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AN ANALYSIS OF ISLANDED HYBRID MICROGRID IMPLEMENTATION USING CANALS AS MICRO HYDRO POWER SOURCE WITH SOLAR PV FOR RURAL AREAS OF PAKISTAN

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An Analysis of Islanded Hybrid Microgrid Implementation Using Canals as Micro Hydro Power Source with Solar PV for Rural Areas of Pakistan

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Abstract: Modern technological expansions and human reliance on it has made impossible for the existing infrastructure to fulfil electric power supplies. Besides human living standards are increasing day by day which upsurges per capita electric power consumption. Existing electric power infrastructure cannot be protracted anymore to achieve electric power requirements in the rural areas where it does not exist yet. On the other hand power generation using conventional means is not the preferred option due to its depletion and more significantly due to environmental cautions. To cater the demand of rural community, microgrid utilizing renewable energy resources is one of the viable options to overcome the identified problem. Special emphasis for the implementation of rural microgrids in Pakistan has been given in the paper. This paper deals with the proposed model of Solar Photovoltaic (PV) and micro hydro based hybrid microgrid that can be implemented in the specific area. Paper presents the overview of technical and socio-economic aspects that are noteworthy for the implementation of microgrids in rural areas of Pakistan. One of the site ideal for microgrid has been selected for the case study. Requirements like Demand side management, load forecasting and controls of renewable energy resource has been discussed for the implementation of microgrid in Punjab Pakistan.

Keywords: Micro grid, Rural areas, Algorithm, Hybrid

1. INTRODUCTION

Pakistan is among the countries that are abundant with Renewable energy resources. These sources include Solar, Wind, Biomass, and micro hydel categorically available all across Pakistan. Wind energy is abundant in different areas of Sindh and Baluchistan on the other hand Southern Punjab and upper Punjab is plentiful with Solar and microhydel energy at various parts. Whereas Northern Areas of Khyber Pakhtunkha holds opportunities of harnessing energy through run of the river and micro hydel project including solar energy. Up till now several microgrids all around the world has been installed in different rural areas especially in developing countries where electricity infrastructure is not available. 1.3 billion People around the world cannot access the electric power out of which 84% belongs to rural community (Gaona. *et.al.,* 2015). In Pakistan 40,000 villages are without electricity [AEDB, 2005) whereas Tharparkar has a separate story having more 2,100 villages out of 2,300 villages that are without electricity (Prem 2010). To overcome the awful electric power situation in terms of Pollution, aging infrastructure and provision of electricity to rural areas, microgrid utilizing renewable energy resources can be a helpful option. Microgrids have been installed and tested across the globe in terms of cost effectiveness, power quality and reliability. (Sivarasu. *et.al.,* 2015) discussed the technical challenges and scope of microgrid in India in details whereas (Kobayakawa. *et. al.,* 2014) have taken real operational data of Sagarisl and in India to find out real technical issues and opportunities of setting up microgrid in different areas in India, however the major concern of the research work was load forecasting of rural areas before electrifying microgid. (Castellanos. *et. al.,* 2015) research work is based on electrifying a village of west Bengal in India with design optimization and techno-economic analysis while integrating renewable energy resources in the systems. Seven scenarios for electricity generation were modelled by combining anaerobic digestion and solar PV and different storage elements. Energy Efficiency and conservation is another issue need to be addressed once utilizing renewable energy resources, several methodologies and systems have been developed for energy conservation. Microgrids along with the efficient infrastructure for residence will help building more efficient microgrid that relies less on upstream networks. (Faiz. *et.al.,* 2014) discussed methods for efficient building using automation for energy conservation in buildings.

On the other hand, African nations are also analysing the opportunities for electrification of rural communities using microgrid. (Camblong. *et.al.,* 2009) conducted a survey on the basis of installation of microgrids for non-electrified villages in Senegal. Three regions were selected for survey and data was gathered

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for finding the best possible renewable energy resource of the region and for load forecasting of the complete area.

It was found that best renewable energy resource for the three regions is solar energy where Wind energy is good in some areas. Biomass can be a good option if managed properly. The survey results also identified challenges in setting up the microgrid in selected regions. In continuation of the previous work in an electrification kit for regions in Senegal has been developed. This kit is developed on the basis of results concluded by (Camblong. *et.al.,* 2009) in there research. According to (Alzola. *et.al.,* 2009).

"After identifying necessary previous conditions for the sustainability of any electrification project, a methodology is proposed for the design of the electrification kit. This methodology a typical village and results are extended to differently sized villages in the areas of Thies, Fatick and Kaolack". Tamer

(Khatiba, *et. al.,* 2012) have design an optimization iterative-genetic algorithm for optimizing microgrid of rural areas in Malaysia. The optimization in done in three levels using iterative-genetic algorithm, firstly solar/wind energy resources and storage are optimized secondly tilt angle of the solar array based on Liu and Jordan model and third iterative model for optimization of Inverter size. The basic purpose of the designed model is to find best possible configurations of Energy sources while saving cost. The iterative part of the model finds the possible configurations of the proposed system while the genetic algorithm selects the optimum configuration. Whereas Pakistan is an agriculture economy where a considerable majority of its population depends on agriculture to make their livelihood (Khan. *et. al.,* 2009) Up till now no significant research work has been taken for developing case study for Microgrid in Pakistan. This research paper is focuses towards the development of microgrids in Pakistan which is the real need of rural areas. In this paper aspects that must be taken into account before implementation are considered. This includes demand forecasting of the selected area, renewable energy potentials available and impacts of microgrid in the area. Based on the techniques, methodologies and algorithm used in different parts of the world for Microgrid implementation has been studied which will help to develop successful microgrid in Pakistan.

2. SITE SELECTION

Site selected for the current case study is at district Dera Ghazi Khan, near Taunsa shareef a village named Retra its geographical coordinates are 30° 56' 0" North, 70° 42' 0" East and its original name (with diacritics) is Retra. About 13.6 Km from Retra small community comprising of approximately 50 homes lives for agricultural purposes without electricity and basic necessitates like schools, Hospital etc. The major cause for deficiency in the area is no electric power availability. Like all other parts of the country this area is blessed with abundant solar energy. A canal name Chashma linked canal is basic resource of water for agricultural use. Chashma Right Bank Canal is an interprovincial irrigation Project. It commands a total area of about 606,000 acres of land on the right bank of River Indus in the Khyber Pakhtunkhwa (KPK) 366,000 acres and 240,000 acres in Punjab Province (Ahmed. *et.al.,* 2015).The canal is 170 miles long (106 miles in KPK & 64 miles in Punjab). It off - takes from right bank of existing Chashma Barrage and extends southward upto Taunsa Barrage on the Indus River. The canal has total discharge capacity of 4879 Cusecs at its head (3079 Cs for KPK & 1800 Cs for Punjab). The head on the canal is around 4 meter high that can be utilized for generation of Micro hydel energy for local community. Whereas people in the area are well familiar with the solar energy as several homes are already utilizing solar energy for running small loads like DC fans and for charging emergency portable LED lights. Nearly all residents of the area use to keep cattle, goats for agricultural purpose. Abundant natural gas can also be produced using anaerobic digestion. Since this area is ideal for development of microgrid while utilizing micro hydel and solar energy for power generation and biogas as another option for electricity generation.

Fig. 1. Satellite view of Site near Retra, Taunsa Shareef

3. TECHNICAL ASPECTS OF SELECTED SITE

3.1 Availability Distributed Generators

Selected site can harness the solar potential as well as small hydro potential. Solar irradiation level for the selected site is 5.5/kWh/m2. Whereas a head with length 4 meter is available which can be utilized for small power generation. The added benefit of Hydel energy will supply continuous power subject to the availability of water in the canal.

3.2 Solar Energy Power Generation

Abundant solar energy is available at the selected site. 5.5 to kWh/m2/day have been claimed in at press.org. This potential can be utilized as a source of distributed generation. Each home needs to install system of only one kW. This means 50 kW of generation is available using solar power. On the other hand figure 2 shows that average temperature in the area reaches maximum 40°C in the month of June and July. Whereas in figure 3 availability of sun in summer is for 8 hours which shows enough energy harness in day time. This energy can be stored for night also. The climatic data shows the viability of the solar potential utilization in the area. Average rainfall in the area is low which confirms maximum solar potential utilization for complete year. Only month July in figure 4 shows heavy rains up to 60 mm which in turns shows good signs for hydel power generation.

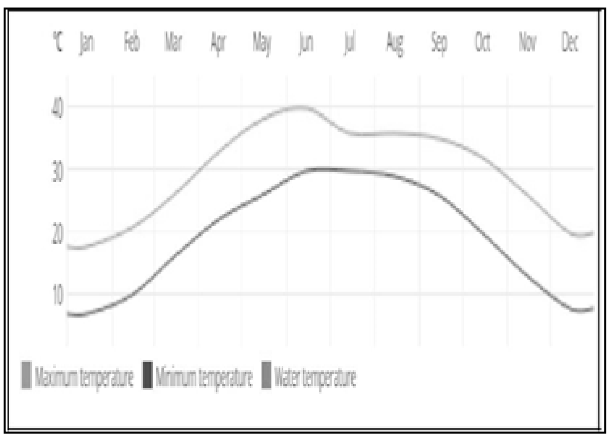

Fig. 2: Monthly Temperatures at Site

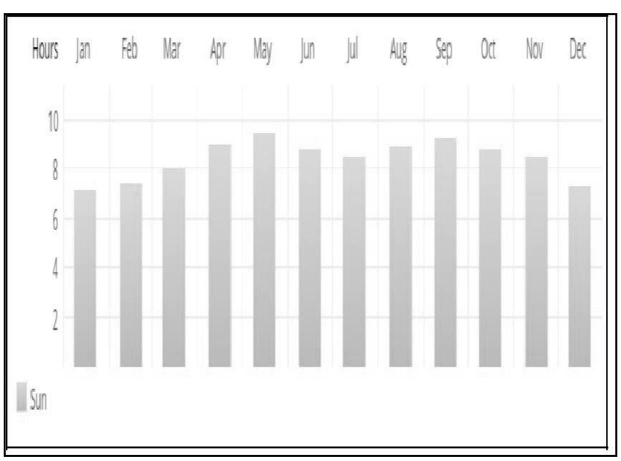

Fig.3: Availability of Sun in Different months at Site

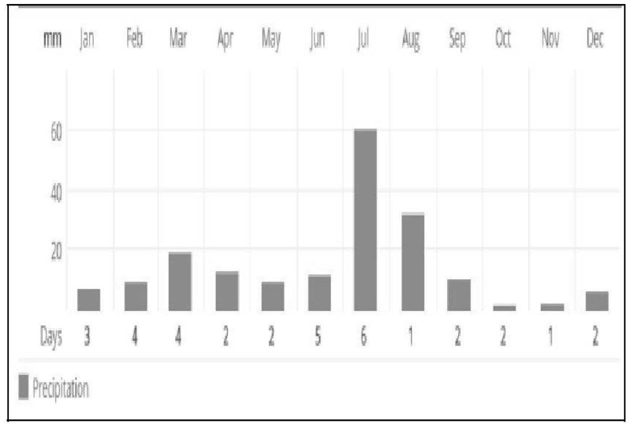

Fig. 4: Annual Precipitation in the Area

3.3 Hydel Power Generation

Hydel energy can be harnessed using Chasma Right Bank canal near the site. A 4 meter head with concrete bridge is available. This height is good enough to harness electrical power. According to (Nasir 2016) a vertical Kaplan turbine that has been designed for low heads can be a useful option The turbine has been successfully tested in Nokhar branch canal Punjab Pakistan at the head height of 1.5 meters. The water flow rate at given height is recorded as 722 cusec. The total power generation using the Kaplan turbine at 200 kW subject to availability of water. Figure 5 below shows the site view of power at Nokhar branch kanal Punjab Pakistan.

Fig. 5: Available Head at Nokhar Branch Canal (Nasir 2016)

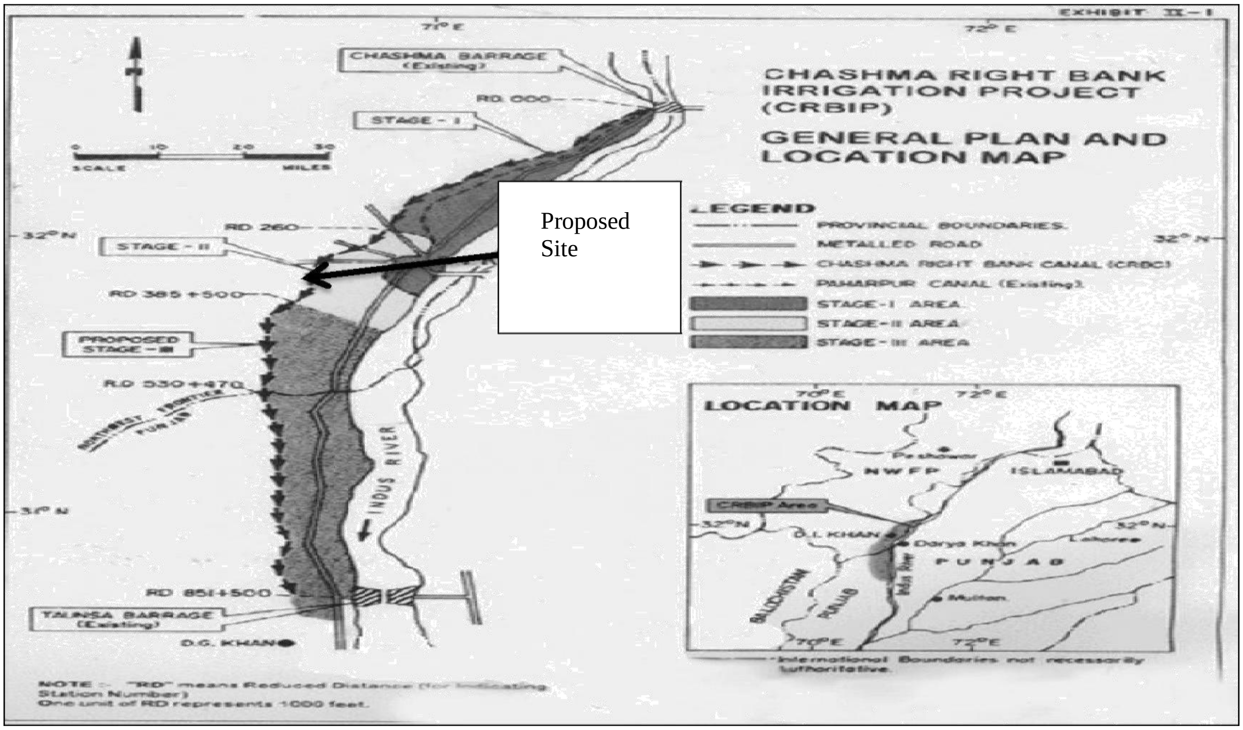

Fig. 7: Complete Chashma Right Bank Canal Plan and Location Map with Proposed Location

On the proposed site. Same Vertical Kaplan can be utilized. According to Hydel power Potential Pakistan report published by Pakistan Private Power infrastructure board (PPIB). Chashma Right bank canal has been identified as raw site having. 0.78 MW potential.

3.4 Power Generation of Distributed Power Generators

Solar power generation at the site is calculated related to the available homes. Each house hold can have 1 kW system installed at roof top. Total 50 Homes will generate 50kW. Sun availability is normally for 8 hours which means 50kW system can generate 400kWh of solar Energy every day and 0.146 GWh annually.

Hydel potential as identified in PPDB report as 0.78 MW. At specific site having head of approx. 4 meter head with the water flow rate approx. 450 cusec from available 1800 cusec water discharge for Punjab, it can generate power 500kW with efficiency of 60% with Kaplan turbine. This power will be available 24 hours a day. The only drawback is water unavailability under the month of Feb and March. During these months due to cold weather conditions solar energy would be sufficient to fulfil energy demands. The following calculations may slightly vary due to exact data unavailability hence these hydro calculation may be approximated.

3.5 Demand and Supply Measure

50 Homes in proposed system has 2 rooms, a wash room, with refrigerator, washing machine and TV.

Peak load at any time would be 44 kW where the total available power using solar would be 50 kW. A 50kW battery bank will be required for peak sheaving and backup at night.

Total system would require 50 kW system grids.

3.6 Microgrid Infrastructure

Proposed microgrid infrastructure is based upon micro hydel plant and solar photovoltaic power. Total system includes Inverter DC and AC bus bars batteries with inverters and loads. Inverters have been considered as an essential part for AC microgrids. In islanded mode or in grid connected mode, inverters are required for power dispatch to the load and charging battery banks. Development of different control technologies for inverters have been evolved over the years whereas Uninterrupted power supply (UPS) systems are used for supplying powers to the load and from microgrids to upstream networks. (CF Ahmed, 2014), Model Predictive Controller-based, Single Phase Pulse Width Modulation (PWM) Inverter for UPS Systems since it can be utilized for uniteruppted power supplies for smaller scale microgirds.. Total power generated would be 50 kW where battery banks will be utilized for peak sheaving and operating at night. Total load at peak would be 44kW. This total load is calculated according to the table given in table 2. Figure 9 shows the architecture of the microgrid to be installed.

3.7 Proposed Algorithm

Control algorithm has been designed using smart controller. This controller will calculate total running load and available PV power. In case available PV power is greater or equal to the load then this controller will charge the batteries through hydel power. In case solar PV power is lesser than demand, then this controller will share the power with PV. At night this micro hydel along with the batteries will provide power to the load. In this way no added fossil fuel generators would be required in case of emergency. On the other batteries will be utilized less due to added power availability of micro hydel that is available 24 hours a day. Figure 8 below shows the overall flow chart of the proposed algorithm. The added benefit in the proposed

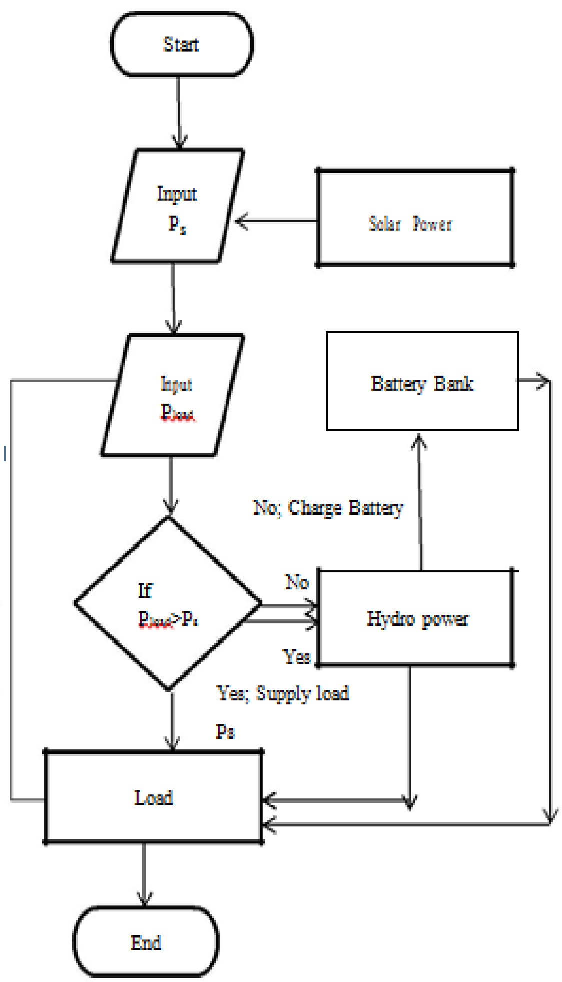

Fig. 8: Proposed Control Algorithm Flowchart

microgrid architecture is canal hydro energy. Energy can be continuously harnessed through micro hydro plant. Since the total peak load forecast is 44kW and generation in the day time will be 50kW through solar PV. At this time micro hydel can either supply partial power to load or it can be utilized to charge batteries for night time whereas solar PV to provide power in the day time.

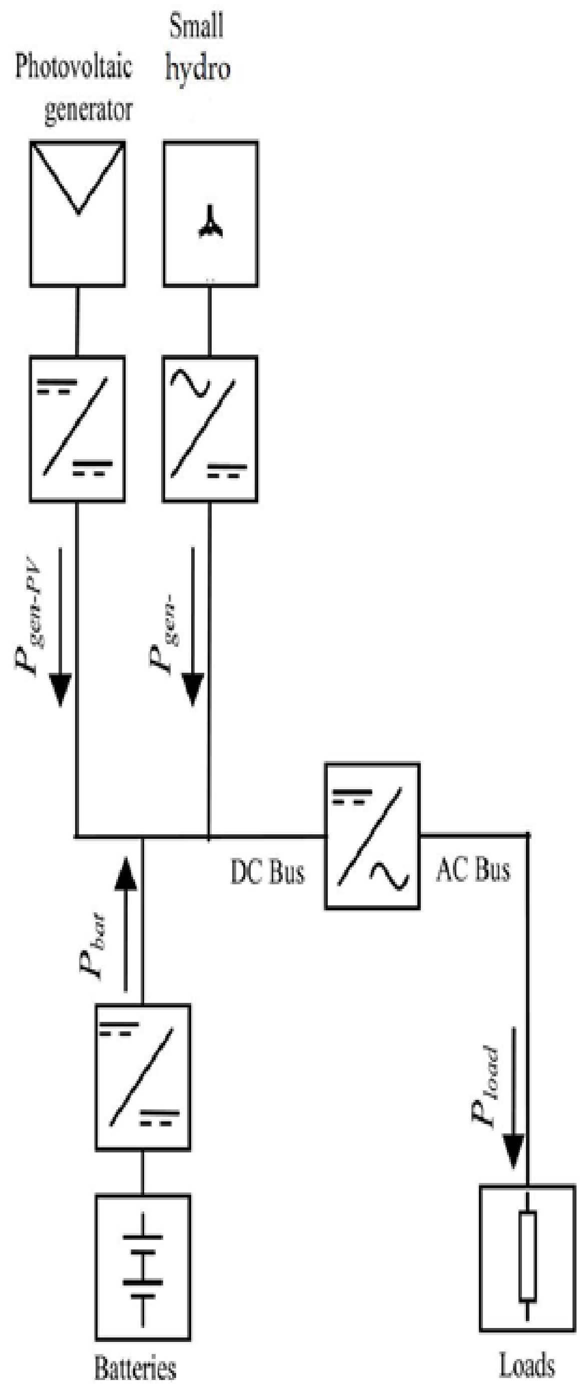

Fig. 9: Proposed Microgrid Infrastructure

4. PROBLEM BEING FACED BY LOCAL COMMUNITY

Following are the problems being faced by the local community.

4.1 Hospitals

The other challenge related to the site is unavailability of hospitals. In case of emergency like snake bites which is very common in the area there is no dispensary or hospital for emergency patients. This causes high death probability in the area. Since hospitals are also directly associated with the electricity need. There is no place to preserve injections and other medicines. The temperature in the area rise to 46 to 48 in summer, to preserve medicines refrigeration is must, which again requires electricity.

4.2 Schools and community places like masjid

Unfortunately, in this modern world still there is no school in the area. This necessity has been ignored by the government organizations. Without electricity, one even cannot think for the availability of advanced computer laboratories and basic needs like fans and lights for study. Furthermore, masjid (worship place) in the area uses microphones and speakers for prayers but this directly runs on battery, which is charged, from somewhat 13 km away from the site. This adds difficulties for worshippers.

4.3 Communication

There is no communication means available in the area except mobile phone which again requires electricity to become functional. Nevertheless private communication companies approached the area and mobile phones signals area available. Due to unavailability of electricity and expensive solar charger that people cannot afford, community has got another cheap alternative. This alternative is charging cell phones while using motor bike batteries. Since this is not the solution but people look after this to get their cell phone charged

5. SOLUTIONS

5.1 Micro grid as a sustainable solution

Discussed problems are directly or indirectly associated with the electricity demand in the area. Upon the views of local community solar panels has been utilized by them but due to less knowledge about its utilization and improper installations makes it unreliable that ends its operation within few month or year. On the other hand still solar energy alone is a costly option and cannot bear by common people. A grid with their own generation means and properly installed will greatly affects the system in positive way and will raise the living standards of the local community. The solution is self-sustainable mainly because of own generation capacity and flexible tariff structures. Tariff structures can be proposed as follows.

5.2 Tariffs

Tariff of the microgrid system will be based on the consumption of each household. Consumer utilizing more energy will be charged more on the other hand maintenance cost of the system will be also added in the tariff. To overcome the tariff burden special offers like free of cost water pumping station availability at off-peak hours will attract the local resident to go for the microgrid option. According to National Electric Power regulatory authority (NEPRA) tariff for solar energy has been considered as 14.5 Rs/kWh.

5.3 Community Place to get Electrified

Community places like mosques, common sitting areas, hospitals and schools should be facilitated with free of cost energy like lighting and fans for limited time hours for common sitting areas in evening and to supply Hospital with 24 hours energy, Schools should have energy access in day time only. This will attract the resident to adopt the microgrid in the area

6. CONCLUSION

This paper is based on the initial strategy that will be deployed for the installation of microgrid at Retra. The selected site is a hub of agricultural activity in the area. People in the area are somehow connected with agricultural activities which also is the main source of their income. To further strengthen the economy, basic utilities are very important to be supplied. To get the best output out of these areas in terms of economy is to provide basic necessities and raise the living standards of local community. The selected site is not the only site in Punjab. There are several such sites available across Pakistan that have the capability to develop self-sustainable microgrids based on the available potential of the renewable distributed generation sources. In this way those areas that are beyond the reach of national grid can be electrified by consuming own renewable energy sources. Even in areas where electric grid is available, these microgrids can be deployed to reduce reliance on conventional systems.

The study shows positive results in term of available power and required demand. A complete laboratory for microgrid testing before implementation is required for future research work. On the other hand a complete system showing potential of distributed generators across Pakistan on geographical basis will help to identify the available renewable resources to be deployed in the area in terms of either to supply grid or develop a separate grid as done in this case. This research work and preceding research will help to provide necessary knowledge to introduce microgrid based on renewable energy resources in the rural areas of Pakistan.

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