; Ruther, R., Technical and Economic Analysis of a PV/Diesel Hybrid System Applied to Rural Electrification for Isolated Communities in the Northern Brazilian Region, Power Electronics Specialists, 2005 IEEE 36th Conference, 11-14 Sept. 2005 Page(s):257 - 261

[39] M.D.Bellar,M.Aredes, J.L Siha Neto, L.G.Barbosa Rolim, Ulises De A.Miranda, R.M.Fernandes, A.F.C Acquin, V.C.Petersen- Four- Wire Single Phase to Three

Phase system for Rural Distribution Networks, 35th annual IEEE Power Electronic Specialists Conference, 2004

[40] Nazrul Islam -Remote Area Power supply Systems(RAPSS) – A Framework for implementation and Operation

[41] N.H.Ravindranath , H.I Somashekar, S.Dasappa, C.N Jayasheela Reddy ,Sustainable biomass power for rural India: Case study of biomass gasifier for village electrification

[42] Opportunities for sustainable Energy- Renewable Energy, By RET

[43] Owen, E.L., Rural electrification: the long struggle, Industry Applications Magazine, IEEE,Volume 4, Issue 3, May-June 1998 Page(s):6, 8, 10 - 17 Digital Object Identifier 10.1109/2943.667902

[44] P.Asmuth & J.F.Vestege- Optimal Network Structure for distribution systems with micro grids

[45] Ravi.G.Deshmukh & Raj Kiran V.Biloikar Optimization of Rural Electric methods- A comparative analysis of grid extension vs. Distributed generation

[46] R.Chedid, S,Saland, S.Karanki,M. Yehia & R.Al-Ali- Optimization of Electric Distribution Networks fed by conventional & Renewable Energy Sources -

[47] Renewable Energy for Rural livelihood –United Nations Development Programme project of the Government of India, Project Document-2003

[48] REPP(Renewable Energy Policy Project) Research Report- Rural Electrification with Solar Energy as a climate protection Strategy- Steven Kaufman

[49] Status of Renewable Energy & Energy Efficiency in South Asia- South Asia Background paper

[50] Sebitosi, A.B.; Pillay, P., White LEDS for rural lighting, Power Engineering Society General Meeting, 2003, IEEE,Volume 4, 13-17 July 2003 Page(s):

[51] Sebitosi, A.B.; Pillay, P.- Applications of advances in automotive electronics to rural electrification: the 42 V power-net for rural power distribution, Power Engineering Society General Meeting, 2003, IEEE, Volume 4, 13-17 July 2003

[52] Siyambalapitiya, D.J.T.; Rajapakse, S.T.K.; de Mel, S.J.S.; Fernando, S.I.T.; Perera, B.L.P.P.,Evaluation of grid connected rural electrification projects in

developing countries, IEEE Transactions on Power Systems ,Volume 6, Issue 1, Feb. 1991 Page(s):332 - 338

[53] Soler, R.; Thomas, F.; Dhaiby, N.-E.; Bakri, M., Optimizing the place of PV systems in rural electrification planning in Morocco, 2003. Proceedings of 3rd World Conference on Photovoltaic Energy Conversion,Volume 3, 12-16 May 2003 Page(s):2574 - 2577 Vol.3

[54] Stone, J.L.; Ullal, H.S.; Chaurey, A.; Bhatia, P., Ramakrishna Mission initiative impact study-a rural electrification project in West Bengal, India, , 2000. Conference Record of the Twenty-Eighth IEEE Photovoltaic Specialists Conference,15-22 Sept. 2000 Page(s):1571 - 1574

[55] Sabharwal, S., Rural electrification cost including transmission and distribution losses and investments, IEEE Transactions on Energy Conversion, Volume 5, Issue 3, Sept. 1990 Page(s):493 - 500

[56] Sen Gupta, D.P., Rural electrification in India: the achievements and the shortcomings, TENCON '89. Fourth IEEE Region 10 International Conference 22-24 Nov. 1989 Page(s):752 - 755

[57] Tani, T.; Kamiyacho, S.; Takahashi, M.; Semba, H.; Hashizaki, K.; Inoue, T.; Wade, H. A study of utilization of photovoltaics for rural electrification in the republic of Kiribati, Conference Record of the Twenty Fourth ; IEEE Photovoltaic Specialists Conference - 1994, 1994 IEEE First World Conference on Photovoltaic Energy Conversion, 1994., Volume 2, 5-9 Dec. 1994 Page(s):2399 - 2402 vol.2

[58] Tapanlis, S.; Kininger, F.; Klammer, J., A comparison of different approaches to rural electrification by PV, Proceedings of 3rd World Conference on Photovoltaic Energy Conversion, 2003, Volume 3, 12-16 May 2003 Page(s):2341 - 2342 Vol.3

[59] Thirault, D.; Besanger, Y.; Hadjsaid, N.; Almeida, A.; Huard, G., Ecoelectrify: a tool to design electric distribution systems for rural areas in developing countries, Power Engineering Society General Meeting, 2003, IEEE,Volume 4, 13-17 July 2003

[60] The Economics of PV Household Electrification- A report by World Bank

[61] Thiel, S.; Mostert, C.-H.; Enslin, J.H.R., Universal power electronic solution to low-cost rural electrification, AFRICON, 1996., IEEE AFRICON, Volume 1, 24-27 Sept. 1996 Page(s):335 - 340 vol.1

[62] T.H.Fazwi,K.F.Ali,S.M EL Sobki , Routing optimization of primary rural distribution feeders, IEEE transactions on power apparatus and systems, vol. PAS-101, may 1982

[63] TERI: Enhancing Electricity access in Rural Area through distributed Generation based on renewable energy- A policy Discussion forum base paper

[64] The business council for sustainable energy: USAID - Increasing Energy Access in Developing countries: Role of DG, May 2004

[65] Utility based off-grid rural electrification with renewable energy- ECOFYS

[66] Vincent S. Perez, Renewable power in emerging Countries: A business case for investing in renewable power in merging countries, May 2006

[67] Wallace, W.L.; Tsuo, Y.S., Photovoltaics for rural electrification in the People's Republic of China

[68] W.H Kersting , W.H Phillips ,Modeling and Analysis of rural electric distribution feeders, IEEE transactions on industry applications, Vol 28, No. 4/ August 1992

[69] Wind Power : A clean and Renewable supplement to the world's energy mix- Micheal Treadow, May 8, 2006

[70] Winrock International : Renewable Energy State of the Industry Report – May 2001

[71] Woodrow Clark, William Isherwood- Distributed Generation: remote Power Systems with Advanced storage technologies

[72] World Energy Council : Renewable Energy in South Asia – Status & Prospects- November 2000

[73] World Energy Council : The Challenge of Rural Energy Poverty in Developing Countries – October 1999

[74] Bulk Electric Supply and Distribution, Er. V.K Jain

[75] Electric Power Distribution, A.S Pabla

[76] Rural Electrification Corporation, India specifications and standards

[77] Electric Power Distribution System Engineering, T. Gonen

[78] Power Sub-Transmission and Distribution System- Prevailing Practices in India, Central Board of Irrigation & Power.

[79] www.REN21.net

[80] www.nrel.gov

[81] www.mnes.nic.in

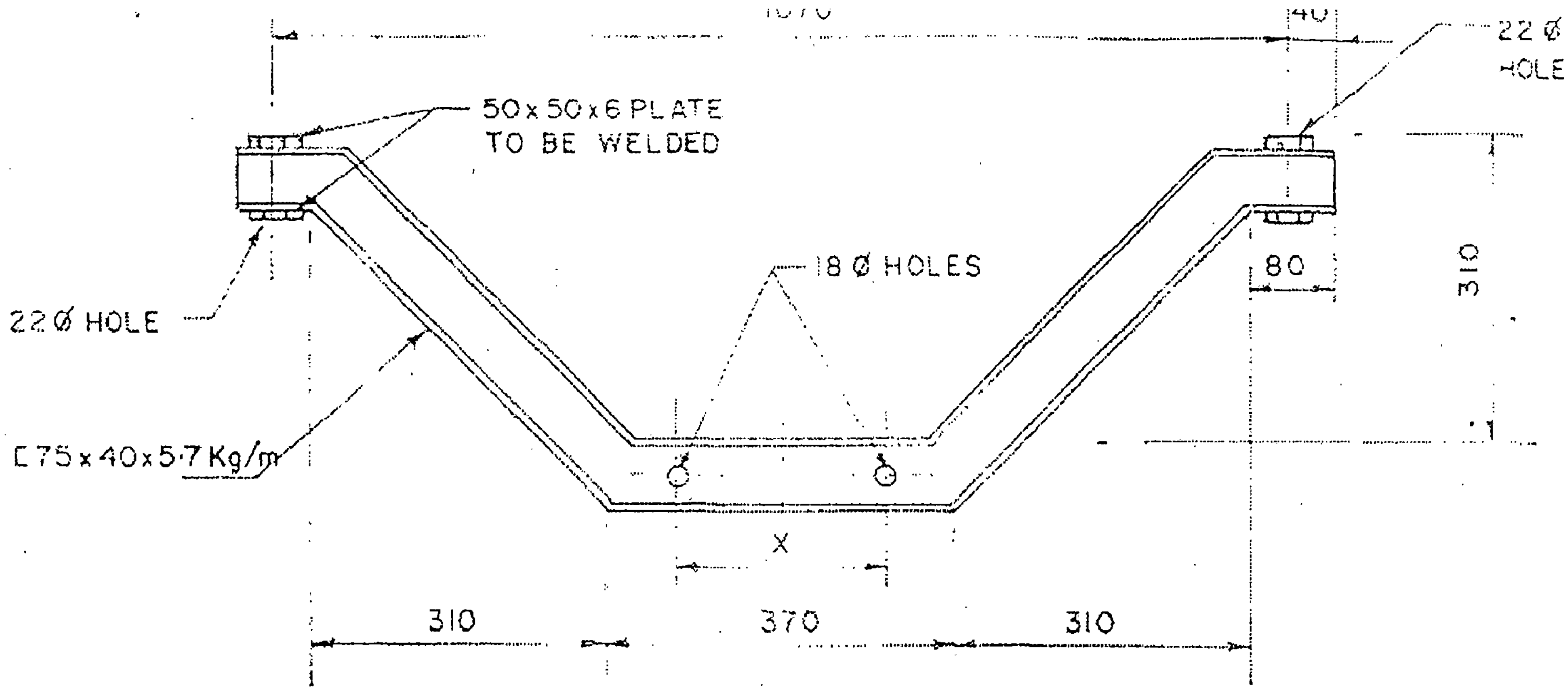
[82] www.uerc.in

[83] www.recindia.nic.in

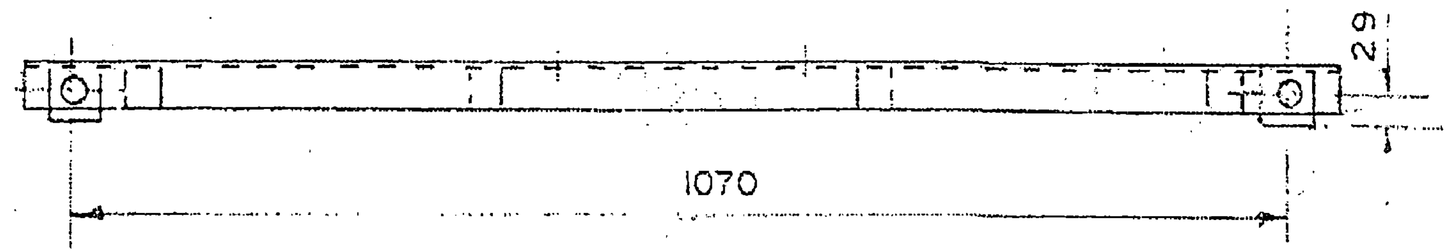
[84] www.eia.doe.gov

[85] www.localpower.org

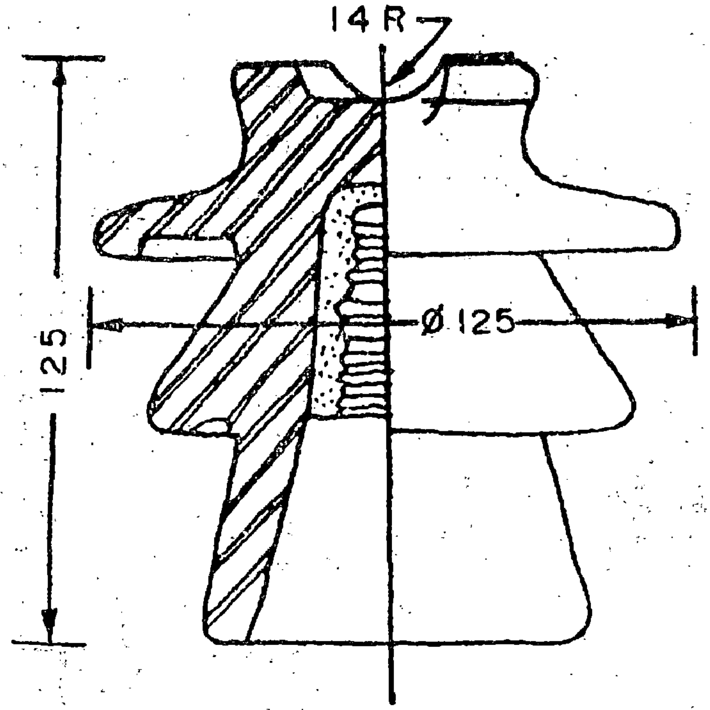
[86] www.eere.energy.gov



ELEVATION



PLAN



Spesification- (a) Insulator - 731- 1971
(b) Insulator fittings - IS 2486 (Part-I) 1971
IS 2486 (Part-II) 1974

:HNICAL DETAILS

Highest System Voltage in kV Rms 12

.) Wet Power Frequency withstand Test in kV Rsm... 35

.i) Power Frequency Puncture withstand Test in kV Rms....

r) Impulse Volteg withstand Test in Peak....75

Creepage Distances at the Highest System Voltage

(a) Normal and Moderatly Polluted Atmosphere in mm... 230

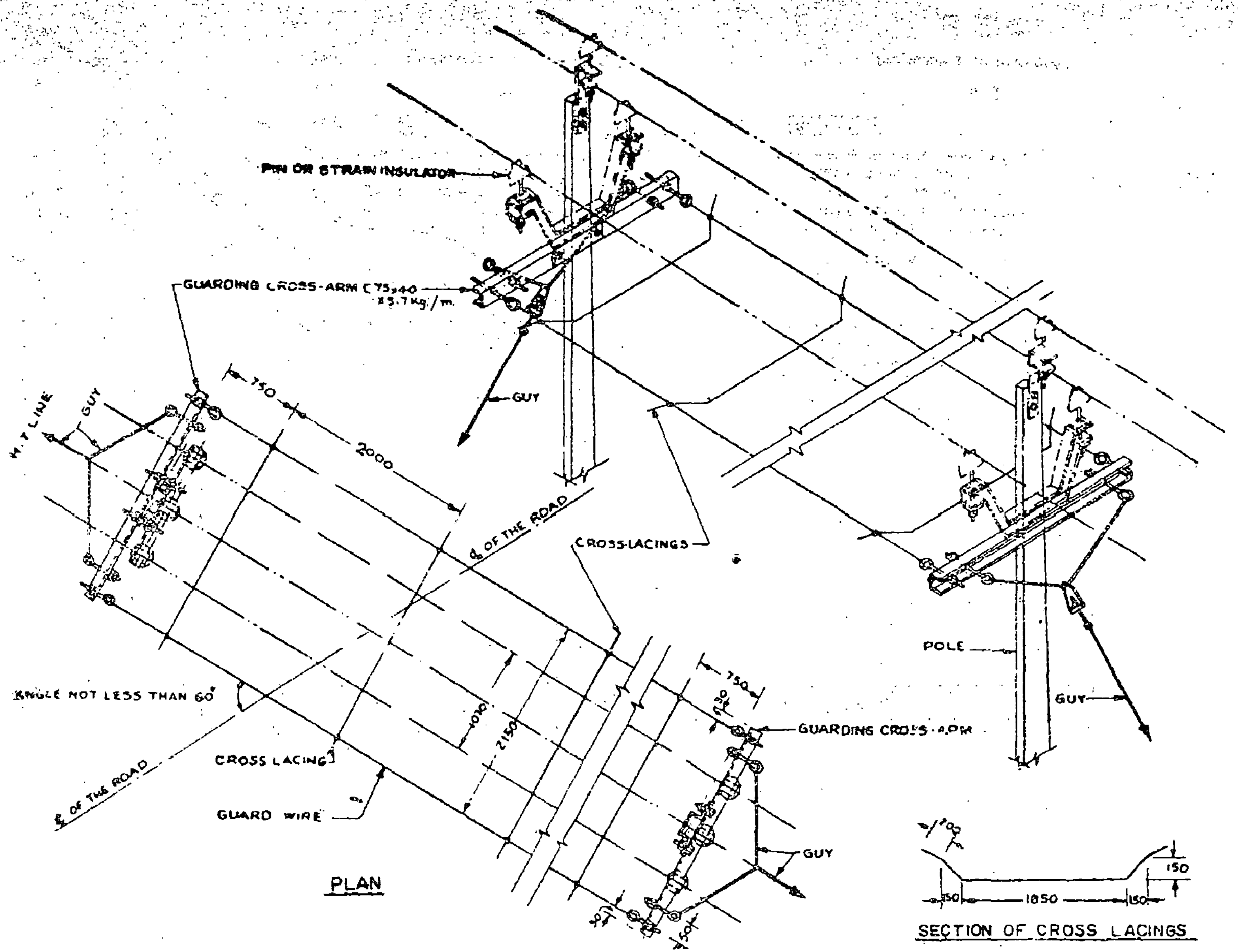
.) Minimum Failing Load in KN......5

.i) Store Code No. - H200713

.ii) Weight in Kg. 1.9 (Approx)

. DIMENSIONS IN MM.

11 kV Pin Insulator



REC

CONSTRUCTION STANDARD

A-1

NOTES

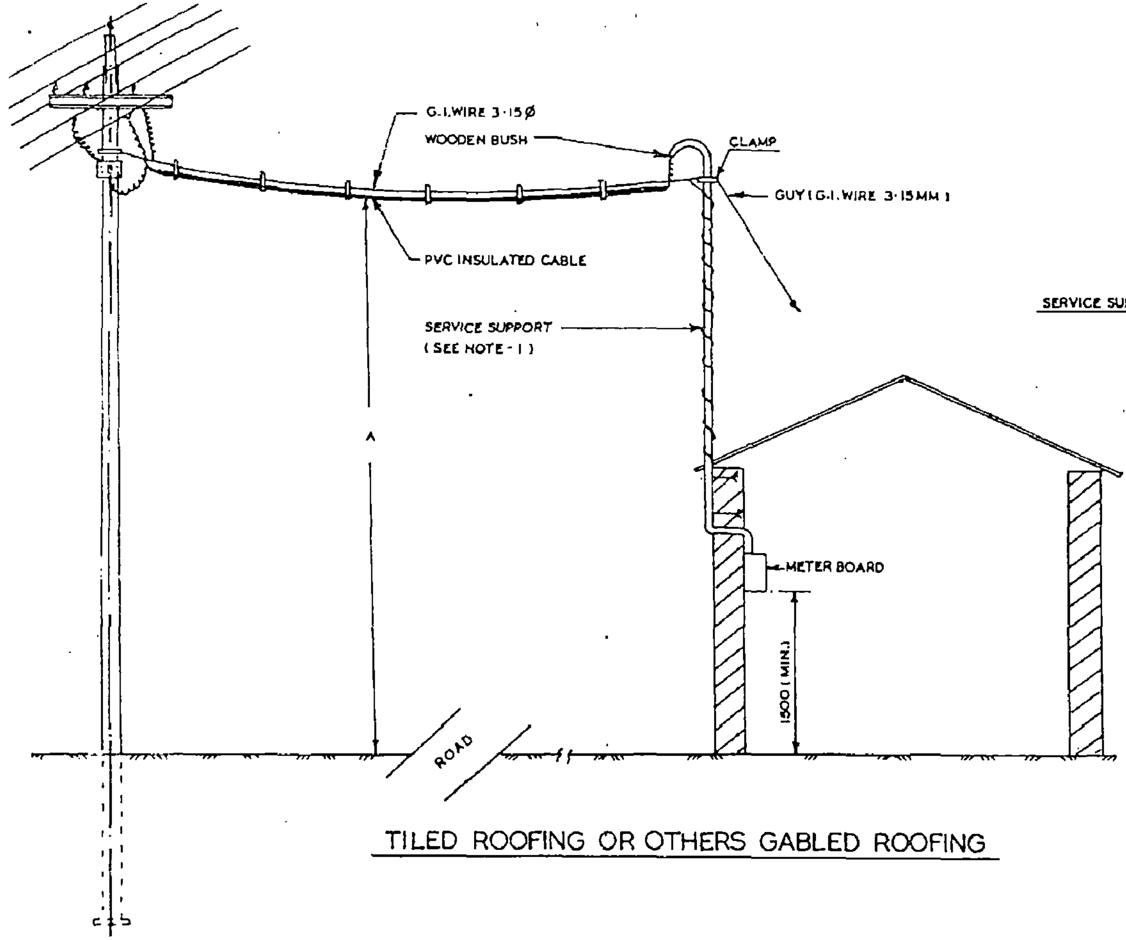
1. No. OF CROSS LACINGS TO SUIT THE REQUIREMENTS CROSS LACINGS BE PROVIDED FOR THE WIDTH OF THE ROAD PLUS ONE EACH NEAR THE SUPPORT
2. FOR CROSS LACINGS AAC, ACSR CONDUCTOR FROM SCRAP LENGTHS OR 3.15 mm G.I. WIRE CAN BE USED.
3. AS PER I.E. RULE 88 (3) THE GUARD WIRES SHOULD HAVE THE BREAKING STRENGTH NOT LESS THAN 635 Kg EITHER 4 mm G.I. WIRE OF MINIMUM STRENGTH 55 Kgf/mm² HARD QUALITY OR 5mm G.I. WIRE OF MINIMUM STRENGTH 33 Kgf/mm². SOFT QUALITY BE USED AS PER IS 280 1962
4. SPECIAL SUPPORTS MAY BE NEEDED TO ALLOW MINIMUM CLEARANCE FROM GROUND AS PER I.E. RULE NO. 77 i.e. 6.1 METRES & TO TAKE CARE OF ADDITIONAL WIND LOAD DUE TO GUARD WIRES.
5. STRUCTURES ON EITHER SIDE OF THE ROAD TO BE EARTHED
6. CROSSING ANGLE SHOULD NOT BE LESS THAN 60°

BILL OF MATERIAL	
GUARDING CROSS ARM	2
Y-GUYS	2
BACK CLAMPS	2
EYE BOLTS-16 mm ϕ	8
GUARD WIRES	AS REQD
EARTHING COMPLETE	2
BOLTS 16 mm ϕ	4

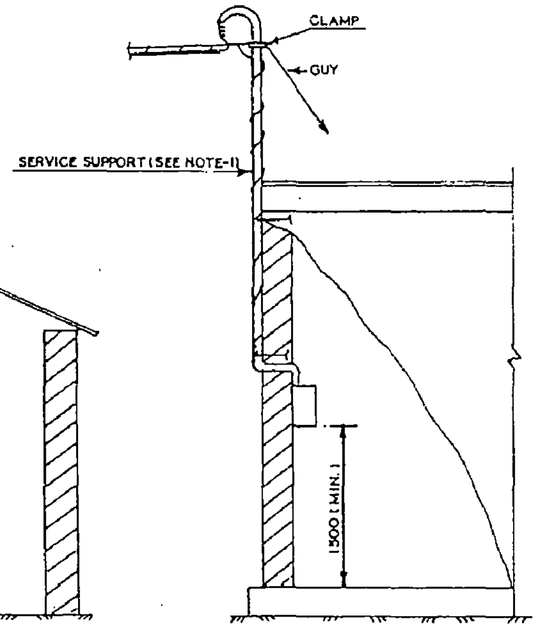
ALL DIMENSIONS IN mm UNLESS OTHERWISE INDICATED

11 kV Lines—Protective Guarding Across the Road. (All dimensions in mm unless otherwise indicated)

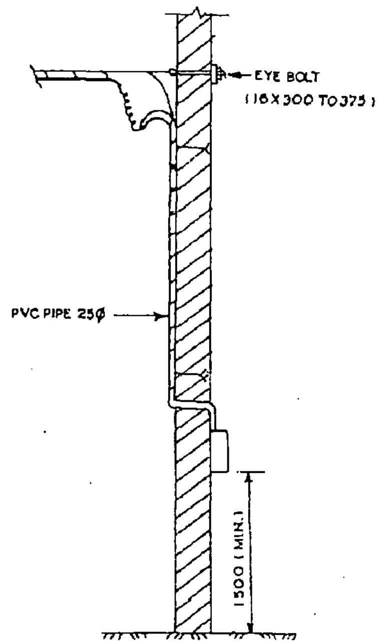
CONSTRUCTION STANDARD
H-I



TILED ROOFING OR OTHERS GABLED ROOFING



SINGLE STOREY - FLAT/R.C.C. ROOFING



MULTI-STOREY OR SINGLE STOREY BUILDING WITH HIGH ROOFING

TABLE - I

YPE AND SIZE OF SERVICE CABLES

TYPE	CONNECTED LOAD	SIZE
IN CORE (ARMOURED) C INSULATED BLE AS PER SPEC. 26/1983	UPTO 2KW	$2{\cdot}5 mm^2$
	ABOVE 2KW TO 4 KW	$4{\cdot}0 mm^2$

TABLE - II

TYPE / SIZE OF SERVICE SUPPORTS AND PERMISSIBLE SPANS

TYPE OF SUPPORT	SIZE OF SUPPORT	PERMISSIBLE SPAN IN METERS			
		ROAD CROSSING WITH GROUND CLEARANCE (A) ≮ 5·8M	ALONG THE ROAD WITH GROUND CLEARANCE (A) ≮ 5·5M	ALONG THE ROAD WITH RELAXED GROUND CLEARANCE (A) ≮ 4·6M*	ELSEWHERE WITH GROUND CLEARANCE (A) ≮ 4·0M
M.S. ANGLE WITH PVC PIPE	35X35X5 25 DIA.	N.R	N.R	35·0	35·0
M.S. ANGLE WITH PVC PIPE	50X50X6 25 DIA.	34·0	35·0	N.R	N.R
G.I. PIPE	20(I.D)	N.R	N.R	25·0	35·0
G.I. PIPE	25(I.D)	17·0	20·0	N.R	N.R
RIGID STEEL CONDUIT	25·0 (O.D) WALL THICKNESS = 2·00	N.R	N.R	25·0	35·0
RIGID STEEL CONDUIT	32 (O.D) WALL THICKNESS	17·0	20·0	N.R	N.R

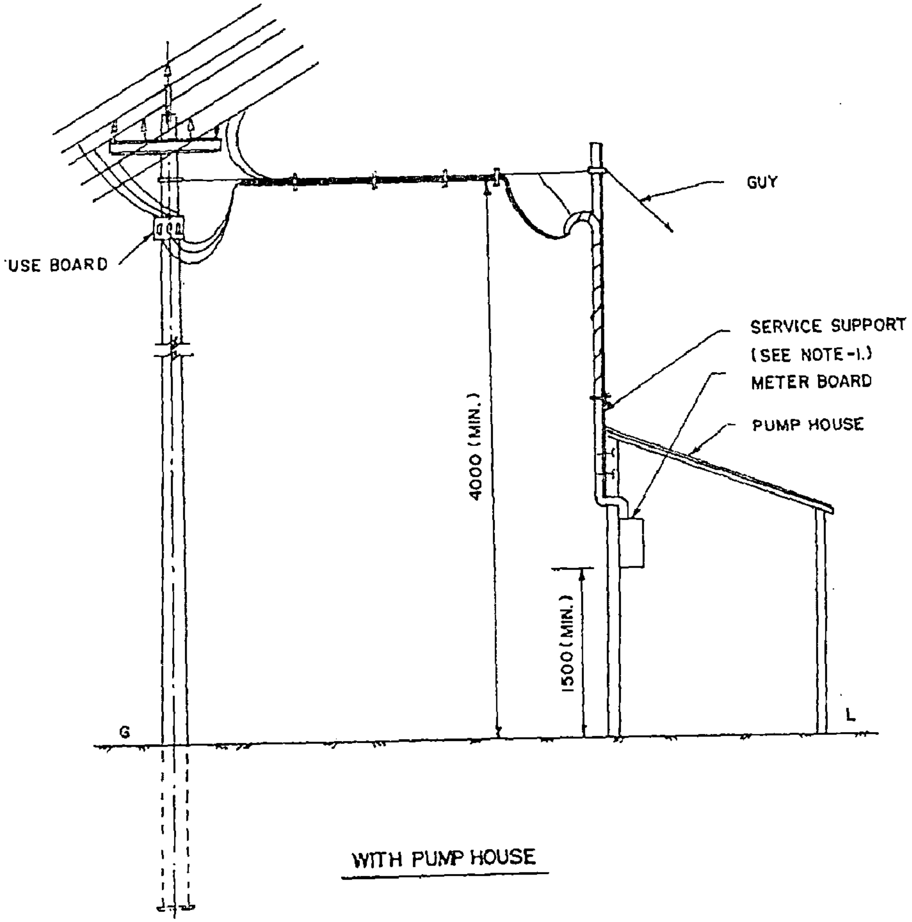
NOTES:-

1. SERVICE SUPPORT SHALL COMPRISE OF EITHER M.S. ANGLE (WITH PVC PIPE 25 DIA. CONFORMING TO IS: 2509 - 1973) OR G.I. PIPE (MEDIUM CLASS CONFORMING TO IS: 1161 - 1968) OR RIGID STEEL CONDUIT ("VERY HEAVY DUTY" HIGH PROTECTION CATEGORY WITH A MINIMUM YIELD STRESS OF 310 MP CONFORMING TO IS: 9537 (PART - I & II) - 1980 / 81.
2. BEARER WIRE TO BE USED WITH PVC INSULATED CABLE SHALL BE OF HARD QUALITY CONFORMING TO IS: 280 - 1978. SUITABLE CLIPS OR LASHING ROD AS PER REC SPECIFICATION NO. 25/1983 MAY BE USED FOR SUPPORTING THE CABLE WITH THE BEARER WIRE.
3. AS AN ALTERNATIVE TO THE USE OF SEPARATE G.I. WIRE FOR SUPPORTING THE CABLES, PVC CABLE WITH EMBEDDED BEARER WIRE AS PER REC SPEC. 27/1983 MAY BE USED. THIS IS PARTICULARLY USEFUL IN COASTAL AND POLLUTED AREAS WHERE CORROSION OF G.I. WIRE IS A PROBLEM.
4. CLAMPS TO BE MADE FROM 40X3 M.S. FLAT.

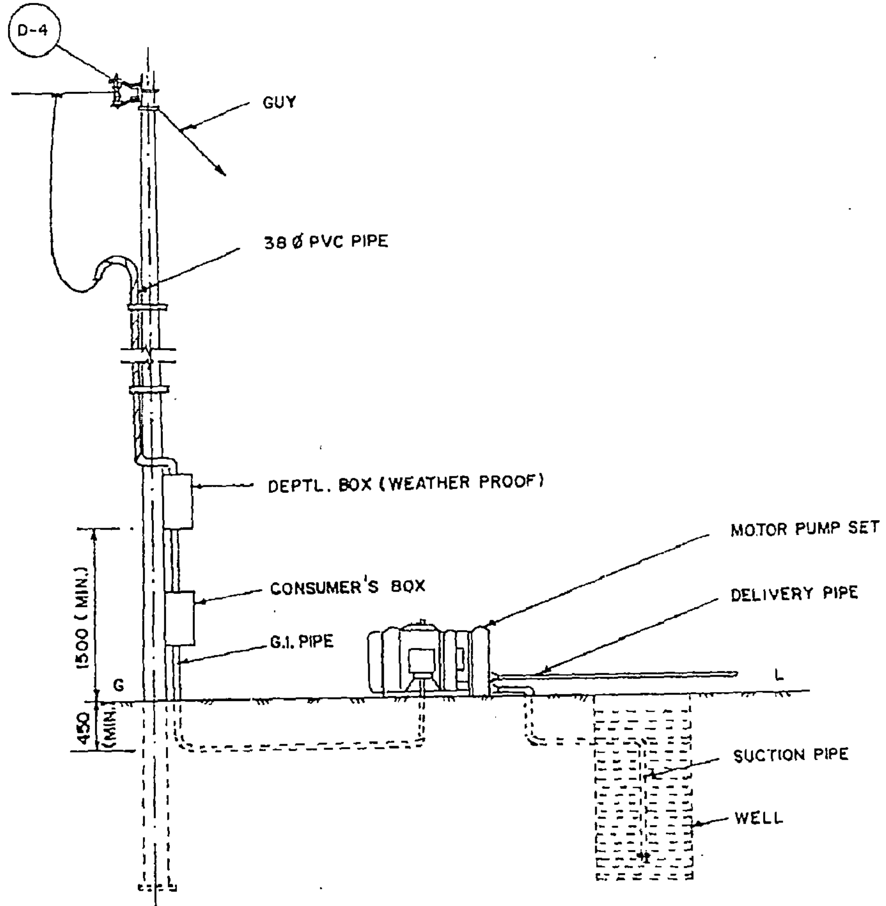
ALL DIMENSIONS ARE IN mm.

सर्विस कनैक्शन
सिंगल प्रावस्था
विद्युतरोधी तार

SERVICE CONNECTIONS
SINGLE PHASE
(INSULATED WIRE)



WITH PUMP HOUSE



WITHOUT PUMP HOUSE

TABLE-I

TYPE AND SIZE OF SERVICE CABLES

TYPE	CONNECTED LOAD	SIZE
CORE ?MOURED)	UPTO 2·2 KW (3 H.P)	2·5 mm²
INSULATED R REC- FICATION NO. 1983(2RUNS)	ABOVE 2·2 KW (3H.P) TO 3·7 KW (5 H.P)	4 mm²
CORE IOURED) NSULATED R REC- FICATION ?/1983	ABOVE 3·7 KW (5H.P) TO 7·5 KW (10 H.P)	6·0 mm²
	ABOVE 7·5 KW (10H.P) TO 11 KW (15 H.P)	10·0 mm²

TABLE-II

TYPE/SIZE OF SERVICE SUPPORTS AND PERMISSIBLE SPANS

TYPE OF SUPPORT	SIZE OF SUPPORT	PERMISSIBLE SPAN IN METERS
M.S. ANGLE WITH PVC PIPE	50X50X6 38 DIA.	21·0
G.I. PIPE	40 (I.D)	27·0
RIGID STEEL CONDUIT	50 (O.D) WALL THICKNESS 2·0	27·0

NOTES:-

1. SERVICE SUPPORT SHALL COMPRISE OF EITHER M.S. ANGLE (WITH PVC PIPE 38 Ø CONFORMING TO IS: 250-1973 OR G.I. PIPE (MEDIUM CLASS CONFORMING TO IS: 1161-1968) OR RIGID STEEL CONDUIT (VERY HEAVY DUTY.) HIGH PROTECTION CATEGORY WITH A MINIMUM YIELD STRESS OF 310 MPa, CONFORMING TO IS: 9537 (PT II)-1981
2. BEARER WIRE TO BE USED WITH PVC INSULATED CABLE SHALL BE OF HARD QUALITY, CONFORMING TO IS: 280-1978 SUITABLE CLIPS OR LASHING ROD AS PER REC SPECIFICATION NO. 25/1983 MAY BE USED FOR SUPPORTING THE CABLE WITH THE BEARER WIRE.
3. AS AN ALTERNATIVE TO THE USE OF SEPARATE G.I. WIRE FOR SUPPORTING THE CABLES, PVC CABLES WITH EMBEDDED BEARER WIRE AS PER REC SPECIFICATION NO. 27/1983 MAY BE USED. THIS IS PARTICULARLY USEFUL IN COASTAL AND POLLUTED AREAS WHERE CORROSION OF G.I. WIRE IS A PROBLEM.
4. CLAMPS TO BE MADE FROM 40X6 M.S. FLAT
5. THE MAXIMUM SPANS INDICATED IN TABLE II ARE BASED ON THE MINIMUM GROUND CLEARANCE OF 4·0 M AS SHOWN. HIGHER GROUND CLEARANCES, AS APPLICABLE IN THE CASE OF ROAD CROSSING OR ALONG THE ROAD, ARE NOT ENVISAGED IN THIS CONSTRUCTION STANDARD.

ALL DIMENSIONS ARE IN mm.

सर्विस कनेक्शन
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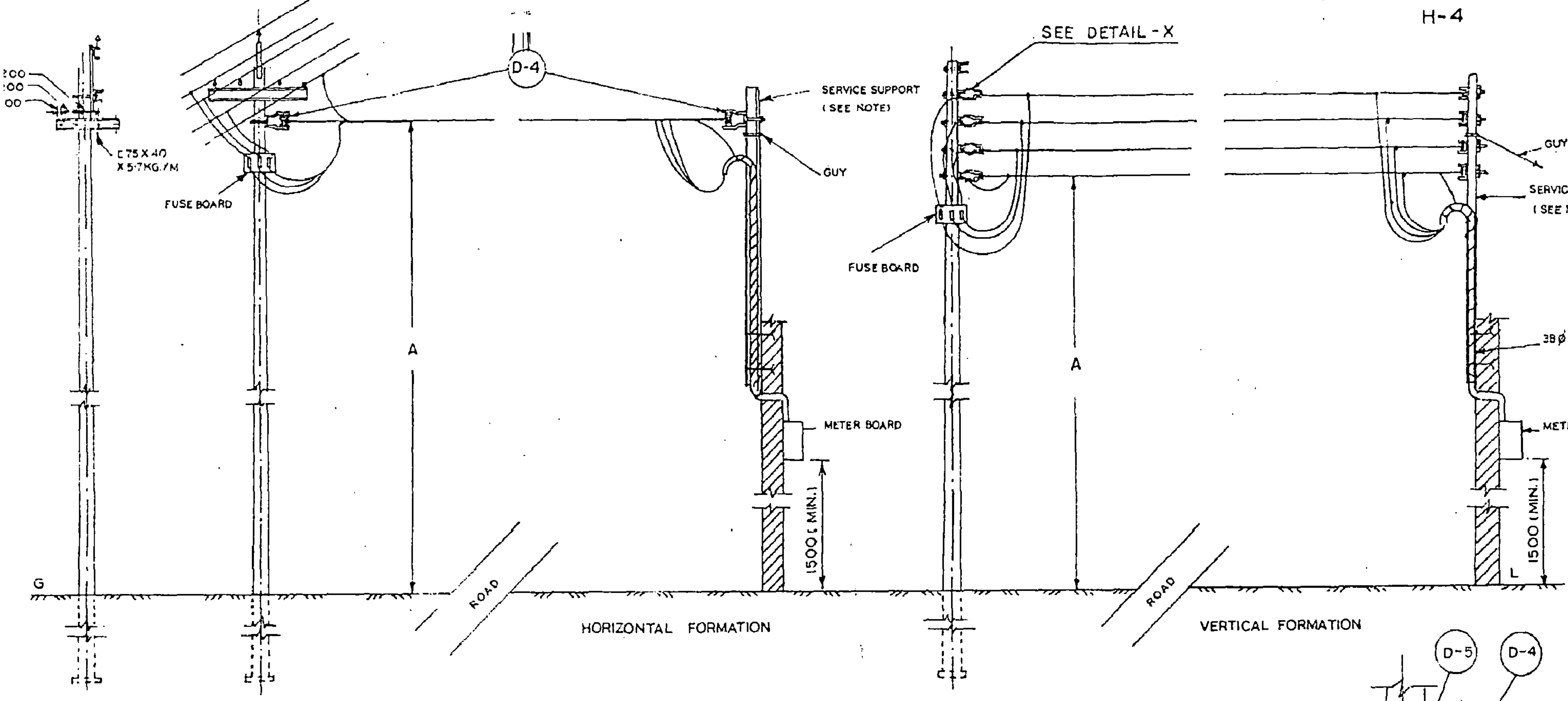
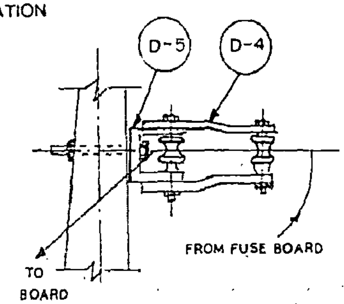
कृषि
SERVICE CONNECTIONS
THREE PHASE

REC
CONSTRUCTION STANDARD
H-4





DETAIL - X

TABLE - I

TYPE AND SIZE OF SERVICE CABLE

TYPE	CONNECTED LOAD	SIZE
IN CORE RMOURED) INSULATED LE AS PER SPEC. NO 1983 RUNS)	UPTO 2.2 KW (3H.P)	$2.5 mm^2$
	ABOVE 2.2KW (3H.P) TO 3.7 KW (5H.P)	$4.0 mm^2$
R CORE RMOURED) INSULATED LE AS PER SPEC. NO 1983	ABOVE 3.7KW (5 H.P) TO 7.5KW (10H.P)	$6.0 mm^2$
	ABOVE 7.5KW (10 H.P) TO 11 KW (15H.P)	$10.0 mm^2$

TABLE - II

TYPE / SIZE OF SERVICE SUPPORTS AND PERMISSIBLE SPANS

FORMATION	TYPE OF SUPPORT	SIZE OF SUPPORT	PERMISSIBLE SPAN IN METRES: ROAD CROSSING WITH GROUND CLEARANCE (A) ≮ 5.8M	ALONG THE ROAD WITH GROUND CLEARANCE (A) ≮ 5.5M	ALONG THE ROAD WITH RELAXED GROUND CLEARANCE (A) ≮ 4.6M *	ELSEWHERE WITH GROUND CLEARANCE (A) ≮ 4.6M
HORIZONTAL	M.S ANGLE WITH P.V.C. PIPE	50X50X6 38 DIA.	N.R	N.R	31.0	31.0
	M.S.ANGLE WITH PVC PIPE	65X65X6 38 DIA.	21.0	25.0	NR	NR
	G.I.PIPE	40	15.0	17.0	35.0	35.0
	RIGID STEEL CONDUIT	50(O.D) WALL THICKNESS=2.0	15.0	17.0	35.0	35.0
VERTICAL	M.S.ANGLE	50X50X6	N.R	N.R	19.0	19.0
	M.S.ANGLE	75X75X6	20.0	24.0	NR	NR
	G.I.PIPE	40	NR	N.R	24.0	24.0
	G.I.PIPE	50	21.0	24.0	N.R	N.R
	RIGID STEEL CONDUIT	50 (O.D.) WALL THICKNESS=2.0	N.R	N.R	24.0	24.0
	RIGID STEEL CONDUIT	63 (O.D) WALL	21.0	24.0	N.R	N.R

NOTES:-

1. SERVICE SUPPORT SHALL COMPRISE OF EITHER M.S.ANGLE (WITH PVC PIPE 38 DIA. CONFORMING TO IS: 2509-1973) OR G.I. PIPE (MEDIUM CLASS CONFORMING TO IS: 1161-1968) OR RIGID STEEL CONDUIT ('VERY HEAVY DUTY HIGH PROTECTION') CATEGORY WITH A MINIMUM YIELD STRESS OF 310 MPa CONFORMING TO IS: 9537 (PART-II-1981)
2. CLAMPS TO BE MADE FROM 40X6 M.S.FLAT.

ALL DIMENSIONS ARE IN mm.

सर्विस कनेक्शन
3-प्रावस्था औद्योगिक
(अनावृत तार)

SERVICE CONNECTIONS
3-PHASE INDUSTRIAL