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A REVIEW OF MINI-GRID USED FOR ELECTRIFICATION IN RURAL AREA

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Abstract: This paper presents the overview of mini-grid technology and recent development of mini-grid in the field rural electrification in the last years. there are many developing country which have renewable energy and hybrid energy based mini-grid. The mini-grid is found to be very effective and economical for the electrification of rural area in comparison with the grid extension and other conventional technology like diesel generator and power storage devices. There are lot of problems in this technology like voltage instability problem, failure of synchronization etc. In this field a lot of research is required for the mitigation of the technical problems occurs in mini-grid.

Keywords: Mini-grid, Hybrid mini-grid, Rural electrification, decentralized generation, Renewable energy

I. Introduction

The world constraint of fossil fuels reserves and the ever rising environmental pollution have provoked strongly during last few decades the development of renewable energy sources (RES). The need of having available sustainable energy systems for replacing gradually conventional ones demands the improvement of structures of energy supply based mostly on clean and renewable resources [1]. 80% of global population lives in developing areas. India is one of the countries where the present level of energy utilization, by world standards, is very low [2].

The challenges for the electrification in the India are the rural areas or location, they are away from the load centre. There are two methods of supplying electricity to these rural areas:

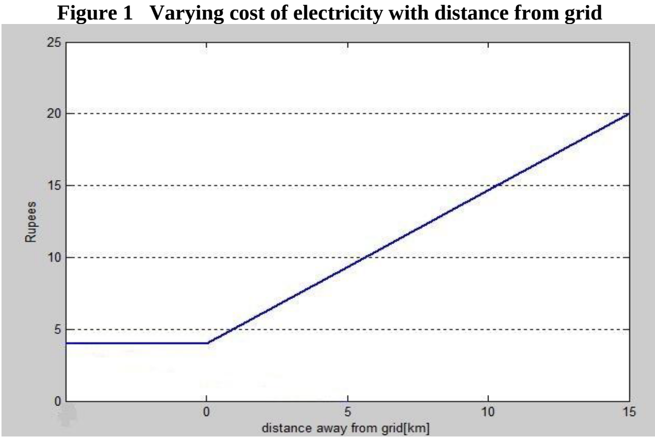
1) With the help of existing grid, near to that area.

2) With the help of decentralized generator [3].

The transportation of fuel like coal, oil is ether not possible or not economical because these villages may locate in the rural area like forest, desert, and hills. Therefore with the help of renewable energy available in that area.

The extension of grid is not possible in all these unelectrified village because with the increase in distance of grid, the cost of electricity is increases very much as shown in fig. 1. So it is not feasible [4].

Figure 1 Varying cost of electricity with distance from grid



Mini-grids are a new concept that is currently being developed in response to the problem of integrating renewable energy into the existing electrical grid. Mini-grids can be defined as a set of electricity generators and, possibly, energy storage systems interconnected to a distribution network that supplies the entire electricity

demand of a localized group of customers. A key feature of mini-grids is that they can operate autonomously with no connection to a centralized grid. However a mini-grid may be designed to interconnect with the central grid and operate under normal conditions as part of the central grid with disconnection occurring only if required to maintain power quality (e.g. if there is a central grid failure). Alternatively, a mini-grid may be designed to operate autonomously in a remote location with the option to connect to the central grid when grid extension occurs [5].
This review paper comprises of total VI sections, the gaps found after the going through the literature of mini-grid is given in section II, we described problems that occurred during the operation of mini-grid in section III, the case study of some sites are described in section IV, compensation of mini-grid connected load is explained in the V section

II. Gaps found in the litreture of mini-grid

i. There is no standard available for Mini-grid.
ii. Unbalanced load or sudden increase in load causes voltage drop take place in network.
iii. Sizing and Placing of voltage compensation device i.e. capacitor is difficult.
iv. Fault analysis of minigrid is not described in details.
v. Congestion analysis of mini-grid is not done.

III. Problems in mini-grid

Glenn et al. [6] Mini-grids hold great potential as a transition path for our current electricity grids- as a way to moving towards adaptable, dynamic power systems with a diversity of generation and complex power flows, but using relatively traditional control methods. In short, by abstracting the need to control large numbers of distributed devices away from the centralised electricity system and moving the locus of control to within the minigrid, we simplify many of the control challenges faced. Mini-grids are not without their challenges though, and issues remain regarding dealing with dynamic behaviour such as motor start up currents, or fault detection, particularly in islanded mini-grids operating from a large number of relatively small generation devices.
The voltage drop in mini-grids during the peaks loads is very high in some cases is the voltage drop at tail end is around 36% [7].
The parallel operation of two or more than two generators is a complex process and needs advance control system which was not available in existing micro-hydro plants (small power plant) in the isolation mode.[8]

IV. Case studies

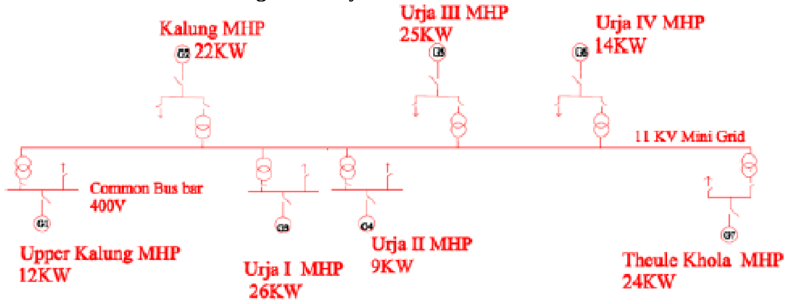
There are seven micro-hydropower plants in the village of Nepal ranging from 9 kW to 26 kW with total output power of 132 kW are operated on standalone and then they was connected to mini-grid power system of length approximately 8 km operating at11 kV with ACSR Rabbit conductor for power transmission. The details of the plants with their locations, installed capacity and beneficiary households are presented in Table I.

Table I: Details of the Micro-hydropower plants [8].

.S.No.	Name of Plants	Location	P_{kW}	HHs
1	Theule Khola MHP	Sarkuwa	24	290
2	Kalung Khola MHP	Paiyun	22	230
3	Urja Khola I MHP	Rangkhani	26	250
4	Urja Khola II MHP	Rangkhani	9	120
5	Upper Kalung Khola MHP	Paiyun	12	120
6	Urja Khola III MHP	Paiyun	25	210
7	Urja Khola IV MHP	Damek	14	140

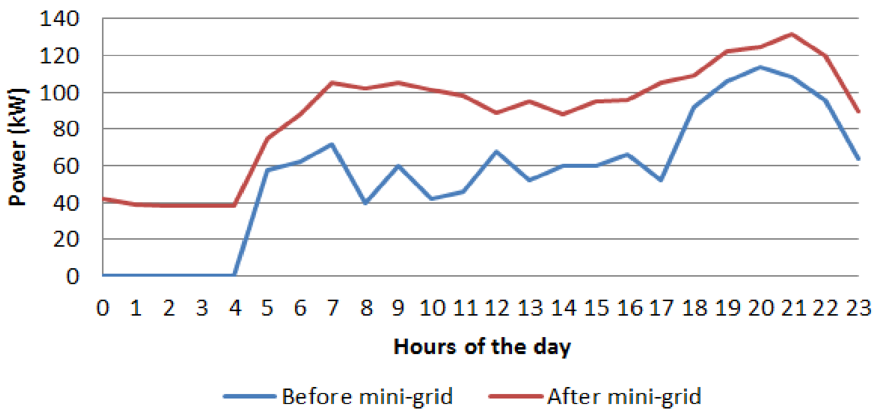
The layout of the Mini-Grid with axial network is given in the Fig. 2 which shows the arrangements of bus bar, transformer, breakers, 11 kV transmission line and the installed capacity of the individual Micro Hydropower Plants [8].

Figure 2 Layout of the Mini-Grid.



After mini-grid the utilization factor has risen abruptly from 42% to 67% as shown in Fig. 3.

Figure 3 Average hourly load curve of mini-grid.



The design of mini grids of nine SHP plants located in the Bageshwar district of Uttarakhand running in isolated mode only for 8 hrs/day wasting the energy of 16 hrs/day. Based on system layouts, transmission routing, line length and selection of conductor, 5 different alternates of mini-grids were developed to connect these SHPs together as well as with the nearby 33 kV grid substations located at approximately 15, 17 and 9 km from nearby SHPs in order to improve the load factor[9].

Table 2 Location of SHPs sites[9]

S. No.	Name of SHPs, Existing S/S	Installed capacity	Block	Longitude(E) (Approx.)	Latitude(N) (Approx.)
1.	Kanolgad	150 kVA	Kapkote	79°46’00’’	29°56’00’’
2.	Lamabagad	200 kVA	Kapkote	79°45’19.6’’	29°57’17.4’’
3.	Toil	62.5 kVA	Kapkote	79°53’00’’	30°06’00’’
4.	Leti-I	62.5 kVA	Kapkote	80°03’00’’	30°01’00’’
5.	Leti-II	62.5 kVA	Kapkote	79°49’30’’	30°04’00’’
6.	Lathi- I	125 kVA	Kapkote	80°04’00’’	29°55’30’’
7.	Lathi – II	125 kVA	Kapkote	80°03’00’’	30°02’00’’
8.	Ratmoli	62.5 kVA	Bageshwar	79°51’00’’	29°46’00’’
9.	Satyeshwar	62.5 kVA	Bageshwar	79°49’00’’	29°46’00’’

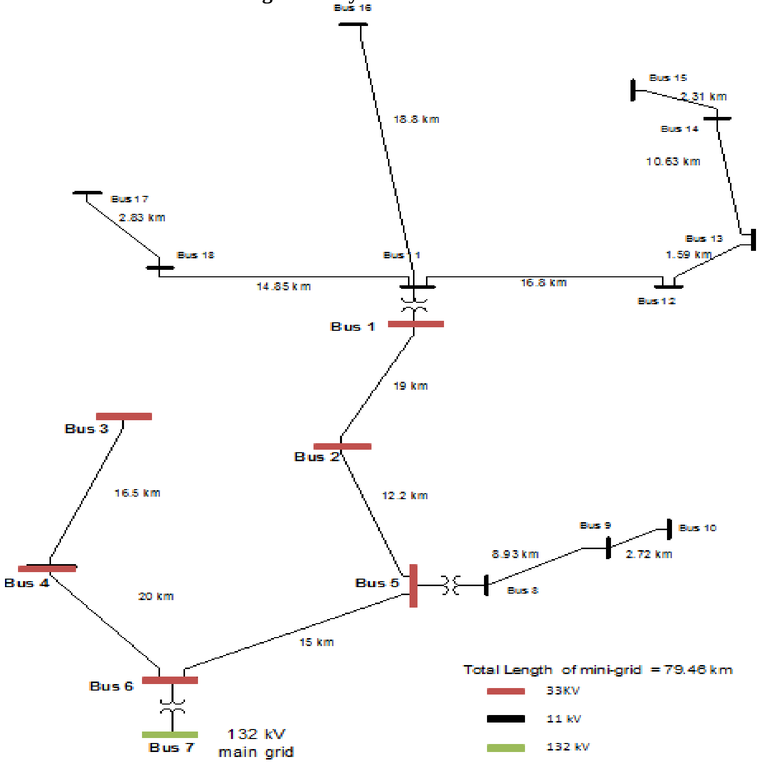
The five alternative are proposed for these SHP stations to interconnected with the mini-grid and variable annual cost of all the alternatives are given in Table 3.

Table 3 Total capital and variable cost for all five alternates [9]

Network connection	Length (km)	capital cost (Rs in lacs)	annual interest 12% (Rs in lacs) (a)	depreciation 1% (Rs In lacs) (b)	O&M (Rs in lacs) 1.50% (c)	variable annual cost (a+b+c)
Alternate - I	105.47	369.145	44.2974	3.69145	5.537175	53.526025
Alternate - II	125.13	437.955	52.5546	4.37955	6.569325	63.503475
Alternate - III	89.63	313.705	37.6446	3.13705	4.705575	45.487225
Alternate - IV	100.26	350.910	42.1092	3.5091	5.26365	50.88195
Alternate - V	79.46	278.110	33.3732	2.7811	4.17165	40.32595

So the optimized Alternate is V. As this line is the shortest among all the alternatives, so minimum capital cost for this line. Since total annual energy loss in this system is highest. the layout of V alternative is shown in Fig 4.

Figure 4 Layout of Mini-Grid.



V. Compensation of mini-grid connected load

Methods of improving the voltage drop in the mini-grid [3]:

i. Increase the voltage of transmission to reduce the I^2R losses. However it is not feasible in all the cases.
ii. Redistribute load and straighten feeders.
iii. Increase the size of conductor.
iv. Install feeder in parallel in overloaded section.
v. Install new feeders.
vi. Use switched shunt capacitor.
vii. Install a new substation.

However the installing of new substation is the last choice and shunt capacitor is found to be very effective in low voltage network [10].

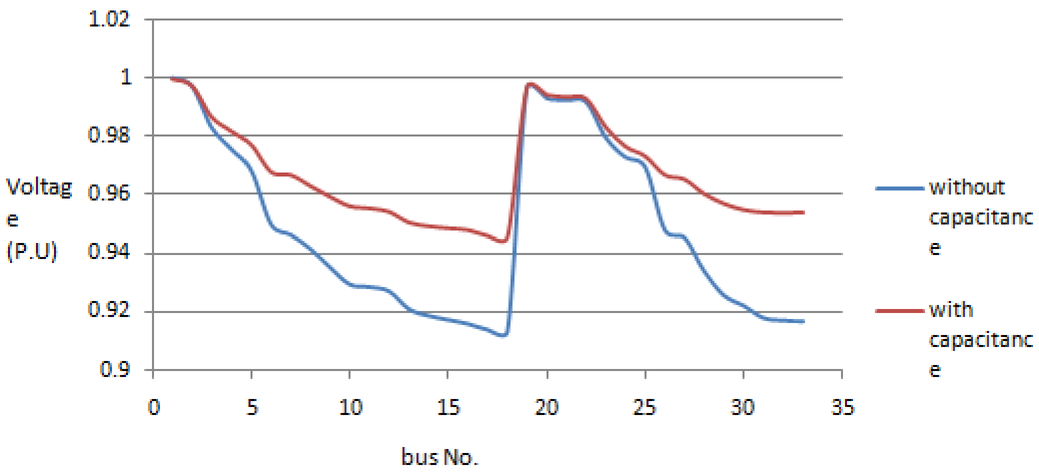
IEEE 13 and 33 bus radial distribution test system is used as the load connected to the load bus of mini-grid. These load bus systems are taken from IEEE standards. Mini-grid supplies the required power to the load. by performing the load flow analysis of mini-grid connected load by backward and forward sweep method, the bus voltage of 13 bus is shown in Table 4 [11].

Table 4 Bus voltage of 13 bus system

NODE NO.	MAGNITUDE (p.u.)	ANGLE (Degree)	NODE NO.	MAGNITUDE (p.u.)	ANGLE (Degree)
1	1	0			
2	0.994621	-0.300425	8	0.988034	-0.739442
3	0.993077	-0.414712	9	0.991497	-0.531479
4	0.992158	-0.482459	10	0.991359	-0.541958
5	0.989256	-0.647319	11	0.991338	-0.54362
6	0.988856	-0.677687	12	0.988702	-0.689289
7	0.98845	-0.708309	13	0.988678	-0.691172

In 13 bus system it is found that the voltage at buses is under acceptable limit as shown in Table 4 and there is no need of capacitor for voltage compensation. The bus voltage of 33 bus system is not in the acceptable limit so there is a need of compensation. The reactive power compensation is done by using switch shunt capacitor and then the voltage comes in the acceptable limits. The fig. 5 shows the bus voltage of 33 bus system with and without compensation [11].

Figure 5 Comparison of Bus voltage with and without capacitor



VI. Discussion and conclusion

A lot of research is needed in future for the economic operation and installation of mini-grid, So that some standards can be made Mini-grid can be connected to main Grid (Central grid, state Grid etc.) to provide the stability, to meet power deficit and to transfer extra power to the grid. With the help of mini-grid the local energy available in any area can be transferred from one point to other. By the use of switch shunt capacitor for providing reactive power compensation is found to be very effective in these low power network.

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