Estimation of Minimum Cost of Providing Energy for a Rural Microgrid Using Monte

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***Abstract*—Rural microgrids may be supplied from various inputs. The commonly used ones are solar PV, grid input, wind energy and diesel generation. Battery backup may or may not be included. In the absence of the grid, the system may continue to operate in the islanded mode. The present paper attempts to discuss a simple strategy for designing a power delivery scheme that can provide the needed energy to the microgrid at least cost, when a number of different energy inputs collectively feed the microgrid. Using Monte Carlo simulations, we determine the cost of supplying energy at least cost to the microgrid (via the PCC). The various options generated by the simulations are arranged in order of the least cost for energy supply and then top five options are recommended for planning of energy management of the microgrid. The approach proposed here is a simpler alternative to the conventionally use optimization approaches that make use of various metaheuristic algorithms like the PSO, GA etc.**

Keywords: Energy Management, Rural Microgrid, Monte-Carlo, Renewable Energy and Grid Inputs, Battery Energy Storage

I. Introduction

Rural microgrids are perhaps the best choices for providing energy to rural villages in developing countries, where supplying electricity is a major difficulty. Different types of energy inputs have been used in various rural microgrids. Some of the varied options are described in [1]-[8].

In most types of rural microgrids, generally solar energy inputs are used in conjunction with diesel generation. Additionally the microgrid may include inputs from a nearly grid supply and battery storage. Thus, with multiple inputs it becomes necessary to determine the optimal mix of the energy inputs so as to satisfy the energy needs of the microgrid at least cost.

The design of a microgrid energy management scheme is usually done using an optimization approach. In the literature, various options have been tried using different algorithms. Some of these are described in [9]-[16]. Most of the conventionally used optimization approaches involve complex formulation and coding. As an alternative, a simpler strategy is suggested using the Monte Carlo simulation Approach. In this method, we generate multiple random generations (typically greater than 10,000) of input options and evaluate for each set of options the cost of the total energy .The options which show the least cost, will obviously be the best options. Using data of a hypothetical rural village in a developing country, we attempt to illustrate the proposed methodology as an example.

II. The Microgrid

A microgrid can be thought of as a local power distribution system which operates by itself, but may also and may be connected to the external macrogrid [17]. Microgrids include distributed generation and storage units as well as local energy demands.

The microgrid contains various renewable energy inputs (solar, wind etc), connected loads on AC and DC buses and energy storage backups. Essentially, a microgrid consists of three or four main components.

1. Local Generation consisting of various distributed generators using renewable energy or fossil fuel (diesel).
2. Loads that involve electricity consumption for various domestic applications for single devices, lighting, space cooling and heating of dwellings, health centres etc.
3. Energy Storage Systems to assist multiple functions, such as ensuring power quality, including frequency and voltage regulation, smoothing the output of renewable energy sources, providing backup power for the system and playing crucial role in optimization of costs. Batteries are generally used for the energy storage.
4. A fourth component may be the inclusion of a grid supply, if available near the village.

Figure 1 shows a simple microgrid used in this example.

III. Problem Formulation

In this microgrid,

Pu = energy contribution of the grid
Px = energy contribution of the diesel generator
Py = energy contribution of solar PV system
Pb = energy contribution of the battery (ensuring that the SOC constraint is satisfied)

Pz = Total energy available at the microgrid

$$Pz = Pu + Px + Py + Pb \tag{1}$$

The following are to be noted:

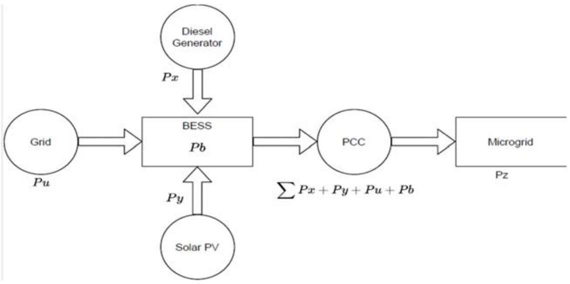

Fig. 1: Rural Microgrid with Four Energy Inputs

The total energy as available to the microgrid at the PCC is taken to be 1.0 p.u.

Energy options-grid, diesel generator and solar PV are expected to provide the total energy individually, if the need arises. Thus in terms of power delivery, we will have the following constraints:

$$0 < Pu < 1.0\ pu \tag{2}$$

$$0 < Px < 1.0\ pu \tag{3}$$

$$0 < Py < 1.0\ pu \tag{4}$$

The battery storage may be permitted to deliver power upto 70% of its SOC. Hence the constraint for the battery power delivery is :

$$0 < Pb < 0.7\ pu \tag{5}$$

$$Pzmax = \sum Pu + Px + Py + Pb = 3.7 \tag{6}$$

Using Monte Carlo random variable values for the above four inputs are generated within the specified operating limits as defined by constraints (2)-(6). Let

Cx, Cu, Cy and *Cb* be the respective costs of operation for the input units – diesel generation, grid solar PV and battery. If *Cz* be the total cost of operation of the PCC based on generated power, then total cost of energy delivered at the PCC is:

$$Cz = Cx * Px + Cu * Pu + Cy * Py + Cb * Pb \tag{7}$$

Using several hundred runs (ideally more than 5000) we obtain multiple values of *Cz*, which are arranged to yield the top most economical options for providing energy to the microgrid. However, in this case, we have used 1000 runs as we feel that further improvements in better results may not result. Since statistical probability of load matching is involved, the Monte Carlo appears to be ideally suited for generating various conditional cases for least cost operation of the microgrid.

The simulations were carried out in MS Excel of MS office software. Since the best input mix is to be evaluated, arbitrary operating costs have been assigned to the energy inputs as follows: This is done keeping typical commercial energy cost trends of these energy inputs in the market.

Cx = Rs 120 per p.u of energy/power contribution
Cu = Rs 80 per p.u of energy/power contribution
Cy = Rs 170 per p.u of energy/power contribution
Cb = Rs 140 per p.u of energy/power contribution

Table 1 gives a the results obtained using MS EXCEL of Microsoft Office package

TABLE 1: SIMULATED RESULTS

S. No.	Cz	Pu	Px	Py	Pb	Cu	Cx	Cy	Cb
6	148.1867	0.13736	0.090064	0.083465	0.801437	80	120	170	140
7	155.1446	0.328894	0.165673	0.0.39539	0.73022	80	120	170	140
8	158.5877	0.081943	0.259575	0.1.0318	0.738161	80	120	170	140
9	161.5978	0.02706	0.106627	0.047563	0.989657	80	120	170	140
10	162.1396	0.365491	0.042637	0.009047	0.901757	80	120	170	140
11	162.3466	0.026868	0.140412	0.106006	0.8595191	80	120	170	140
12	162.911	0.069105	0.167802	0.136476	0.814611	80	120	170	140
13	166.637	0.016078	0.194839	0.236278	0.727163	80	120	170	140
443	297.2358	0.813088	0.828359	0.131607	0.788661	80	120	170	140
444	297.2631	0.330771	0.230642	0.705171	0.880323	80	120	170	140
445	297.5069	0.19341	0.352493	0.805055	0.734826	80	120	170	140
446	297.5471	0.287592	0.055775	0.924253	0.790883	80	120	170	140
447	297.6473	0.544648	0.346171	0.630767	0.752175	80	120	170	140
448	297.8368	0.348072	0.280242	0.600606	0.958992	80	120	170	140
449	297.931	0.821086	0.762266	0.151206	0.821908	80	120	170	140
450	298.1167	0.994847	0.028363	0.545779	0.873879	80	120	170	140
451	298.1908	0.826674	0.131681	0.570324	0.852143	80	120	170	140
452	298.2268	0.425075	0.341089	0.697654	0.747778	80	120	170	140
836	373.6679	0.273661	0.953967	0.607391	0.957446	80	120	170	140
837	373.6933	0.634009	0.934195	0.481229	0.921859	80	120	170	140

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Table 2: Results Showing the Best Options

S. No.	Cz	Pu	Px	Py	Pb	Cu	Cx	Cy	Cb
1	135.8713	0.256454	0.053944	0.040528	0.728514	80	120	170	140
2	138.802	0.289989	0.018766	0.004237	0.804506	80	120	170	140
3	139.0354	0.106296	0.075375	0.014564	0.850078	80	120	170	140
4	140.2508	0.281932	0.044355	0.029428	0.766935	80	120	170	140
5	144.9887	0.114889	0.011829	0.19015	0.728948	80	120	170	140

Based on these simulation results, the top five best (minimum cost) solutions were identified, These are shown in Table 2 as follows.

Table 2 shows that the least cost option of Rs 135.87 per p.u of total energy while the last option shows a least cost of Rs 144.9 per p.u of total energy. The planner is provided with 5 best choices, so that in the event of the best choice not being chosen for various reasons, the next best options in line may be taken up.

IV. Conclusion

The paper is an attempt to examine an alternative to conventional optimization techniques to evaluate the best generation mix for rural microgrids. Monte Carlo simulation runs are used to accomplish the energy management and planning. The results show that such an alternative methodology can be usefully applied for rural microgrid energy resource inputs planning.

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