OPTIMIZED DESIGN OF MINI-GRID SYSTEM FOR HILLY REGION

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Abstract: *In order to provide a continuous and reliable power to rural areas where grid extension is either very costly or not possible, formation of a Mini-grid will be very effective solution. In hilly regions of India, hydro power potential is available, but it is not being completely utilized for power generation till date due to unavailability of the grid. This paper presents an optimized design of a Mini-grid system where nine micro hydro power stations (MHPs) of Bageswar district are selected which are connected with two sub stations , load Centres ((because all MHPs are spread in two blocks Kapkote and Bagheswar so two substations are considered). These MHPs work only for 8 hours in a day, and for remaining 16 hours, power generation is wasted. The excess generated power from these MHPs is transferred to available load centres or grid by interconnecting them. However, interconnection of MHPs and load centres is costly because of their demographic situations. These plants are situated in hilly area so the shortest path may put more mechanical stress on the line compared to the other possible path. That would affect the life of the line, and finally reliability of system. The other possible path would increase the line length and finally affect the cost of the project. Hence, an optimization needs between the cost of project and reliability of the system. This paper is an effort to develop a method for optimization of interconnecting lines between MHPs/SHPs for hilly areas by using Genetic Algorithm (GA). Distances between MHPs, distances between substations and MHPs, elevation of MHPs and substations, highest and lowest elevation in any path, and path profile by placing the locations of different MHPs and sub-stations measured through GOOGLE EARTH. By using these data, reliability in terms of interruption time has been calculated.*

Key words: *Distributed Generation (DG), Genetic Algorithm (GA), Google Earth (GE), Mini-Grid (MG), Micro Hydro Power Station (MHPs).*

1. Introduction

The different sources of energy are hydro, thermal, nuclear and non-conventional energy resources like wind, solar and biomass, Small/Micro Hydro Power plants, etc. It has been proved that electrical power consumption is a good parameter for measurement of economic growth and prosperity of any country. Developed countries have better energy consumption as compared to developing countries like India, where generation is very less in Comparison to demand. According to census 2011, around 70% population is still living in rural areas where access of power is very less or not possible. Local population mainly depends on kerosene for lighting and on woods for making food. Even now, some villages are not connected to our power system. Ministry of power has set a goal to increase per capita energy consumption and availability of power for all.

Some remote village cannot be connected to the national grid as the grid extension is very costly. According to a report from the International Energy Agency, the electrical network is technically within reach of 90% of the population, but only 43% are actually connected because people cannot afford the cost of connection. In these scenarios, effective utilization of renewable energy or distributed generation is the only option available for electrification of these villages. Mini-grid formation by using small energy generating stations is a good option for rural electrification [1, 2]. A mini grid system is an electricity distribution network operating typically below 11 kV and its capacity is limited to 10 kW to 10 MW [3, 4]. The first solar mini grid was commissioned in 1996 in Sunder bans Islands. Now around 5000 villages have been covered through mini-grids [5]. By connecting two or more hydro units, one Mini-Grid may be formed. A mini-grid system can be either isolated or grid-connected [6]. Different types of Mini-grid connections are discussed in literature [7]. Biomimetic of complex energy systems helps to improve the design of Power system [8]. Mini-grid system size and configuration is discussed by Werner and Breyer after studying 155 Mini-grid systems [9]. On the basis of the types of coupling used, the mini-grids are classified into three categories:[10, 11].

A. Mini-Grid with DC coupling: In this type of coupling, electrical energy generated from different sources like wind, small hydro, diesel is first converted to DC by using an AC/DC converter and electrical energy from solar is directly fed to the DC bus. AC load is supplied through a DC/AC inverter and DC load is supplied directly. A battery is connected to the DC load bus through a bidirectional DC to DC converter, which will charge and discharge according to load to avoid overcharging.

B. Mini-Grid with AC coupling: In this type of coupling, DC generating components connect with bus through an inverter and AC generating components are connected through an AC/AC converter used for stable coupling. A bidirectional master inverter is used to control the energy supply for AC loads and the battery charging. Electrical power to DC load can be supplied through the battery.

C. Mini-Grid with DC/AC coupling: In this type of coupling, AC generating buses connect to AC buses through an AC/AC converter. DC generating sources are connected to AC buses through an inverter. Power to DC load can be supplied by a battery, and AC load can be supplied through an inverter.

For low voltage transmission systems, grid network, three phase three wire, mesh bus system configuration would be the reliable choice for Mini-Grid system [12-14]. Table 1 lists the detail International Standards for a Mini-Grid [15].

Table 1
International Standards for a Mini-Grid

Standards	Explanation	Comments
IEC62257-1:2003 Part 1	General introduction to rural electrification	It introduces general considerations on rural electrification and rural electrification projects specification for the setting up of low voltage renewable energy and hybrid systems.
IEC62257-2:2004 Part 2	From requirements to a range of electrification systems	It proposes a methodological approach for the setting up and carrying out of socio-economic studies as part of the framework of decentralized rural electrification projects. It provides some structures and technical solutions that could be recommended.
IEC 62257-3:2004 part 3	Project development and management	It proposes a framework for project development and management and includes recommended information that should be taken into consideration during all steps of the electrification project. It also comments on responsibilities involved in the implementation of rural power system.
IEC 62257-4:2005 part 4	System selection and design	It provides a method for describing the results to be achieved by the electrification system independently of the technical solutions that could be implemented.

In mountain areas, large amount of rivers and streams are present. Their flowing water has large potential which can be harnessed and used to generate electricity. However, the grid extension in mountain area is more costly and large hydro is not economically and technically viable due to unavailability of sufficient potential. In such case small hydro or micro hydro is a good option to supply power to local communities in a reasonable price. Many small hydro power plants have been constructed and their power is mainly used for lightening purpose. During night time, these plant feed power to the consumer, but in day time power is not required for them. So individual MHP operates only for 8 to 10 hours, remaining time, these plants do not operate. If, these plants get interconnected, then rest of the energy can be utilized. For interconnecting these plants and load centres several path and configuration are possible. Several intelligent techniques are reported in the literature for possible cost effective and reliable interconnection of plants [16-18]. In this paper GA has been used to obtain an optimum and reliable interconnected structure by using the locations of MHPs and substations. GA is a search technique, which is based on the process of natural selection. GA has a broad application area such as in bio-informatics, chemistry, manufacturing, physics, economics and engineering etc. [19-21].

2. Site Selection and Mapping

The available generating capacity of an island mini-grid is limited. This creates a serious problem in detecting fault conditions in an island Mini-grid. Some electrical loads such as motors have large start-up current so that protection devices may consider it fault current and get tripped [22-24]. The inverters for grid connection should be designed according to standards AS4777 and IEEE1547. If the detected grid voltage and frequency vary outside a range specified by the utility, the inverter must be disconnected from the AC supply within two seconds. To design a Mini-grid, selection of site and preparation of map of that area is very important task.

2.1 Site Selection

In site selection for design of Mini-grid, four basic conditions are needed to verify, which are-

i. Ability of villagers to pay.
ii. Presence of a committed organization and motivated leadership.
iii. Availability of a power supply.
iv. Not to pose any obstacles to the implementation of a mini-grid.[25]

Mini-grid formation is a good option in mountain area because in this area grid extension is a very costly. In mountain areas, good hydro potential is generally available. So there is good scope of development of MHPs and SHPs. In this work 9 MHPs of Bageshwar district of Uttarakhand which are running in isolated mode of operation are selected for formation of Mini-grid. They have been operated for 8 hours per day and remaining 16 hour hydro energy is wasted. After grid installation this energy can be supplied to the main grid or other load centres. Fig. 1 [26] shows the Map of Uttarakhand in India whereas the enlarged view of Uttarakhand is shown in Fig. 2 [27]. After selection of area, data about the location of MHPs and substation needed to be collected. The location of MHPs and substations which is to be interconnected from Mini-grid is given in Table 2 [28].

Fig. 1. Map Of Uttarakhand in India

Fig.2. Enlarged view of Uttarakhand

Table 2
The Location of MHPs and Substations

S. No.	Name of SHPs, Existing S/S	Installed capacity	Block	Longitude(E) (Approx.)	Latitude(N) (Approx.)
1.	Kanolgad	100 kW	Kapkote	79°46’00’’	29°56’00’’
2.	Lamabagad	200 kW	Kapkote	79°45’19.6’’	29°57’17.4’’
3.	Toil	62.5 kW	Kapkote	79°53’00’’	30°06’00’’
4.	Leti-I	62.5 kW	Kapkote	80°03’00’’	30°01’00’’
5.	Leti-II	62.5 kW	Kapkote	79°49’30’’	30°04’00’’
6.	Lathi- I	125 kW	Kapkote	80°04’00’’	29°55’30’’
7.	Lathi – II	125 kW	Kapkote	80°03’00’’	30°02’00’’
8.	Ratmoli	62.5 kW	Bageshwar	79°51’00’’	29°46’00’’
9.	Satyeshwar	62.5 kW	Bageshwar	79°49’00’’	29°46’00’’
10.	Kapkote S/S	--	Kapkote	79 °54’00’’	29 °57’36’’
11.	Kafligai S/S	--	Bageshwar	79 °45’00’’	29 °43’48’’

2.2 Mapping

A map is helpful in planning and design process. The map of that area is required in which a Mini-grid has to be designed. A mapping tool, Google Earth, a virtual globe, map and geographical information program [29] is used for generation of data for MHPs sites [30]. The measuring process is started by clicking the ruler icon on the toolbar **(Tools > Ruler)** and then clicking in the 3D viewer. To change the shape (Path Polygon and Circle) different tabs can be selected within the measuring tool. The measurement will appear in the dialog box as shown in Fig.3.

2.3 Making of Sites

Mapping the area under consideration, is started with a sketch that includes a rough layout of roads, trails, paths and streams that are going through the community. The data on roads, trails, paths and streams, which is very necessary to design of a mini-grid in Bhageswar district, are obtained with the help of Google Earth by connecting 9 MHPs and two substations. These data are

- Distance between MHPs, distance between substation and MHPs and distance between MHP to substations.
- Total number of paths possible to interconnect 9 MHPs and 2 Substations and distance between them.
- Path profile for each possible path.

Total number of roads and rivers for each possible path.

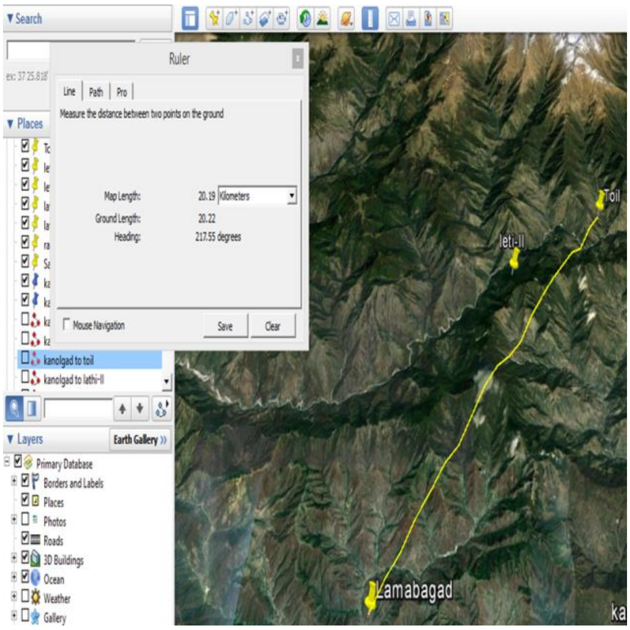

Fig. 3. Measurement of distance between two MHPs through Google Earth

2.4 Distances between MHPs and Substations

The position of MHPs and substations can be easily observed in the Google Earth picture as shown in Fig. 4. Yellow points are indication of MHPs plants while blue points are the indication of substations. The picture shows distances from Ratmoli MHP to remaining other MHPs and substations. The measured distances from Ratmoli to other MHPs and substations are given below.

Ratmoli to Kanolgad	22.10 km
Ratmoli to Lamabagd	23.70 km
Ratmoli to Toil	20.63 km
Ratmoli to Leti-I	15.27 km
Ratmoli to Leti-II	34.50 km
Ratmoli to Lathi-I	28.50 km
Ratmoli to Lathi-II	37.70 km
Ratmoli to Satyeswar	03.63 km
Ratmoli to Kapkote Substation	23.00 km
Ratmoli to Kafligaiy Substation	11.20 km

Like Ratmoli, other distances from other MHP to remaining MHPs and substations are obtained, as given in Table 3.

2.5 Path Profile and Elevation of MHPs

The path profile of Kanolgad to Satyeswar is shown in the Google Earth picture in Fig. 5. The respective data of Kanolgad to Satyeswar is given below.

No of roads	1
No of streams	2
Elevation of Kanolgad MHP	1486 m

Elevation of Satyeswar MHP	1255 m
Highest elevation of path	1900 m
Lowest elevation of path	839 m
Distance between Kanolgad MHP to Satyeswar MHP	20.7 km

Fig. 4. Possible connection of Ratmoli MHP to other MHPs and substations

Table 3
Distances between MHPs and MHP to Substations

MHPs and Substation distances (kilometre)	Kanolgad	Lamabagad	Toil	Leti-I	Leti-II	Lathi- I	Lathi – II	Ratmoli	Satyeshwar	Kapkote S/S	Kafligai S/S
Kanolgad	0	2.57	24.6	33	17.8	32.9	33.5	22.1	20.7	15.8	23.9
Lamabagad	2.57	0	21.3	30.5	14.9	31.9	30.8	23.7	22.7	14.5	25.9
Toil	24.6	21.3	0	19.9	7.5	28	19	39.5	40.5	17	43.5
Leti-I	33	30.5	19.9	0	24.2	11.2	2	35.8	37.3	17.2	44.7
Leti-II	17.8	14.9	7.5	24.2	0	30.5	23.8	34.5	35.5	15	40.4
Lathi- I	32.9	31.9	28	11.2	30.5	0	13.4	28.5	31	17.7	39.1
Lathi – II	33.5	30.8	19	2	23.8	13.4	0	37.7	40	18.3	47.4
Ratmoli	22.1	23.7	39.5	35.8	34.5	28.5	37.7	0	3.63	23	11.2
Satyeshwar	20.7	22.7	40.5	37.3	35.5	31	40	3.63	0	23.9	7.98
Kapkote S/S	15.8	14.5	17	17.2	15	17.7	18.3	23	23.9	0	29.2
Kafligai S/S	23.9	25.9	43.5	44.7	40.4	39.1	47.4	11.2	7.98	29.7	0

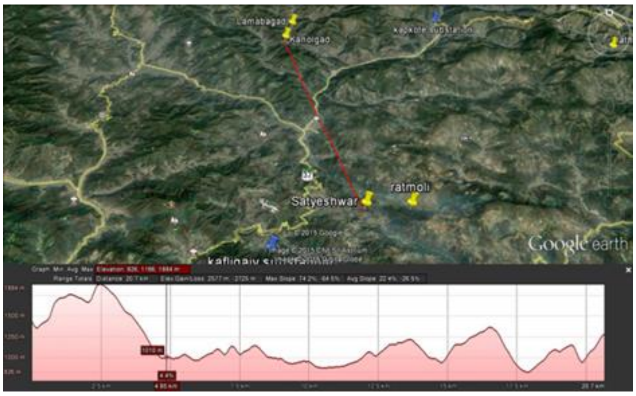

Fig. 5. Path profile of Kanolgad to Satyeswar

Like Kanolgad to Satyeswar, other path and path profiles are observed and elevation of each MHP and substations has been found as given in Table 4.

Table 4
Elevation of each MHP and Substations

Name Of MHPs And Substation	Elevation(Meter) (From Mean Sea Level)
Kanolgad	1486
Lamabagad	1285
Toil	2166
Leti-I	1529
Leti-II	2462
Lathi- I	1170
Lathi – II	2135
Ratmoli	1116
Satyeshwar	1255
Kapkote S/S	1114
Kafligai S/S	1580

3. Optimization of Line Length

For optimization of line length GA has been used to generate useful solutions by representing the candidates of the answer by chromosomes. The adjustment of the chromosomes is done by the concept of evolutionary operations. Basically, it is a searching process based on the laws of natural selection and genetics. A simple GA consists of three operations: *Selection*, *Genetic Operation*, and *Replacement*. In Selection GA operator selects chromosomes from a population of candidate solutions for the optimization task to be solved. New solutions are created by applying reproduction operations (crossover and mutation). The Crossover operator chooses a location randomly and exchanges the subsequence's before and after that location between two chromosomes called parents' chromosomes to create two new chromosomes called children chromosomes. i.e. Strings 10000100 and 11111111 are selected as parents strings could be crossed over after the third location in each to produce the two new springs 10011111 and 11100100. Mutation randomly flips some of the bits in a chromosome. i.e. String 00000100 is mutated at its 2nd position and creates new string 01000100. Mutation can occur at each bit position of a string with some probability, generally very small i.e. 0.002.

Fitness is a function, which is used to describe the satisfaction level of the chromosomes. The fitness of the resulting solutions is evaluated and suitable selection strategy is then applied to determine which solution will be maintained into the next generation. The general conditions for termination are given below.

i. Fixed number of generations completed.
ii. Allocated time reached.
iii. The highest ranking solution's fitness has

reached and the successive iterations no longer produce better results.

iv. Manual inspection.

v. Combinations of the above.

Optimization is done considering following parameters:

3.1 Choice of Voltage

Choice of voltage is one of the major factors that affect the cost of line which affects in turn the cost of the project. In general voltage of the line is taken as 0.6 KV per km of the length of the line. But most common voltage for short distance lines is 11 KV [31, 32] and hence 11 KV has been selected for our Mini-grid.

3.2 Reliability Calculation

Reliability is calculated in terms of interruption time (occurrence of failure and repair time) for each path. The path, which has more interruption time, is less reliable. The following assumptions are made while calculating the reliability of each path.

1. Ten hour interruption time is considered for each path consisting of both MHPs on same elevation level, and having less than 10 km distance and no roads or river in the path.
2. If there will be an elevation difference between the connecting sites, the mechanical stress on the connecting line would be more and thus, the chances of occurrence of failure would be more. As a result interruption time for the path would increase. Thus, on the basis of elevation difference of both MHPS an increase of 30 minutes per 100 m in interruption time is considered.
3. Longer the connecting lines, the chances of occurrence of failure would be more. As a result interruption time for the path would increase. So it is assumed that on the 1 km increase in the distance would cause 15 minutes increase in interruption time.
4. If a road is available in the path, the equipment and material required for repairing the line will be easily accessible. Consequently repair time for the line would get reduced. It is assumed that availability of road would reduce 3 hours interruption time for the whole life span of a line.
5. If more than one road is available in the path, the equipment and material required for repairing the line will be more easily accessible because chances of road closer to fault position would increase. Consequently interruption time for the path would further reduce. So it is assumed that on increase of one road in the path would cause 30 minute reduction in interruption time.
6. If a stream is available in the path, it will create trouble in repairing of the line in case fault occurred in the line. Consequently interruption time for the path would increase. It is assumed that the presence of a stream would increase 1 hour interruption time for the path.

As an example, the calculation of reliability interruption time for a path connecting MHPs "Kanolgad to Leti" is being illustrated below.

Interruption time in this path

$$= 10 + \frac{43 \times 0.5}{10} + (33 - 10) \times \frac{1}{4} + 1 \times (-3) + 1 \times \left(\frac{-1}{2}\right) + 1 \times 1 = 13.47\ hours$$

Where,

Distance between Kanolgad to Leti I = 33 km

Elevation difference of both MHPs = 43 m

No. of roads in the path = 2

and No. of streams in the path = 1

Like Kanolgad to Leti I, reliability of other paths is calculated in a similar manner as given in Table 5.

Table 5

Reliability of Connecting Paths

MHPS and Substation reliability (Interruption time) hours	Kanolgad	Lamabagad	Toil	Leti-I	Leti-II	Lathi- I	Lathi – II	Ratmoli	Satyeshwar	Kapkote S/S	Kafligai S/S
Kanolgad	0	9	18.05	10.96	15.83	15.31	17.12	13.88	12.83	14.81	15.45
Lamabagad	9	0	19.22	19.35	18.11	15.05	22.38	10.27	10.33	8	13.46
Toil	18.05	19.22	0	15.66	12.48	19.18	14.41	20.63	20.69	15.01	17.31
Leti-I	10.96	19.35	15.66	0	19.21	11.6	13.03	15.27	14.20	11.87	15.93
Leti-II	15.83	18.11	12.48	19.21	0	18.59	15.09	20.86	18.92	15	16.51
Lathi- I	15.31	22.38	19.18	11.6	18.59	0	13.67	10.40	13.18	8.7	16.83
Lathi – II	17.12	10.27	14.41	13.03	15.09	13.67	0	10.09	18.9	14.30	20.13
Ratmoli	13.88	10.33	20.63	15.27	20.86	10.40	10.09	0	11.7	9.26	10.62
Satyeshwar	12.83	8	20.69	14.20	18.92	13.18	18.9	11.7	0	7.18	11.63
Kapkote S/S	14.81	13.46	15.01	11.87	15	8.7	14.30	9.26	7.18	0	13.65
Kafligai S/S	15.45	13.46	17.31	15.93	16.51	16.83	20.13	10.62	11.63	13.65	0

3.3 Objective Function

The objective in this problem is an optimum design of Mini-grid by considering the distance and reliability where reliability is calculated in terms of interruption time. During the interruption time concerned MHP generated electricity will get wasted. It will affect revenue generated by Mini-grid. Considering plant life of 30 years, loss due to interruption time is added in the cost of the mini-grid. The objective function can be described by (1)

$$f = C_1F_1 + C_2F_2 \quad (1)$$

Where, F_1= total line length of Mini-grid.

F_2= total interruption time of connected path.

C_1= Cost of line per km line length.

C_2= Cost of interruption

The per kilometer cost for design of 11 KV line is taken as Rs. 245700 [34]. The cost of interruption has been calculated by considering following points.

Cost of electricity = Rs.4 per unit.
Average number of interruption per year = 1.5
Average unit generated by MHP = 100 kW/h
Plant life = 30 years

3.4 Constrains

There are two constrains in design of Mini-grid, which are given below.

i. Each MHP and substation must be connected.
ii. Substations should be connected with at least two MHPs.

3.5 Parameters for Genetic Algorithm

Parameters of genetic algorithm are given below.

i. Population size=50
ii. Generations=500
iii. Stall generation limit=200

4. Simulation Results and Analysis

Simulation Results

Fig. 6 shows the flow chart for GA implementation to obtain an optimized structure of proposed Mini-grid after imposing both constraints (considering distances and reliability).

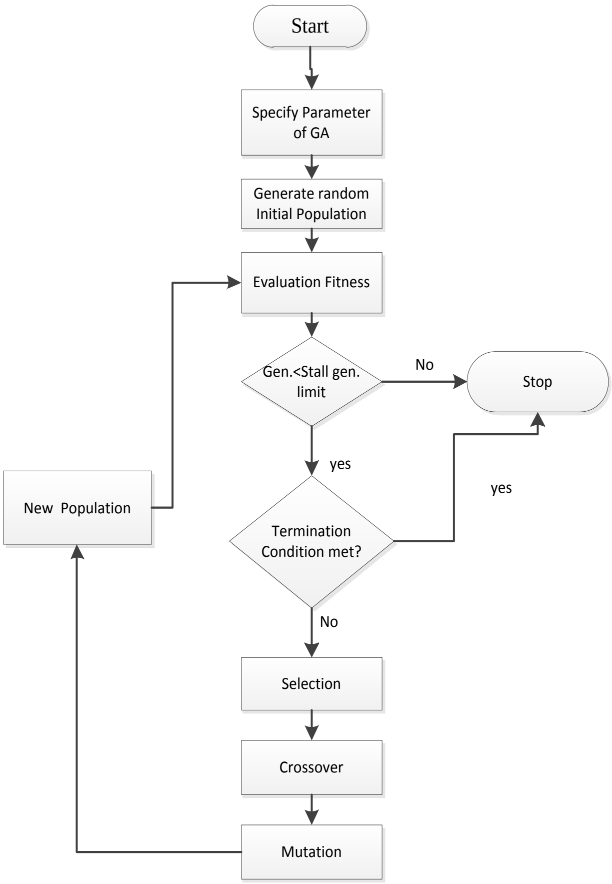

Fig. 6. Flow Chart to obtain an optimized structure of proposed mini-grid

The position of various MHPs and substations in XY co-ordinates which are the latitude and longitude of MHPS and substations is shown in Fig. 7. Name of MHPs and substations are also displayed in Fig. 7.

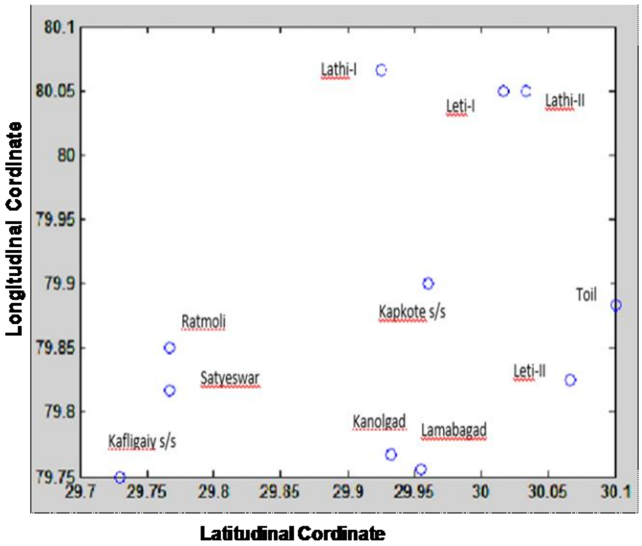

Fig. 7. Locations of MHPS and substations

The over-lapped image of all possible configurations is shown in Fig. 8 which is obtained by placing the locations and distances between MHPs in Google earth. This shows all possible ways to connect a MHP with other MHPs and substations.

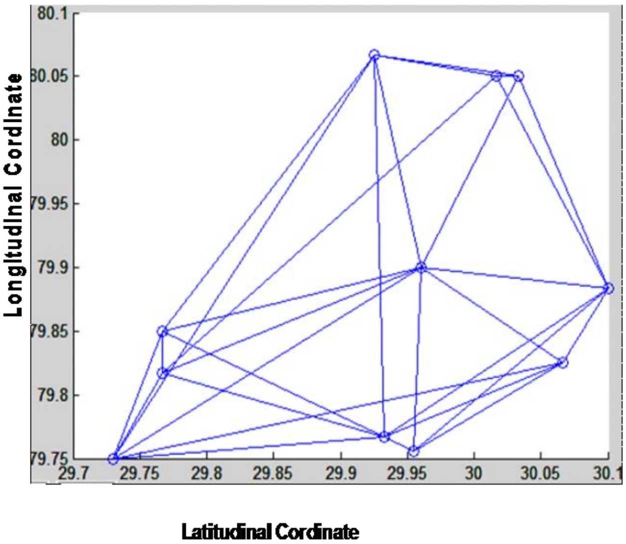

Fig. 8. Overlapped image of all possible ways of connection

The optimized connection of Mini-grid, considering only distances between MHPs and substations is depicted in Fig. 9. The length of Mini grid is 133 km. Fig. 10 gives an optimized structure for the Mini-grid after considering line length and reliability.

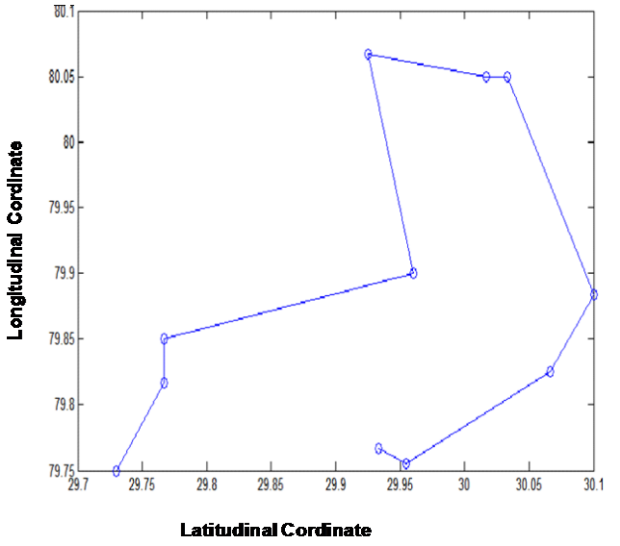

Fig. 9. Optimized path for mini-grid considering only distances between MHPs and substations

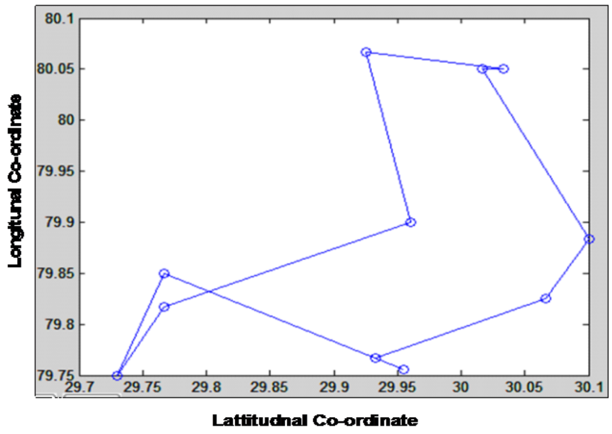

Fig.-10: optimized path for interconnection of MHPS and substations

4.2 Analysis of result

After locating positions of MHPs and substations, the obvious structure that we would probably consider would be like as Fig.11 (Manually Drawn in Paint).

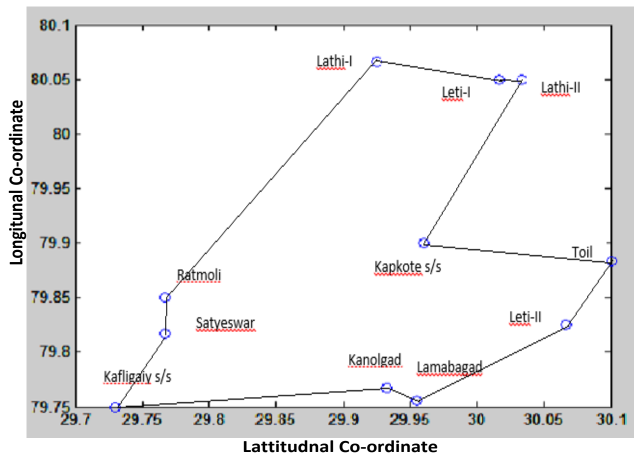

Fig.-11: Obvious Structure

For analysis of result to verify that our obtained algorithmic structure is optimum, we have to compare both structure in terms of reliability and Cost of the project. The comparison is shown in Table 6.

Table 6
Comparative Analysis of Mini-Grid Structures

S.No.	Obivious Structure	Distances (km)	Intruption Time (Hours)
1.	Kafligaiy to Satyeswar	7.98	11.63
2.	Satyeswar to Ratmoli	3.63	11.7
3.	Ratmoli to Lathi-I	28.5	10.4
4.	Lathi-I to Leti-I	11.2	11.6
5.	Leti-I to Lathi-II	2	13.03
6.	Lathi-II to Kapkote S/S	18.3	14.3
7.	Kapkote S/S to Toil	17	15.01
8.	Toil to Leti-II	7.5	12.48
9.	Leti-II to Lamabgad	14.9	18.11
10.	Lamabgad to Kanolgad	2.57	9
11.	Kanolgad to Kafligaiy	23.9	15.45
	Total	**137.48 km**	**142.71**
	Cost of Project*	**33778836 Rs**	
		≈Rs.338 Lakhs	
	Obtained Algorithmic Structure		
1.	Kafligaiy S/S to Satyeswar	7.98	11.63
2.	Satyeswar to Kapkote S/S	23.9	7.18
3.	Kapkote S/S to Lathi-I	17.7	8.7
4.	Lathi-I to Lathi-II	13.4	13.67
5.	Lathi-II to Leti-I	2	13.03
6.	Leti-I to Toil	19.9	15.66
7.	Toil to Leti-II	7.5	12.48
8.	Leti-II to Kanolgad	17.8	15.83
9.	Kanolgad to Ratmoli	22.1	13.88
10.	kanolgad to Lamabagad	2.57	9
11.	Ratmoli to Kafligaiy S/S	11.2	10.62
	Total	**146.05 km**	**131.68**
	Cost of Project*	**35884485 Rs**	
		≈Rs. 359 Lakhs	

* Cost of project = Total length of Structure X 245700 [34]

On comparison, it can be easily observed that the obvious structure has more interruption time (142.71 hours) than obtained algorithm based structure (131.68 hours). So, considered obvious structure would have been optimum if it is for plane region but for hilly region, it is not. Hence, by analysis we can say obtained structure is optimum for given hilly region.

Thus, total line length of our optimised Mini-grid structure is 146 km and cost of project for making this type of structure comes out to be Rs. 359 lakhs.

5. CONCLUSION

A Mini-grid has been designed by interconnecting 9 MHPs with 2 substations in order to utilize the wasted potential of MHPs and to transfer the excess power where power is in deficit. For this purpose Bhagheswar district of Uttarakhand has been selected where 9 MHPs work only for 8 hours in a day and for remaining time, these plants do not produce electricity. By using the location of these 9 MHPs and two substations, all 11 positions have been located on Google Earth map. The related parameters which are required to design a Mini-grid in that area have been taken as distances between MHPS and distances between substations to MHPs, path profile, elevation of plants, maximum and minimum elevation of path, etc. By using these parameters, Genetic Algorithm has been used to calculate the approximate reliability of each interconnection path in terms of interruption time. The path, which has more interruption time, is less reliable The expected project cost for design of Mini-grid has been found to Rs. 359 lakhs which is calculated by assuming per km cost of 11 kV line as Rs. 245700.

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