Optimization of renewable energy based microgrid for Mehran UET Jamshoro

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Abstract. Renewable energy sources are promising good for providing efficient energy resource with environment friendly advantage. The supply side planning because of microgrid is making it important as transmission fixed and operational costs are reduced. This paper focuses on the optimal design, life cycle cost, and power quality analysis of microgrid. Two options were selected: in the first option isolated microgrid is designed and in the latter option microgrid is connected with the national grid. The both models were compared for economic point of view. The compared optimized model is created for which power quality is analyzed and discussed. The most famous energy modeling software named HOMER hybrid renewable energy system, is used for comparing the models while MATLAB/SIMULINK is used for simulating the model for power quality analysis.

1. Introduction

Microgrid offers a good way for integration of Distributed Energy Resources (DERs). The DERs are very unpredictable making the energy resource less reliable for to depend on it. Basically, microgrid is defined as it is a distribution network with bounded area that accumulate local generation with DERs which may contain energy storage devices and self-sufficient load that forms a cluster of system that is self-reliant [1, 2] Hence, it can operate individually with controllable option national grid or in islanded mode. The integration has still main problems related to operation, power quality, control and protection. [3, 4].

Microgrid advocates various communities for lowering their dependence on utility supply and thus cutting CO₂ emissions from conventional resources by incorporating distributed energy resources from renewable energy resource [5]. Renewable energy resource for example wind energy and solar energy plays important role in operation of microgrid. However, with intrinsic property of variation of such resources complicates the operation. Meanwhile distributed energy resources (e.g., battery bank, solar and wind), distributed generation (e.g., diesel-fuel generators or gas-fueled turbines) or controllable loads are integrated into the microgrid[6]. Therefore, the performance of the system depends upon the environmental conditions. At some places wind energy is available in vast quantity while at some places only solar energy is present in abundant quantity. The price of purchasing and operation of the
both i.e wind and solar systems are different. It is need to analyze at which point solar PV cells and wind turbines are at optimized costs. For the optimization HOMER hybrid renewable energy system software is used. HOMER is powerful tool for optimization and sensitivity analysis[7].

RESs are pollution free, safe, good for environment and sustainable of power generation and their escalation in use is proliferating all around the world[8]. However, the advantages discussed above by using RESs come with a few power quality challenges. Power quality is responsible for reliability of microgrid and therefore it needs of paying attention towards it which is unavoidable. Use of microgrid sometimes needs to integrate with network grid. Satisfactory and reliable operation of integrated network is very difficult task due to challenges created by PQ problems produced by generation technological differences and environmental challenges. Since last few years, the major use of power electronic converters employed for integration has raised power network problems such as harmonic distortion and frequency stability due to decrease overall inertia[9-11].

The irregular occurring nature of Renewable Energy Resources is major reason for PQ problem with microgrid. The traditional synchronous generators had less PQ issue in comparison to Power Electronics (PE) based generation technologies. The leading PQ concern is fluctuation in frequency and voltage which is due to irregular nature of renewable energy system[12-14].

The other important problem of PQ is the harmonics. Harmonics linked with microgrid can be distinguished into two categories: the first category is due to PE inverters used for integrating and the other category is caused by nonlinear connected load. In the first category, harmonics are generated when PE inverters are employed for integration which operates at very high frequency and injects that high frequency current components into the system [15, 16]. In the other category harmonics is caused by the nonlinear load connected of point of common coupling. These harmonics creates issue like overheating of lines, resonance, unnecessary tripping by protection devices[17, 18].

This paper is basically divided into two sections. First section shows the optimization of microgrid using HOMER based on net present cost of the system from list of different configuration. The second section tends to discuss the power quality problems and methods to overcome the power quality problems.

2. Methodology
For performing the desired output work the methodology has been used is HOMER software for optimization the microgrid. Output of the HOMER is used for input in MATLAB/SIMULINK for power quality analysis for the faults and evaluation of voltage & current profiles during the abnormal condition.

For optimal designing and to evaluate the techno-economic feasibility of different combination of system the famous software HOMER is used.
2.1. **HOMER**

HOMER software developed by the National Renewable Energy Laboratory Canada (NREL) in the USA has been used for the economic assessment of the HES. HOMER is used for designing on-grid and off-grid systems, and it also facilitates in comparing different distributed generation technologies. HOMER software can be used to compare different hybrid systems based on their economic and technical advantages. HOMER performed three major tasks: simulation, optimization, and sensitivity analysis. In the simulation process, energy balance calculations are performed by HOMER software for each system configuration. HOMER then finds the optimal and feasible system configuration. In the optimization process, HOMER simulates all possible system configurations and sorts them out based on NPC.

2.2. **MATLAB/SIMULINK**

MATLAB/SIMULINK is powerful simulation software for analyzing and modeling the real-time system in optimum way. The SimPowerSystem toolbox is used for simulation of real-time distribution system of PQ disturbances. Simulink model comprises distribution nonlinear load, transformer energizing, capacitor bank switching, induction motor starting and line fault.

2.3. **Data profile**

Mehran UET is an academic institute so for this case energy consumption is higher in the morning time while at the night time only residential colony and teachers/students hostel is biggest consumer of power. The energy consumption information for Mehran UET was collected after every 1 hour for the whole year. It is found that the energy consumption was counted as 17.529 MWh/day with 4.7 MW peak power demand.
As discussed in the figure 2 the upper bar shows the maximum demand and the lower bar shows the minimum demand at any time for each month. The average power consumption is also calculated by taking the average of minimum and maximum demand which is shown by the bar in the middle. It can be seen that the annual peak demand i.e. 4.7 MW occurs in the month of August due to hot weather and the annual minimum demand i.e. 2.3 MW occurs in the month of January.

2.4. Solar Irradiance
The monthly solar irradiance data for the location of 25 24.5’N latitudes and 68 15.6’E longitudes were obtained from the “National Renewable Energy Laboratory database” [19, 20]. The annual scaled average solar radiation in Jamshoro is 5.54 kWh/ m2/ day, and maximum solar irradiance is 6.74 kWh/m2/day. The monthly solar irradiance and clearance index are shown in figure 3.
“The total amount of solar radiation on the surface of the earth divided by the extra-terrestrial radiation at the top of the atmosphere is known as the clearance index”. The profile shows that the location has good solar potential that can be used for generating power using PV cells.

2.5. Wind Speed
The annual average wind speed of Jamshoro district is 7.28m/s with a maximum wind reached to the speed of 8.5 m/s. This data is obtained with the help of Pakistan meteorological Department as shown in the figure 4.

![Figure 4. Wind Profile of MUET Jamshoro](image)

The long-term seasonal wind speeds are found to be relatively higher from February to September as compared to other months. The maximum wind speed occurs in June.

2.6. Power Quality Disturbance Models
The produced carrying property of disturbance for simulation and analysing. In this paper six type of PQ disturbances are created by the use of mathematical models as shown in the table below Table 1. The PQ disturbances signals are generated by simulation and their behaviour is similar to real situation. It has also advantage that the signal could be varied by parameters in a very wide range and also in controlled position. The signals created with mathematical models can be easily used for classification of PQ disturbances to extract their distinctive features.

3. Simulation and Results

3.1. Optimization
This section is divided into two parts: in the first part optimization and simulation of Microgrid simulated by HOMER Software is discussed. In the second part, PQ parameters of the simulated microgrid is discussed by using MATLAB software.

In the optimization process, distinctive optimal configurations are obtained, and the most prudent one is selected in the wake of running the simulation. The search space for the optimization procedure appeared as shown in figure 5. Taking the NPC as the main selective parameter, the optimized result for HOMER is a PV-Wind-grid hybrid system because it is the most economical option.
With 1,826kW of PV, 600kW wind, 966kW converter, and grid were the most optimal configuration to fulfill the required energy demand. The total NPC, Initial Capital investment, and COE for the hybrid system are 5.4M$, 3.06M$ and 0.0628 $/kWh, respectively. The NPC and COE of this configuration is much less as compared to all other configurations.

Figure 5. Optimization Results of Hybrid System

Figure 6 illustrates the monthly electricity production in kW from PV, wind, and grid. The maximum electricity production is in August. The electrical output of the proposed hybrid system is shown in Table 1. The excess electricity generated by the hybrid system and unmet are also given in Table 1. It shows that PV and wind penetration reduces electricity consumption from the grid and greenhouse gas emissions.

Figure 6. Monthly Electricity Generated from PV-grid System

Table 1. Technical Details of the Optimal Configuration

| System Architecture | PV Array | Wind | Converter | Dispatch Strategy |
|---------------------|---------|------|-----------|-------------------|
| 1.826kW             | 600kW   | 966kW| Load Following |

| Electrical Output |
|-------------------|
| Quantity          | PV-array | Wind | Grid | Total     |
| Production (kWh/yr.) | 3,263,005 | 2,304,749 | 294,402 | 8,511,795 |
| Fraction          | 38.30%   | 27.10% | 34.6% | 100%     |

| Excess Electricity and Unmet Load |
|-----------------------------------|
| Quantity | kWh/yr. | Percentage | Total |
| Excess Electricity | 361,792 | 4.25% | 361,792 kWh/yr. |
| Unmet Load | 0 | 0 | 0 kWh/yr. |
3.2. PQ Disturbance waveforms

The Power Quality Disturbance are produced in MATLAB software with the help of parametric equations. Sampling frequency is 10 kHz, it mean two hundred points of each cycle that is appropriate for the practical performance. The waveform has nominal value of 1.00 magnitude. The frequency used is 50 Hz i.e fundamental frequency of the cycle.

Since voltage magnitude used is 1.0 pu so various samples of voltage sag which is in between 01 to 10 cycle of 0.1 to 0.9 pu values can be produced for testing purpose. In the same way, voltage swell samples could be generated with the magnitude ranging from 1.1 to 1.8 pu. The interruption can be generated if the value of magnitude of voltage decrease below 0.1 pu at any point. For the simulation of pure harmonics and harmonics components of 2nd, 3rd, 5th and 7th order are varying from 05 to 15 percentage of fundamental frequency different possible combinations.

For testing and training purpose of signal parameter it is possible that it can be varied in a very wide range with a controlled manner through PQ signal modeling with the help of parametric equations. The resulted waveforms and the parameter variation range are similar to real PQ signals.

4. Conclusion and Future recommendation

This study presents an economic evaluation of Microgrid based on PV-wind-Grid to meet the energy demand of HEI, i.e., MUET, Jamshoro. Different system configurations were analyzed in HOMER by simulation, having different renewable resources penetration levels. These system configurations were analyzed using sensitivity analysis parameters like wind speed and solar irradiance, and an optimal hybrid system configuration was proposed based on COE and NPC. Power Quality parameter were simulated for the project with parametric equation and Simulink models.

The COE for practical setups, when PV penetration is 38.3%, wind penetration is 27.1% with the connected grid system is 0.0628 $/kWh, which is less as compared to the cost of grid electricity i.e.0.114 $/kWh. The proposed hybrid system is cost-effective and ensured reliability to meet the required demand. However, the initial capital is much higher, but it must not be the decisive factor taking into consideration the electricity shortfalls and rising energy demand.
With the help of MATLAB/Simulink environment power quality disturbances are analyzed by Electrical power distribution model and mathematical models. The power Quality disturbances created by the methods are similar. The two methods are also similar with real Power Quality disturbances.

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References
[1] Arain Q A, et al. 2017 Clustering based energy efficient and communication protocol for multiple mix-zones over road networks Wireless Personal Communications 95 (2) pp 411-428
[2] Karugarama M K 2016 Mitigation of Blackout in Kigali Using a Microgrid with Advanced Energy Storage and Solar Photovoltaics (Doctoral dissertation, Virginia Tech)
[3] Haritza C, et al. 2016 Research experimental platforms to study microgrids issues International Journal on Interactive Design and Manufacturing (IJIDeM) 10 (1) pp 59-71
[4] Tan D 2015 Emerging System Applications and Technological Trends in Power Electronics: Power electronics is increasingly cutting across traditional boundaries IEEE Power Electronics Magazine 2 (2) pp 38-47
[5] Yuan C, Illindala M S and Khalsa A S 2017 Co-optimization scheme for distributed energy resource planning in community microgrids IEEE Transactions on Sustainable Energy 8 (4) pp 1351-1360
[6] Su W, Wang J and Roh J 2013 Stochastic energy scheduling in microgrids with intermittent renewable energy resources IEEE Transactions on Smart grid 5 (4) pp 1876-1883
[7] Khalil L, et al. 2020 Optimization and designing of hybrid power system using HOMER pro Materials Today: Proceedings
[8] Gielen D, et al. 2019 The role of renewable energy in the global energy transformation Energy Strategy Reviews 24 pp 38-50
[9] Ulbig A, Borsche T S and Andersson G 2014 Impact of low rotational inertia on power system stability and operation IFAC Proceedings Volumes 47 (3) pp 7290-7297
[10] Jiang Y, Pates R and Mallada E 2017 Performance tradeoffs of dynamically controlled grid-connected inverters in low inertia power systems 2017 IEEE 56th Annual Conference on Decision and Control (CDC) pp 5098-5105 IEEE
[11] Dag O and Mirafzal B 2016 On stability of islanded low-inertia microgrids 2016 Clemson University Power Systems Conference (PSC) pp 1-7 IEEE
[12] Shi J, et al. 2012 Forecasting power output of photovoltaic systems based on weather classification and support vector machines IEEE Transactions on Industry Applications 48 (3) pp 1064-1069
[13] Andrade J R and Bessa R J 2017 Improving renewable energy forecasting with a grid of numerical weather predictions IEEE Transactions on Sustainable Energy 8 (4) pp 1571-1580
[14] Naghdi M, Shafiyi M A and Haghifam M R 2019 A combined probabilistic modeling of renewable generation and system load types to determine allowable DG penetration level in distribution networks International Transactions on Electrical Energy Systems 29 (1) p e2696
[15] Rönnberg, S K, Gil-de Castro A, Bollen M H, Moreno-Muñoz A and Romero-Cadaval E 2015 Supraharmonics from power electronics converters 2015 9th International Conference on Compatibility and Power Electronics (CPE) pp 539-544 IEEE
[16] Bollen M, Olofsson M, Larsson A, Rönnberg S and Lundmark M 2014 Standards for supraharmonics (2 to 150 kHz) IEEE Electromagnetic Compatibility Magazine 3 (1) pp 114-119

[17] Karimi M, Mokhlis H, Naidu K, Uddin S and Bakar A H A 2016 Photovoltaic penetration issues and impacts in distribution network–A review. Renewable and Sustainable Energy Reviews, 53 pp 594-605

[18] Kumar D and Zare F 2015 Harmonic analysis of grid connected power electronic systems in low voltage distribution networks IEEE Journal of Emerging and selected topics in Power Electronics 4 (1) pp 70-79

[19] Akinsipe O C, Moya D and Kaparaju P 2020 Design and economic analysis of an off-grid solar PV in Jos-Nigeria. Journal of Cleaner Production 287 p 125055

[20] Sengupta M and Habte A M 2020 Measurement, Modeling, and Database of Solar Irradiance (No. NREL/PR-5D00-75573) National Renewable Energy Lab.(NREL), Golden, CO (United States)