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Designing of Micro-grid for Rural Electrification Case Study

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Abstract - *This paper highlights the deficit of electricity in Rural India and its provision to overcome, need for the formation of micro-grid, its architecture. The rudimentary requirements for the design of micro-grid is that it must be simple, robust and maintenance free and deliver the supply in both the cases of on-grid and off-grid to the most basic domestic load and local load, which are present in that environment.*

Key Words: **Rural electrification, intensive electrification, micro-grid, peak load, Renewable energy, distributed energy resources.**

1. INTRODUCTION

As the dependency on electrical and electronic equipment is increasing, the energy demand is increasing day by day. Electricity has touched the root of men's daily life in such a way that no one can think about the world without electricity now. It is used for domestic appliances like electric stoves, A/C, fans, refrigerators etc. In factories, machines work with the aid of electricity. A revolution has come in transportation (Electric trains and battery cars) and in communication system by electricity. In the field of medicine and surgery, in defense sector, in amusement sources like television, cinema, in modern equipment like robot etc. electricity plays a crucial role. India transitioned from the being the world seventh largest energy consumer in 2000 to the 3rd largest one in one and half decade.

India has 3rd place after China & U.S. in largest power generation portfolio worldwide and country has been adding generation capacity rapidly [1].The utility electricity sector in India had an installed capacity of 329.20 GW as on 04 April 2017. According to the report of the World Bank, only 78.7 percent of India's population has access to the electricity. 260 million Indians (20 percent of the country population) still have no access to electricity, it is 21.7 percent of the world population which has no access to power [2].

To overcome such dreadful conditions, government is investigating on wind power, solar power and bio-power so that percentage of un-electrified village and household reduces sharply. Now 96% of the villages has been electrified but only 70 % of households have electricity connection. Government brings the concept of intensive electrification in which 100 percent of the household will be electrified in a village and free access to electricity will be provided to the BPL families. The complete electrification goal will be covered up by 2020. Un- electrified villages are mostly lie in the Northern and North-Eastern region. Now States are also taking some initiatives and decisions toward rural electrification.

2. RURAL ELECTRIFICATION

Power access to remote areas by electric connection is a process of rural electrification. A village would be declared as electrified according to vide letter No. 42/1/2001-D (RE) Issued by Ministry of power (MOP), if:

- Basic infrastructure such as Distribution Transformer and Distribution lines are provided in the inhabited locality as well as the Dalit Basti hamlet where it exists.
- Electricity is provided to public places like Schools, Panchayat Office, Health Centers, Dispensaries, Community centers etc.
- The number of households electrified should be at least 10% of the total number of households in the village [3].

Electricity is used for lighting and household activities, for mechanization of many farming operations, such as threshing, milking, in factories. The Rural Electrification Corporation Limited (RECL) was formed specifically to sort out the issues come in providing electricity in all the villages across the country [2]. There are various other schemes launched by government from time to time like Rajiv Gandhi Garmin Vidyutikaran Yojana (RGGVY), Remote Village Electrification Programme, Deen Dayal Upadhyaya Gram Jyoti Yojana (DDUGJY), Pradhan Mantri Gram Vidyut Yojna to expedite the electrification and diversify the procedure. Work has been done for wastage reduction, providing better equipment and improving the overall infrastructure for electrical transmissions in villages etc. but Poverty, lack of resources, lack of political will, poor planning, and electricity theft which is a severe loss of power of one kind and keep away rural area without access to electricity, table 1 below shows the state wise electrification percentage.

Table -1: State wise electrification percentage

Rural Electrification Rate %	No. of UT's & state	electrified villages %
100	15	
99	5	W.B. (99.99), Maharashtra (99.9), Karnataka (99.9) H.P. (99.75), Uttarakhand (99.3)

+95	7	Assam(96.8), Bihar (95.5), Chhattisgarh (97.7), M.P.(97.2), J&K (98.2), Tripura (97), U.P. (98.7)
+90	5	Jharkhand(92.9), Mizoram(93.6), Nagaland(90.8), Orissa (91.9),Rajasthan (90.4)
+80	2	Meghalaya (80.1), Manipur (86.6)
- 80	2	A & N (77.8), A. P. (70.3)

3. MICRO-GRIDS

Micro-grids are electricity distribution systems containing load and distributed energy resources, (such as distributed generators, storage devices, or controllable load) that can be operated in a controlled, coordinated way either while connected to the main power network or while islanded. Microgrids are systems that have at least one distributed energy resource and associated load and can form intentional islands in the electrical distribution systems. Within microgrids, load and energy sources can be disconnected from and reconnected to the area or local electric power system with minimal disruption to the local load [3].

The operation of micro-grids offers distinct advantages to customers and utilities, i.e. improved energy efficiency, minimization of overall energy consumption, reduced environmental impact, improvement in reliability of supply, network operational benefits such as loss reduction, congestion relief, voltage control, or security of supply and more cost efficient electricity infrastructure replacement[4].

4. HOMER

Hybrid Optimization of Multiple Energy Resources, HOMER is the global standard micro-grid software for designing and deploying micro-grids and distributed power systems that can include a combination of renewable power sources, storage, and fossil-based generation (either through a local generator or a power grid). The HOMER model greatly simplifies the task of designing hybrid renewable micro-grids, whether remote or attached to a larger grid. Originally designed at the National Renewable Energy Laboratory, a division of U.S. Department of energy (DOE), for the village power program. There are many others software which we can use for designing and another functioning of the micro-grids like simulation, optimization, and reliability of the systems.

On the basis of Net Present Cost (NPC), Simulation of the system configuration has been done by the HOMER. It estimates whether the system is feasible or not. The NPC of the system is total of cost of installation and operation of the system over a life time [5].

5. REMOTE AREA STUDY

The area of study 11KV feeder load Thalaut – Balichauki (Th-Bck) lies in the sainj sub tehsil of Kullu district at 31o,39'40" N & 77o,14',06" E. Around 0% of total population of Sainj Tehsil lives in urban areas while 100% lives in rural areas. The whole area comes in the Great Himalayan National Park. 25908 people are living in this remote area. Around 9500 people are cultivator and rest of the people are engaged in household activities, guide the tourists and as men power in the project works.

6. HARDWARE CONSIDERATIONS

To attain an implementable design, consideration must be given to the following four major areas:

1. Stability
2. Grid topology
3. Components of Grid

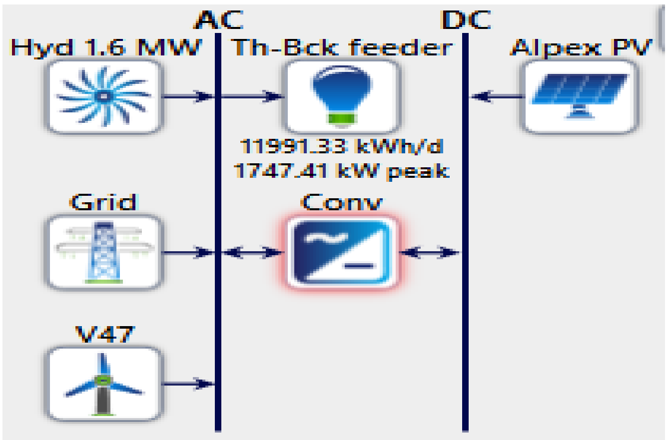

Fig -1: Modelling of microgrid

6.1 STABILITY

It is the main concern that grid must operate in stable state and maintain stability. microgrid is connected to the main grid. It helps in maintaining the synchronism of the Grid by supplying excess energy to the grid or by the decreasing the load from the Grid.

6.2 GRID TOPOLOGY

It is ideated that a designed system comprises a ring topology with power generating sources and load connected to the ring must be capable of meeting the load demand. The power generating sources may be in the form of PV, wind, hydro, etc. It is ideated that the energy storage capability is also included in the ring or together with the distributed power generating sources.

6.3 COMPONENTS OF GRID

6.3.1 Load

The system load is feeder line of Thalaut- Balichouki and comprises the domestic, commercial, noncommercial nondomestic, industrial, agriculture & water irrigation purpose load etc. Daily average load of the feeder is 499.64 KW whereas the peak load is 1747.4 KW. The maximum load occurred in the month of December and minimum in the month of May. The load is single and 3 phase type and there are 54 transformer in this feeder of 25, 64,100 & 250 KVA.

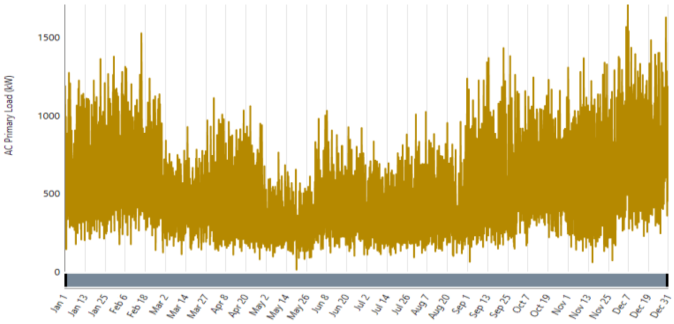

Fig -2: Variation of load Th-Bck feeder

6.3.2 Sources

The load demand is fulfilled by the three source components which are hydro generator, wind turbine and the solar PV module. The selection of these power source components depends upon the availability of the natural resources like water, wind and solar radiations (GHI) at the site.

Water resource: the main source of water is Sainj River, a tributary of Beas, whose discharge varies from 3.384cumec to 84.1cumec and the high head is also get easily.

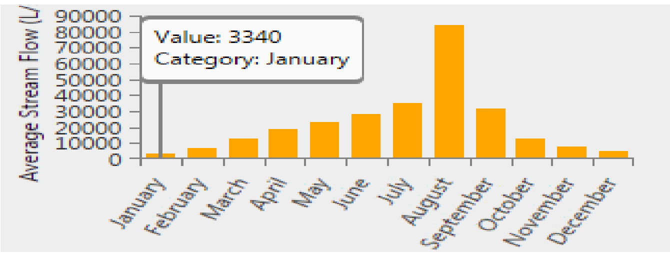

Fig -3: Discharge variation

The discharge of water is minimum in the month of January and maximum in the month of August. As the river is fed by the snow, therefore availability of water is always there throughout the year.

Wind resource: It is another prominent source of power generation. The average flow of wind in the Himalayan region Kullu is 6.38 m/s at height of 50 m. the wind speed is varied from 4.760 m/s to 7.160 m/s.

Solar resources: solar power is the conversion of the solar energy into the electric energy. It is a clean renewable energy. It can be generated directly using photovoltaic cells or indirectly using concentrated solar power. We use photovoltaic cells to produce electric energy by photovoltaic effect in this micro- grid design. Due to surrounding mountains, availability of the sun rays is limited to only 8 hours a day. The derating factor is 96%, which is due to variation of temperature effect and dust.

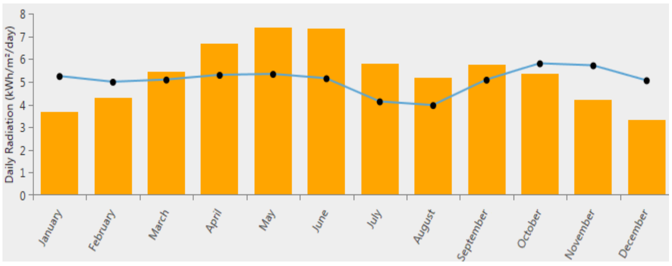

Fig - 4: solar radiation (GHI) profile

6.3.3 Energy Generating Componenet

The hydro turbine is either pelton or francis one according to the availability of head. The maximum capacity of hydro turbine is 2MW to meet the peak load and its 10% variation i.e.175KW which increases the system burden up to 1941 KW. It has been assumed that the turbine has efficiency of 90% and the maximum and minimum flow of discharge is 120% & 70% of the design discharge i.e. 1000 L/s. The power output of the hydro plant is given by

$$P = (h*\eta*g*w)/1000 \quad KW$$

Here h is head, η is the efficiency, w is the water density kg/m^3 and g is gravitational constant $9.81 m/s^2$.

Wind turbine is Vestas V-47 having hub height 50m from surface and having nominal capacity is 660KW. The ground level is 963m. Its capacity is 130KW at average wind speed 6.38 m/s. The power curve of the wind turbine is given in the fig -5: below

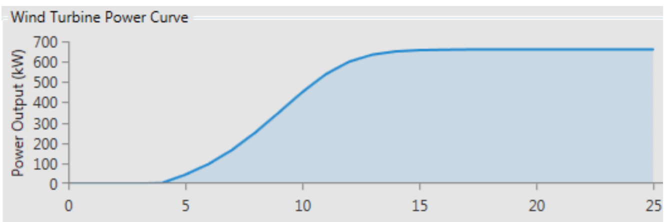

Fig -5: power curve of V-47 wind turbine

For generation of solar power from the PV module, the no. of companies available to provide the PV module have different characteristics, power rating, and price. By keeping in mind, the easy access and most economic factor, we have chosen the Alpex solar PV module of multi crystalline having 72 cells and rating of 320Wp . The system voltage is 1000VDC and maximum voltage 36.55 V. The NOCT of panel is 46 (+- 2%). The energy outcome from the panel is:

$$E = A * \eta * R$$

E= energy output (kWh/month) A= Solar array area (m2), η= conversion efficiency, R= Solar radiation for the month (kWh/m2/day).

7 ECONOMIC ANALYSIS

Economic analysis is based on the NPC. It includes the initial capital cost, maintenance cost, fuel cost and the replacement cost of any component in the project, with future cash flow.

$$\text{NPC} = \frac{\text{total annualized cost}}{\text{Capital recovery cost}}$$

The total annualized cost is the sum of annualized cost of each component. The capital recovery factor is given by

$$CRF = \frac{i(i+1)^{\wedge}n}{(i+1)^n - 1}$$

Where 'i' is the interest rate and 'n' is the no. of years. The interest rate is taken 8% and years for project are 10 in the simulation.
Salvage cost is the value of the component remaining at the end of the project life. It is directly proportional to its remaining life & assumed to be based on the replacement cost. It is given by

$$Salvage = \text{Rcost}\frac{\text{Lrem}}{\text{Lcomp}}$$

L_{COMP} is the component's lifetime (yr.), L_{rem} is the remaining lifetime of the component at the end of project lifetime (yr.)

8 CASE STUDY

Case 1: **Hydro (1.6MW)/PV/battery/Grid**:

This system is not feasible because it will not satiate the peak load demand. The peak load demand is generally occurred in the morning from 6 a.m. to 9 a.m. and in the evening from 6 p.m. to 9 p.m. whereas our solar PV panel do working from 9 a.m. to 5 p.m. Also we can't use large no. of batteries to provide back up because the load feeder is large and heavy and batteries setup will not fulfill the demand. Also if we use a large no. of batteries this make the system capital cost very high. So instead of this setup we prefer hydro of 2MW plant.

Case 2: Hydro (1.6MW)//V47/batteries/Grid:

Here hydro is also considered the main base source of the power supply. The hydro capacity is 1.6 MW and the rest of load is shared by the wind power component and batteries. Although this system gives us feasible solution, the installation cost rises very high. Instead of this option we should go for another installation of hydro or enhance the capacity of hydro which gives us more reliable and smooth power supply than the wind source as there is excess of the discharge present at the site.

Case 3: **Hydro (2MW) /Grid:**

Table -2: Input-data for hydro-turbine

Available head (m)	226.50
Design flow rate(L/S)	1000
Efficiency (%)	90
Maximum flow ratio (%)	80
Minimum flow ratio (%)	118
Pipe head loss (%)	15

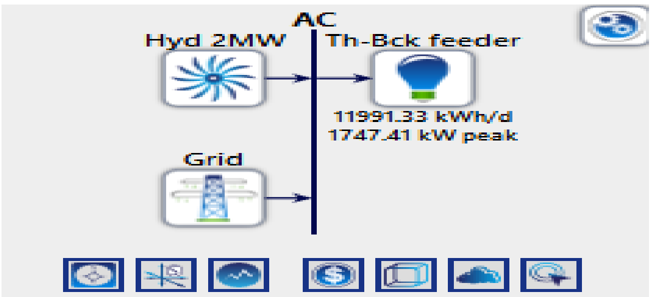

Fig - 6: Modelling of grid case 1

Hydro is the most reliable source of power which met the peak demand easily and render the smooth power supply.

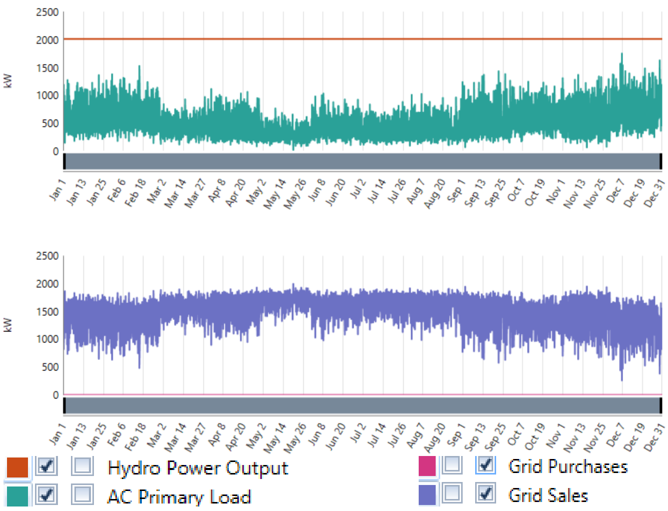

Fig 7: load, hydro power, sale power graph

Case 4: Hydro (1.6MW)/V47/PV/Grid:

Microgrid modelling is given in fig -1, to meet the load demand. Here, we have designed the system which comprises hydro, wind, and solar components. It is connected to the local grid for the backup power supply. Here we have designed the system which remains independent of local grid but if any fault occurs in the micro-grid and the feeder doesn't get any supply so at that time grid must render the supply to the load. The hydro plant is of 1.6 MW to fulfill most of the load requirement especially peak load i.e. 1747 KW with solar and wind power. Here we have installed two wind turbines having rated capacity of

660 KW each and its power generation is 166 KW at the speed 7m/s. Overall it provides power of 240 KW at average speed 6.38 m/s. input data and the power output for the case IV Hyd./V47/PV/Grid has been given below.

Table -3: Input data for Hyd./V47/PV/Grid

Hydro	Solar	Wind
Capacity = 1.6MW	300KW	1320KW
Efficiency(%) = 90	Derating factor(%) 96	Hub height (m) 50
Flow rate (L/s)=1000	NOCT =46° +-2%	
Max. discharge ratio (%) 101	Maximum voltage 36.55	

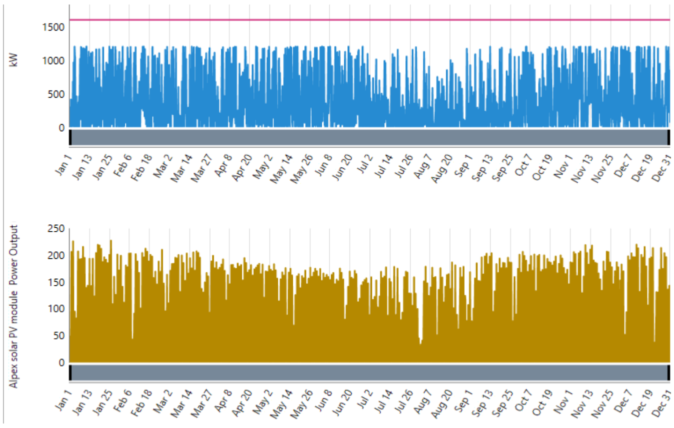

Fig -8: Hydro, Wind & Solar power output

8.2 Comparison of cases:

Table -4: Output of 3rd & 4th case.

Name	Hydro/ Grid	Hydro/PV/V-47/Grid
Hydro turbine	2 MW	1.6 MW
PV module	---	161.14 KW
V-47	---	322.86 KW
Installing cost (Rs)	200M	198M
COE(Rs/KW)	-0.990	-0.0282
NPC(Rs)	-248M	-612M
Operating cost(Rs)	-31.4 M	-16.2M
Energy produced(KWh)	17570526	17234648
Energy sold(KWh)	13193690	12837508

9 CONCLUSION

Among the four cases, it is inferred that the 3rd and 4th cases give feasible solution, these are Hydro/Gird and Hydro/v47/PV/Grid. Besides feeding the load they also earn money by selling power to the grid. The designing of these microgrids has been done by considering that it never depends on grid to purchase the power except malfunction in the grid and serve the load continuously without any interruption in the power flow. The earning from the hydro comes at a very early stage and it overcomes its capital investment although micro-grid is only constructed for the purpose to fulfill the load. We have no. of natural resources to produce more than sufficient energy and we have surplus discharge, which we can use to produce more than 10MW, according to the feeder load we have taken a scant portion of the discharge to install 2 MW plant only. In both the cases we have not installed the hydro plant more than 2MW because our peak load demand is around 1747 KW. The load variation is considered 10 percent, therefore the installation of the plant has been done to produce 1921 KW. If the demand increases rapidly in upcoming years we can increase the production by only increasing the discharge. For very high load nearly 2MW or more than the installation of Hydro/v47/PV/Grid is convenient by ignoring the cost issues. In Hydro/v47/PV/Grid case our installation cost is not supposed to be high as Hydro /Gird but if net present cost and COE is very high. From whole of the research it is convenient to say that the installation of Hydro /Gird is better than Hydro/v47/PV/Grid.

This study finds a solution to meet the highly dense populated area load whose consumption on an average is 500KW with a micro grid. Although all the villages of the area are electrified, not all houses have access to electricity. In the intensive electrification process it can also fulfill the excess load demand besides the normal load for which it is constructed. This study proposes the modular energy system, a microgrid that is suitable to the remote rural communities. The hurdle in this modelling of microgrid is surges in the power output of the PV and Wind resources. It can be reduced or overcame by adopting an energy storing unit which stores the excess power and when the power output of the PV or Wind source is low, it supplies its power to balance unequal power for the smooth and uninterrupted operation of micro-grid.

REFERENCES

[1] Global energy statistical year book Available at: https://yearbook. enerdata.net/ [accessed on 23.05.17]

[2] Rural Electrification corporation available at: www.ddugjy.gov.in/mis/portal / field. study/RE [accessed 15.02.17]

[3] Xuan Liu &Bin Su -2008 "Microgrids – An Integration of Renewable Energy Technologies" journal CICED-2008

[4] Michael Stadler (scientist), Goncalo Cardoso & Salman Mashayesh "Distributed energy resources & Microgrid modelling"

[5] O.M. Longe, K. Ouahado, H.C. Ferreira, S.Chinnappen – 2014 "Renewable energy sources Microgrid Design for Rural area in South Africa" - IEEE2014

[6] Lambert, T., Gilman, P. and Lilienthal, P., "Micro power System Modelling with HOMER, Integration of Alternative Sources of Energy",John Wiley & Sons Inc. pp. 379 – 415. 2006.

[7] SMS Basnet, Haneen Aburub, Ward Jewell & Amir Poudel - 2015" Case Study of Microgrid for Electrification and its Benefits in Rural Nepal" Journal ieee/7343951

[8] W.A. Gronj, I.W. Hofsajer, M. Shumaiwisi & J.I. Braid - 2014 "Design consideration for Rural Modular Microgrid" IEEE2014.

[9] Hisaya Oda “progess & issues in Rural electrification in Bihar” IDE Discussion paper no. 333
[10] Nikos Hatziargyriou -2015 “Microgrids: Architectures and Control” Wiley IEEE Press.
[11] Mahes P.Bhave – 2016 “The Microgrid Revolution” ABC-CLIO, LLC,2016.
[12] Hasan Bevrani, Bruna Francois & Toshifumi Ise-2017 “Microgrid Dynamics &Control” chapter 1- Grid connected renewable energy resources, by Wiley.
[13] Robotiker, Lipsi Estia & Cerer Ucad -2008 Report on “Microgrid Result final Report” Project no. EIE/05/011/SI2.419343
[14] Deichmann, U. Meisner, C., Murray S. and Wheeler D. 2010. The Economics of Renewable Energy Expansion in Rural Policy Research Working Paper 5193, the World Bank Development Research.
[15] Varuna & S.K. Singal. -2007”Review of augmentation of energy needs using renewable energy sources in India”. Renewable and Sustainable Energy Reviews 2007;11:1607–15.
[16] IEA PVPS available at web-site: http://www.iea-pvps-task11.org [accessed on 23.12.2016]
[17] K. Mauch, “Current State of the Art in PV Hybrid Mini-Grids- Early Results from PVPSTask11”http://www.ieapvpstask11.org/id26.htm
[18] Distribution network available ahttps://electricalnotes.wordpress.com/abstract/abstract-of-is-code/is-5039/ [accessed 28.08.2016]
[19] Building of microgrid available at: https://building-microgrid. lbl. gov/about-microgrids [accessed 01: 03 2017]
[20] Un-electrified villages in rural areas available at http://www.garv. gov.in /dashboard [accessed 05.01.2017]
[21] Sunshine availability based on location http://www.pvsavvy.com/s2/ estimate.generation.php [Accessed 05.04.2017]
[22] Renewable Resources data center, solar radiation data available at www.nrel.gov/rredc/solar_resource.html. [Accessed 05.04.2017]
[23] Vestas V-47 wind turbine model. Available at: https://en.wind- turbinemodels.com/ turbines/ 13-vestas-v-47 [Accessed 08.05.2017]
[24] Wind flow data available at: Indiaenvironmentportal. org.in/files/ wind%20speed%20data.pdf. [Accessed: 04.04 2017]
[25] Wind speed prediction in mountain region in India available at http://www.sciencedirect.com/science/article/pii/S0960148115001342 [accessed on 05.05.217]