African Journal of Basic & Applied Sciences 9 (3): 105-111, 2017
ISSN 2079-2034

DOI: 10.5829/idosi.ajbas.2017.105.111

Energy Management of a Microgrid Using Multi Objective Genetic Algorithm

D. Suchitra, R. Jegatheesan, V. Subramaniyan and R. Santhana Venkatesam

Department of Electrical and Electronics Engineering, SRM University, Chennai-603203, India

Abstract: In present scenario, the generation system is directed towards Hybrid Renewable Energy System (HRES) due to the depleting nature of fossil fuel. So HRES provides a better alternative to conventional energy sources. The microgrid consisting of PV, wind, fuel cell, micro turbine and battery as a backup device is considered for analysis under grid connected mode and islanding mode. The composition of microgrid is formulated as a non-linear, constraint multi objective optimization problem to minimize the operating cost and pollutant treatment cost along with reliability. The Non-dominated sorting genetic algorithm II (NSGA II) is used as an optimization tool and it is implemented using MATLAB for hour-wise data of Zaragoza, Spain and test results are furnished.

Key words: NSGA-II · Hybrid Renewable Energy System · Optimization · Microgrid

INTRODUCTION

Diminishing supply of fossil fuel has encouraged a growth in sustainable energies such as the wind and solar power. Autonomous photovoltaic systems are generally used in remote locations, due to the expenses encountered in extending the national grid. A variety of isolated applications, for example, domestic applications, water irrigation and telecommunication repeater stations, have different power requirements. Hybrid power generation systems, especially those including renewable sources of energy, are greatly preferred in the current scenario, because of the rapidly increasing demand for electricity. The current situation of the energy sector with a continuous increase in the energy demand, together with the Greenhouse gas emissions and the exhaustion of the fossil fuel reserves look for enhanced the combination of renewable energy sources for distributed generation. This combination is denoted as Hybrid Renewable Energy Systems(HRES) or simply Hybrid Systems which are composed of one or more renewable energy sources and energy storage systems(ESS). This HRES can work in stand-alone or grid-connected mode.

Many researches have concentrated on the energy management of a microgrid using hybrid renewable energy system. The feasible and optimal solution to the economic dispatch problem was found [1] when the load profile is non-monotonic. The optimized design of micro grid in distribution systems with multiple distributed generation units under different market policies [2] was done. The minimum cost of micro grid was obtained using PSO algorithm. A multi-objective Fuzzy Self Adaptive Particle Swarm Optimization (FSAPSO) algorithm was developed [3] and it was applied to a typical micro grid to minimize the energy cost and emission reduction. The maximum power point tracking has been done via the fuzzy controller with respect to the conventional P and O method [4]. The methods used were Imperialist Competitive algorithm, PSO, Quantum-behaved PSO, Ant colony optimization and cuckoo optimization algorithm. Three PSO-based Energy Management System for a grid connected HRES integrating renewable energy sources, hydrogen system and battery were evaluated through long term Simulation using PSO Algorithm [5]. The Deficiency of power supply probability (DPSP) and the levelised unit cost (LUC) are optimized for a grid independent hybrid PV/wind system by using iterative optimization technique [6].

The multi objective particle swarm optimization technique is applied to the Microgrid and the size of the system components was optimized [7]. The loss of power supply probability was also optimized using Multi Objective Particle Swarm Optimization (MOPSO) Algorithm. Dynamic economic dispatch of a micro grid by establishing the spinning reserve probability constraint of a micro grid was analysed [8]. This System was verified

Corresponding Author: R. Santhana Venkatesam, Department of Electrical and Electronics Engineering, SRM University, Chennai-603203, India.

under two modes of a micro grid namely Grid connected and Islanding Modes. The total net present cost and pollutant emission were optimized [10] for a hybrid standalone power system using NSGA II. The optimization of HRES was done [11, 12] with Genetic Algorithm, Particle swarm optimization, Simulated annealing, Ant colony optimization and Differential evolution algorithm. This paper suggests non-dominated sorting genetic algorithm-II for energy management in a microgrid.

Problem Formulation: The current formulation treats economic emission dispatch problem as a multi-objective problem which attempts to minimize both operating cost and pollutant treatment cost simultaneously while satisfying equality and inequality constraints. The following objectives and constraints are taken into account in this paper.

Objective 1: Operating Cost of the Microgrid System: For the microgrid, the operating cost C_1 of the system [8] can be described as follows:

$$C_1 = C_{Fuel} + C_{OM} + C_{DC} + \left(M * C_{GRID}\right) \tag{1}$$

where,
Fuel Consumption cost of the Dgs

$$C_{Fuel} = K_{fc} * P \tag{2}$$

Operation and Management cost of the Dgs

$$C_{OM} = K_{om} * P \tag{3}$$

Depreciation cost of the Dgs

$$C_{DC} = \frac{ADCC}{P_{\max} * 8760 * C_f} * P \tag{4}$$

Depreciation cost per kilowatt-hour of the Dgs

$$ADCC = InCost * d(1+d)^{lt} / (1+d)^{lt} - 1 \tag{5}$$

where M indicates whether the microgrid is connected to the grid or not: when the microgrid is connected to the grid, M = 1, when the microgrid is in islanding mode, M = 0. C_{GRID} is the cost of interaction between the microgrid and the grid: it is being positive, represents that the microgrid is purchasing power from the grid; when it is negative, it represents that the microgrid is selling power to the grid. P is the output power of the DG, K_{fc} is the coefficient of fuel consumption, K_{om} is the coefficient of operation and management. P_{max} is the maximum power of the DG, C_f is a capacity factor, *InCost* is the installation cost per capacity of the DG, d is the interest rate, set at 8%, lt is the lifetime of the DG.

Objective 2: Pollutant Treatment Cost of the Microgrid System: For the microgrid, the pollutant treatment cost C_2 of the system [8] can be described as follows:

$$C_2 = \sum_{i=1}^{N} \sum_{k} \left(C_k \gamma_{ik}\right) P_i + \sum_{k} \left(C_k \gamma_{gridk}\right) P_{grid} \tag{6}$$

where i is the number of DG, N is the total number of the DG in the microgrid, k is the type of pollutant emission (CO_2, SO_2, NO_x), C_k is the treatment cost of the k^{th} class of pollutants per kilogram, γ_{ik} is the coefficient of pollutant emissions in g/kW, P_i is the output power of DG_i in kW, γ_{gridk} is the coefficient of pollutant emissions of the grid in g/kW, P_{grid} is the output power of the grid in kW.

The constraints of the system [8] are as follows:
(1) Power balance of the microgrid system

$$\sum_{i=1}^{N} P_i + P_{grid} + P_B = P_{load} \tag{7}$$

where P_{load} is the system load, P_i is the output power of DG_i and P_{grid} is the output power of the grid if P_{grid} is positive, the grid transmits power to the microgrid, if P_{grid} is negative, the grid absorbs power from the microgrid. P_B is the output of the battery: when P_B is positive, the battery is discharging, if P_B is negative, the battery is charging.

(2) Power limits of the Dgs

$$P_{i,\min} \le P_B \le P_{i,\max} \tag{8}$$

where $P_{i,min}$ is the lower limit of DG_i and $P_{i,max}$ is the upper limit of Dg_i.
(3) Operation constraints of the battery

$$SOC_{\min} \le SOC(t) \le SOC_{\max} \tag{9}$$

$$-P_{B,\max} \le P_B \le P_{B,\max} \tag{10}$$

The minimum and maximum limit of SOC to be consider as 0.1 and 0.9 as respectively. $P_{B,max}$ is the maximum power of charging and discharging the battery. It is very important to predict the State of Charge (SOC) of the battery accurately for controlling the charging/discharging process. The SOC of a battery while charging is described as follows:

$$SOC(t) = (1-\delta)SOC(t-1) - P_C \Delta t \eta_C / E_C \tag{11}$$

where P_C is negative, it represents the charging power, $\square_C$ is the charging efficiency, E_C is the total capacity of the battery during the calculation period Δt in kW, SOC(t) is the SOC of the battery in period t and SOC (t -1) is the SOC of the battery in period t-1. The SOC of a battery while discharging is described as follows:

$$SOC(t) = (1-\delta)SOC(t-1) - P_d \Delta t / (E_C \eta_d) \tag{12}$$

where P_d is positive, it represents the discharging power, $\square_d$ is the discharging efficiency and *d* is the self-discharge rate of storage in percentage per hour.

Dispatch Strategy: The microgrid with combination of PV, wind, micro turbine, fuel cell and battery as storage devices is termed as Hybrid System. The use of all or most of the sources at a specific time in order to maximize the reliability can significantly increase the total cost of the system during that hour. The Micro Grid is designed to connect or disconnect from the distribution system without any fault. There are two ways of operation of Micro Grid. They are Grid Connected mode and Islanding mode. During Grid connected mode, the phase, voltage, frequency and phase angles of the renewable energy sources, batteries and system loads are synchronized to the grid. In Islanding mode, all generation sources are intermittent and low priority loads may be disconnected depending on the amount of generation available.

Strategy 1-Under Islanding Mode: The DGs will contribute according to ideal scheduling. If the output power of the DGs is more than the load demand, the battery will be charged within its range. If the output power of the DGs is less than the load demand, the battery will be discharged within its range and if a power deficiency still exists in the microgrid, the system has to interrupt part of the unimportant load to confirm the power supply.

Strategy 2-Under Grid Connected Mode: The DGs are priority scheduled. When they cannot meet the load demand, the microgrid system will buy power from the grid.

Optimization Tool: Non-dominated Sorting Genetic Algorithm(NSGA) is a popular non-domination based genetic algorithm for multi-objective optimization. It is a very effective algorithm but has been generally criticized for its computational complexity, lack of elitism and for choosing the optimal parameter value for sharing parameter. A modified version, NSGA-II was developed, which has a better sorting algorithm, incorporates elitism and no sharing parameter needs to be chosen *a* priori. The population is initialized as usual. Once the population in initialized the population is sorted based on non-domination into each front. The first front being completely non-dominant set in the current population and the second front being dominated by the individuals in the first front only and the front goes so on. The individuals in each front are assigned rank (fitness) values or based on front in which they belong to. Individuals in first front are given a fitness value of 1 and individuals in second are assigned fitness value as 2 and so on. In addition to fitness value a new parameter called crowding distance is calculated for each individual. The crowding distance is a measure of how close an individual is to its neighbours. Large average crowding distance will result in better diversity in the population. Parents are selected from the population by using binary tournament selection based on the rank and crowding distance. An individual is selected if the rank is lesser than the other or if crowding distance is greater than the other one. The current population and current offspring are sorted again based on non-domination and finally the best *N* individuals are selected, where *N* is the population size. The selection is based on rank and the on crowding distance on the last front. The NSGA-II algorithm is same as that of [9] and [11].

System Considered: The Solar radiation and wind velocity of Zaragoza, Spain is considered for study. The algorithm is executed using MATLAB for an hour-wise daily data. The data's considered for the optimization are Load data, PV Array, Wind, Battery, Fuel Cell, Micro turbine and Grid. The Power Limits for DGs in Microgrid is shown are Table 1. The hour wise load data for a day is Shown in Figure 1.

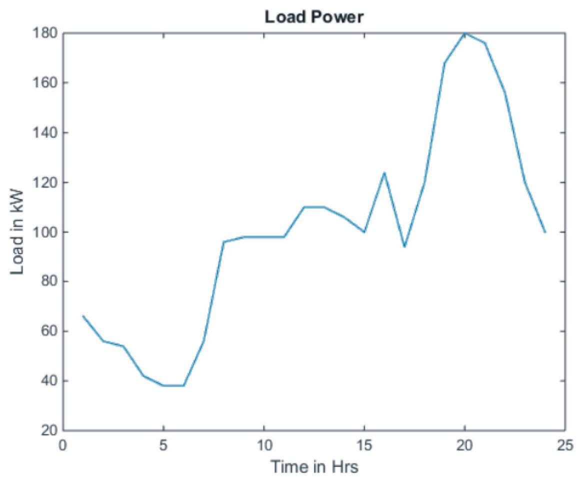

Fig. 1: Load Profile

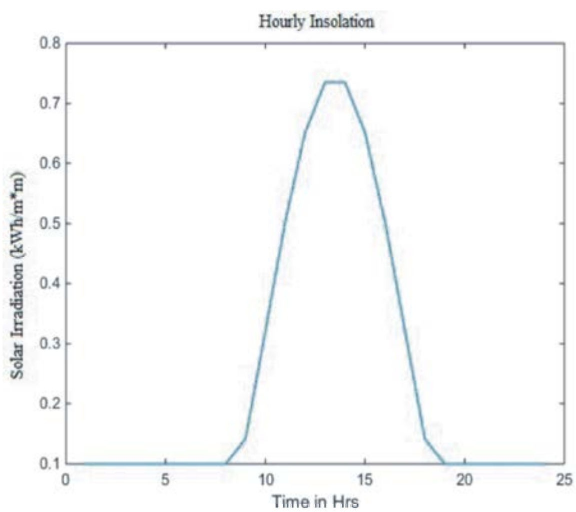

Fig. 2: PV Radiation Data

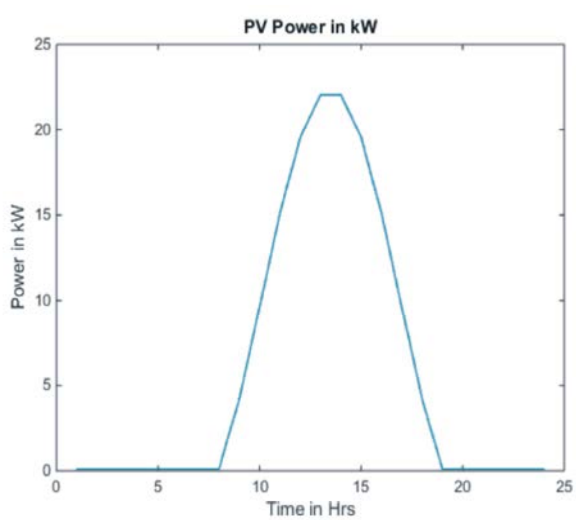

Fig. 3: PV Power

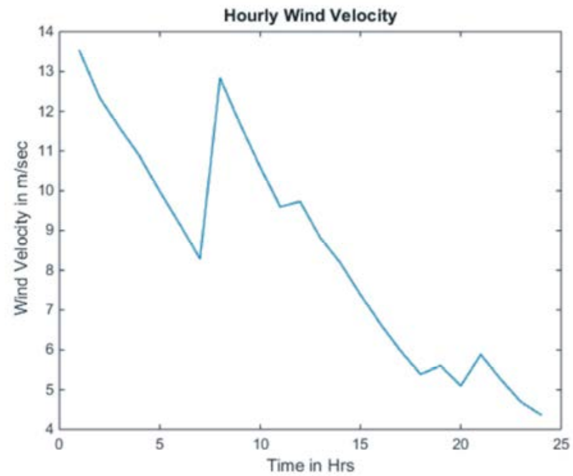

Fig. 4: Wind Velocity

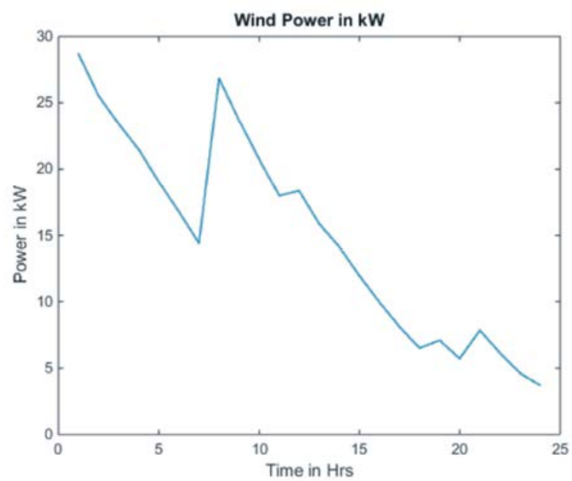

Fig. 5: Wind Power

Table 1: Power Limits of DGs in Microgrid

	Power (kW)	
Type	Lower Limit	Upper Limit
PV	0	30
Wind	0	30
FC	0	30
MT	0	30
BS	-30	30

The hour wise radiation data for the PV Panel and the corresponding power are shown in Figure 2 and 3 respectively.

The hour wise velocity data for the Wind Turbine and the corresponding power are shown in Figure 4 and 5 respectively.

The capacity of the battery is 150 kW/h and the initial state of SOC is assumed to be 50%. When it is in island mode, without the support of a large power grid,

Table 2: Cost Parameters for DGs

Type	l(yr)	InCost(Yen/kW)	K_{om}(Yen/kW h)	K_{fc}(Yen/kW h)
PV	20	66.50	0.0096	0
Wind	10	22.35	0.0296	0
MT	10	16.00	0.088	0.396
FC	10	42.75	0.0293	0.206

Table 3: Parameters of pollutant discharge

Type		CO_2	SO_2	NO_X
Treatment Cost (Yen/kW)		0.21	14.842	62.964
Pollutant Discharge	PV	0	0	0
Coefficient(gram/kW)	Wind	0	0	0
	MT	649	0.206	9.89
	FC	489	0.003	0.01
	Grid	889	1.8	1.6

the power output from the Micro Turbine(MT) meets the load demand to certain extent. The Cost parameters of the DGs are shown in Table 2. The Parameters of pollutant discharge coefficient and the treatment cost of the pollutants are shown in Table 3.

RESULTS AND DISCUSSION

In this section, the results of optimal sizing after the implementation of NSGA II algorithm in MATLAB environment are presented. The main objective is to minimize the operating cost and pollutant treatment cost of the generation and also to meet the load demand. The power from the fuel cell is kept constant at 25 kW.

First, consider simple islanding mode. When the microgrid is in islanding mode, the DG will supply power to the load. In this mode the power generated from Micro turbines are considered to be zero. The DG alone will not be able to meet the demand. The total operating cost of the system is 169.64 Yen without optimization. The excess power (Battery Power), generated power from the DGs, SOC of battery and the unmet load are shown in Figure 6, 7, 8 and 9 respectively.

Now two micro turbines are considered along with the PV/Wind/Battery/Fuel cell system to meet the demand without considering the emission. The output power of micro turbines are randomly generated as X(1) and X(2) for optimization. It has been observed that, still the unmet load exists.

The same problem is then optimized with considering the emission cost. The micro grid will purchase power from the grid because the load is not fully meet by the DG with micro turbine. The exchange power limit value between the grid and microgrid is assumed to be 80 kW. The operating cost and pollutant treatment cost in the grid connected mode is lesser than the islanding mode

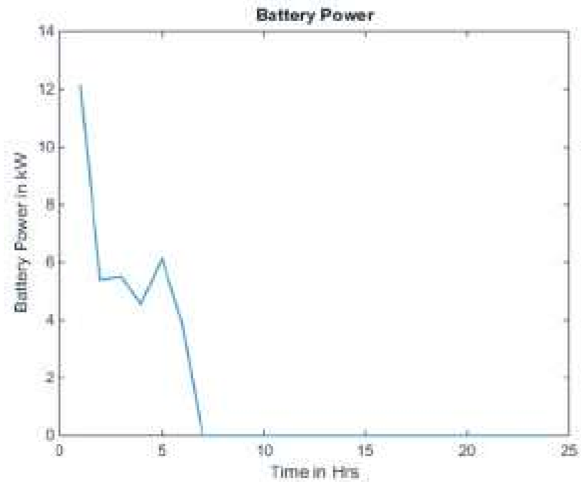

Fig. 6: Battery Power

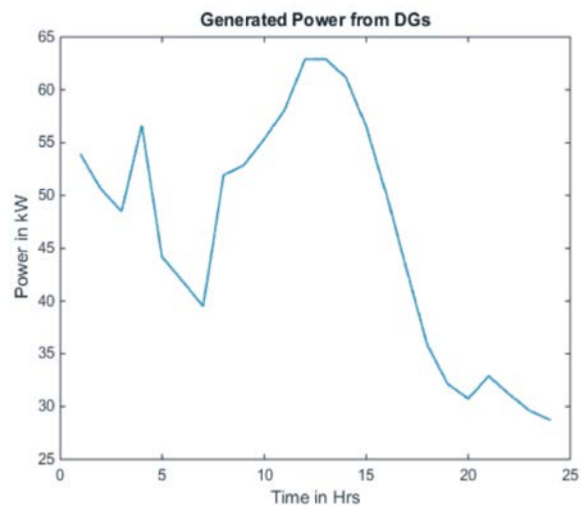

Fig. 7: Generated Power

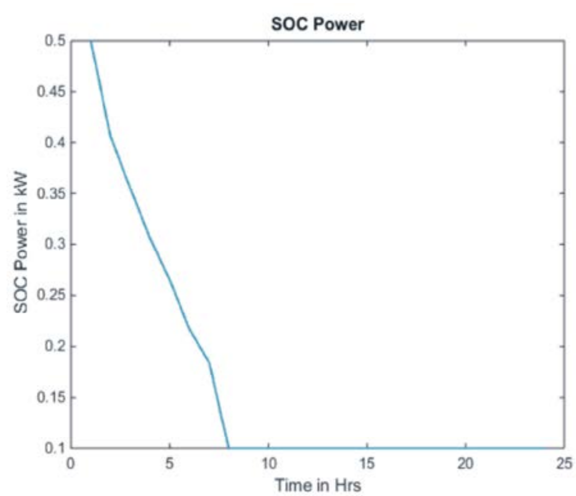

Fig. 8: State of Charge

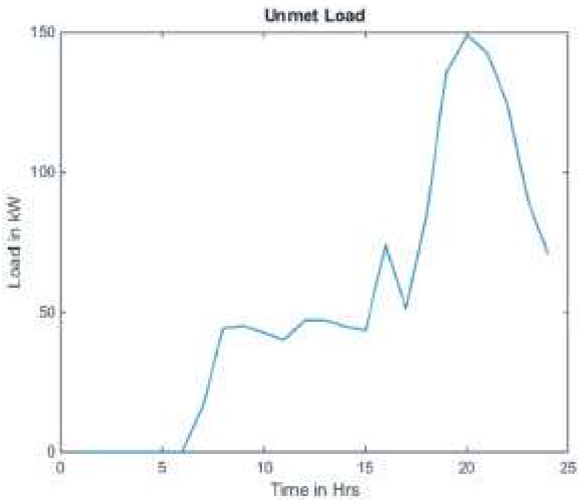

Fig. 9: Unmet Load

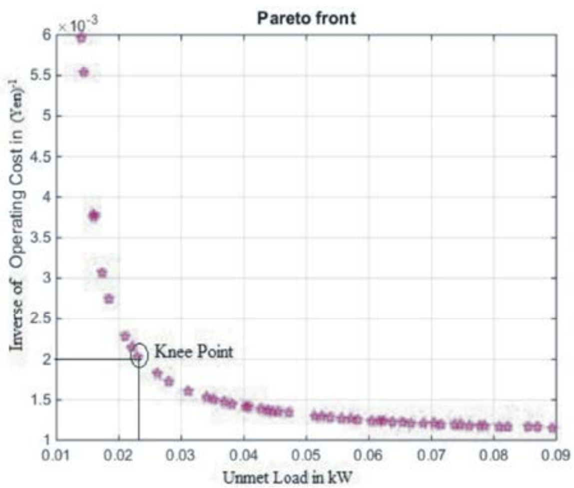

Fig. 10: Islanding Mode -Without Emission

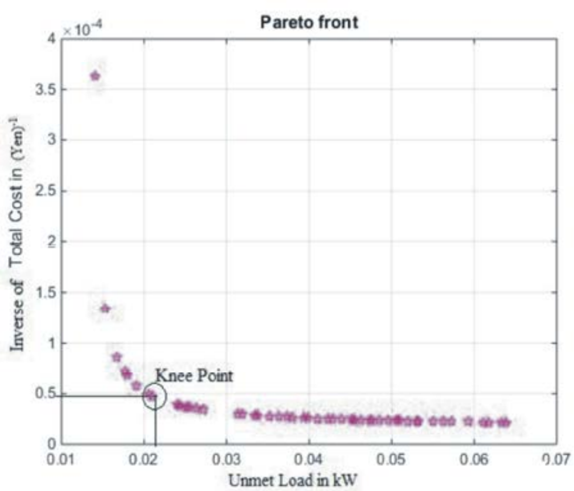

Fig. 11: Islanding Mode -With Emission

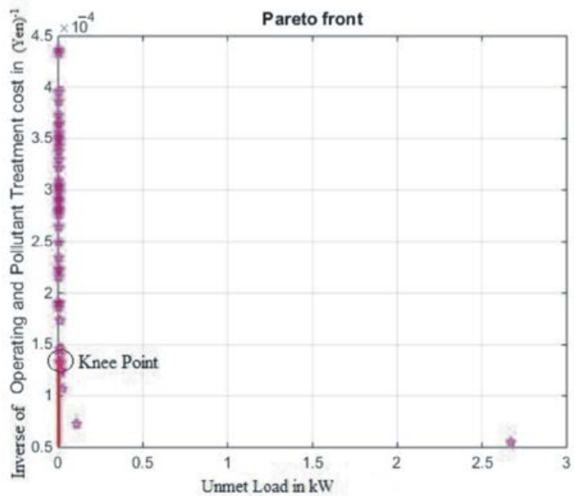

Fig. 12: Grid connected Mode -With Emission

with emission. The Outputs are shown in Table 3 and the Pareto optimal graph for the three cases, without considering emission, including emission and grid connected mode operation are shown in Figure 10, 11 and 12 respectively.

CONCLUSION

Access to a reliable source of electricity is a basic need for every individual; it can improve the standard of living. Implementation of micro-grids can be considered as the most promising solution for rural electrification as it decreases the installation costs and increases the quality of supply. This paper proposes a control strategy optimal operation of a Hybrid Micro-Grid System which can maintain continuous power to meet the load demand in different modes of operation. The combination of wind, PV, micro turbine, battery storage, fuel cell and grid for a sample load has been considered. The Non-Dominated Sorting Genetic Algorithm II (NSGA II) method is applied in order to obtain the optimum solution for operating cost and the pollutant treatment cost. Moreover, providing a suitable means of power exchange between the micro-grid and the utility grid can be beneficial in terms of both the objectives. Numerical results show that, the cost and the reliability has been considerably improved in grid connected mode as compared to islanding mode with emission. Also, in the proposed approach multiple Pareto-optimal solutions can be found in a single simulation sequence. Since the proposed approach does not impose any limitation on the number of objectives, problems with any number of objectives can be solved.

REFERENCES

1. Han, X.S., H.B. Gooi and Daniel S. Kirschen, 2001. Dynamic economic dispatch: Feasible and Optimal Solutions. IEEE Transaction on Power Systems, 16(1).
2. Mohammadi, M., S.H. Hosseinian and G.B. Gharehpetian, 2012. Optimization of hybrid solar energy sources/wind turbine systems integrated to utility grids as microgrid (MG) under pool /bilateral /hybrid electricity market using PSO. Science Direct: Solar Energy, pp: 112-125.
3. Anvari Moghaddam Amjad, Alireza Seifi and Taher Niknam, 2012. Multi-operation management of typical micro-grids using Particle Swarm Optimization: A comparative study. Science Direct: Renewable and Sustainable Energy Reviews, 16: 1268-1281.
4. Bigdeli Nooshin, 2015. Optimal management of hybrid PV/fuel cell/battery power system: A comparison of optimal hybrid approaches, Science Direct: Renewable and Sustainable Energy Reviews, 42: 377-393.
5. Pablo García-Trivino, Francisco Llorens-Iborra, Carlos A. García-Vazquez, Antonio J. Gil-Mena, Luis M. Fernandez-Ramírez and Francisco Jurado, 2014. Long-term optimization based on PSO of a grid-connected renewable energy /battery /hydrogen hybrid system. Science Direct: International Journal of Hydrogen Energy, 39: 10805-10816.
6. Kaabeche, A., M. Belhamel and R. Ibtiouen, 2011. Sizing Optimization of grid independent hybrid photovoltaic/wind power generation system. Science Direct: Energy, 36: 1214-1222.
7. Borhanazad Hanieh, Saad Mekhilef, Velappa Gounder Ganapathy, Mostafa Modiri-Delshad and Ali Mirtaheri, 2014. Optimization of Micro grid system using MOPSO, Science Direct: Renewable Energy, 71: 295-306.
8. Wu Hongbin, Xingyue Liu and Ming Ding, 2014. Dynamic economic dispatch of a micro grid: Mathematical models and solution algorithm, Science Direct: Electric Power and Energy Systems, 63: 336-346.
9. Deb Kalyanmoy, 2001. Multi-Objective Optimization using Evolutionary Algorithms, John Wiley & Sons, Ltd Publications.
10. Suchitra, D., R. Utthra, R. Jegatheesan and B. Tushar, 2013. Optimization of a Hybrid Stand-Alone Power System using Multi-Objective Genetic Algorithm, ISTI Transactions on Electrical and Electronics Engineering, 1(2): 2320-8945.
11. Deb Kalyanmoy, Sameer Agarwal, Amrit Pratap and T. Meyarivan, 2002. Associate Member, IEEE and Fast and Elitist Multi-objective Genetic Algorithm: NSGA-II. IEEE.
12. Hina Fathima A. and K. Palanisamy, 2015. Optimization in microgrid with hybrid energy systems – A review. Science Direct: Renewable and Sustainable Energy Reviews, 45: 431–446.