renewable energy, to reduce production cost (30%) a new algorithm for smart intelligent home energy management system with consumption shifting in demand response program considering various constraints has been proposed in work of Mirhosseini Moghaddam et al. [16] at a islanded mode. But the optimum sizes of energy storage system and real time implementations are not mentioned. In a MG, renewable sources, generators heat and output powers optimum combination is a major problem. To overcome multi-objectives optimization problems, the modified particle swarm optimization (PSO) called as neighbourhood re-dispatch PSO algorithm has been proposed in work of Si et al. [17]. The major objectives were to reduce electricity cost with minimum costs avoiding other parameters. In work of Chen et al. [18] a matrix perturbation theory based distributed optimization dispatch algorithm has been proposed to determine the optimal DG outputs and that also satisfied the supply, consumer demand constraints.

However, the researchers did not sufficiently study about the optimum economic dispatch strategy of islanded MMGs. In this paper genetic algorithm searches the optimum magnitude of the outturn power produced by the dispatchable distributed generator subject to minimization of operating cost. The objective function formulated the input fuel cost, operation cost, and emissions cost subject to various system constraints. The proposed optimization process is implemented on a typical MMG system.

CONTROL STRATEGY

There is no fixed or predefined structure of MGs control system; it depends on the types of configuration and MGs architecture [19]. Furthermore, the MMG system increases the system complexity. The centralized control architecture is discussed here [2, 10, 14, 19] with few modifications. The hierarchical control architecture comprises the following controller as shown in Fig.1: (i) Central power monitoring system (CPMS), (ii) Power management controller (PMC), (iii) Load management controller (LMC), and (iv) Microgrid controller (MGC).

The central power monitoring system (CPMS) is the decision maker and responsible for the economical optimization of the integrated system. It globally minimizes the total operating cost. It is aware about the characteristics of all the micro sources with their respective operational limits, controllable load and state of charge (SOC) of energy storage system (EES). The total load is observed and the supply demand is balanced according to operating strategy of the system.

The CPMS globally runs and sends the control signal to MGC, PMC and LMC for changing the power level under their controlling devices to balance the supply demand. PMC and LMC operate at medium voltage level. PMC controls the power of distributed generation units and EES. LMC monitors the controllable load by load shedding. Each of the MGCs will share out the power changes among its DG units and controllable loads at each MG.

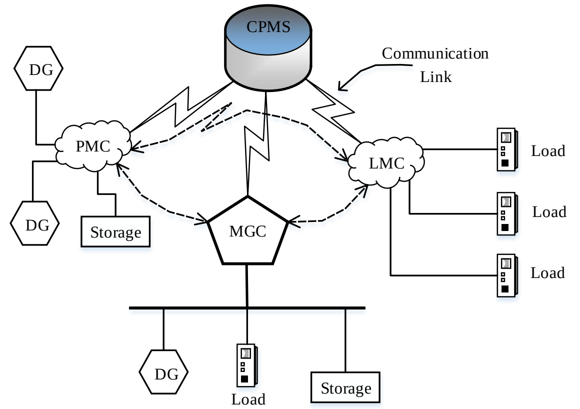

Figure 1. Hierarchical control structure of integrated microgrid

MODEL OF THE STUDIED SYSTEM

The schematic diagram of the studied MMGs system is shown in Fig.2. The adopted test network represents the architecture of a MV grid containing three MGs, several kinds of larger DGs and controllable loads. The MG1 consists with WTG, FC, ESS, MG2 with FC, DG, and MG3 with MTG and FC. Each MG has controllable load. MTG, WTG, ESS and some controllable loads is connected at medium voltage level. Two wind turbine generators is connected at MG1. At medium voltage level three wind turbine generators delivers power. The capacity and operational limits of distribution energy resources is given in Table 1.

The supply demand balance can be written by the following eq.(1) from Fig.2.

$$\sum P_L - \sum \left(P_{DEG} + P_{MTG} + P_{FC} + P_{WTG} + P_{PV} \pm P_{ESS} \right) = 0 \quad (1)$$

Table 1. Capacity and Limits of Microsources

Position	Micro-sources	Capacity (kW)	Lower Limit (kW)	Upper Limit (kW)
MG1	WTG	200	0	200
	FC	200	40	200
	ESS	50	-	-
MG2	FC	200	40	200
	DEG	250	45	250
MG3	MTG	200	30	200
	PV	300	0	300
MV	MTG	200	30	200
	WTG	300	0	300
	ESS	100	-	-

P_J = Net power generated at interval J (kW).

η = Microturbine avail at interval J.

The minimum and maximum loading constraint of MTG is given by eq.(4).

$$P_{MTG}^{Min} \leq P_{MTG} \leq P_{MTG}^{Max} \quad (4)$$

B. ***Fuel Cell (FC)***

The competency of any fuel cell can be described as follows [26] where all unit must be in the same scale.

$$\eta_{FC} = \frac{Electrical\ Power\ Output\ \ (P_{FC})}{Fuel\ Input\ \ (F_{FC})} \quad (5)$$

The typical output power versus efficiency curve of a typical 200 kW fuel cells is shown in Fig.5.

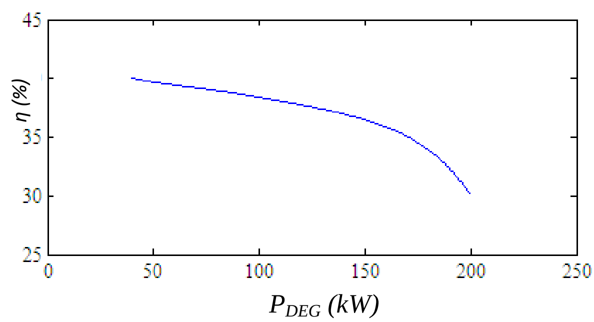

Figure 5. Fuel cell output power vs efficiency curve

The fuel input for the cell can be expressed as [25]:

$$F_{FC} = \sum_J \frac{P_J}{\eta_J} \quad (6)$$

Where the symbols represents their usual meaning

The minimum and maximum loading constraint of FC is given by eq.(7).

$$P_{FC}^{Min} \leq P_{FC} \leq P_{FC}^{Max} \quad (7)$$

C. ***Wind Turbine Generator (WTG)***

It is very common things that the speed of wind changes in every hours, days and seasons. For planning long term the wind distribution can be represents by by Weibull distribution functions as follows [27]:

$$f_v(v) = \begin{cases} \dfrac{\beta}{\alpha} \times \left(\dfrac{v}{\beta}\right)^{\rho-1} \times e^{\left(\frac{\gamma}{\alpha}\right)\beta} & v \geq 0 \\ 0 & Otherwise \end{cases} \quad (8)$$

Where, $\alpha, \beta \,\&\, v$ are the shape parameter, scale parameters of Weibull function and wind speed, respectively.

The output of WTG The performance curve of WTG can be approximated as a function of wind speed (V_w). A third order polynomial function is used to fit the parameters on wind speed and wind turbine performance curve. By using the following expression, the generated output power of WTG can be determined.

$$P_{WTG} = \begin{cases} 0, & V_w < V_{Cut-in} \\ aV_w^3 + bV_w^2 + cV_w + d, & V_{cut-in} \leq V_w < V_r \\ P_{Rated}, & V_r \leq V_w \leq V_{cut-out} \end{cases} \quad (9)$$

Where V_{cut-in}= Cut in speed, V_r=Rated speed and $V_{cut-out}$=Cut out speed.

The power curve of a 100kW turbine is shown in Fig.6 is used in this model [28]. The input wind speed is considered for this model is shown in Fig.7.

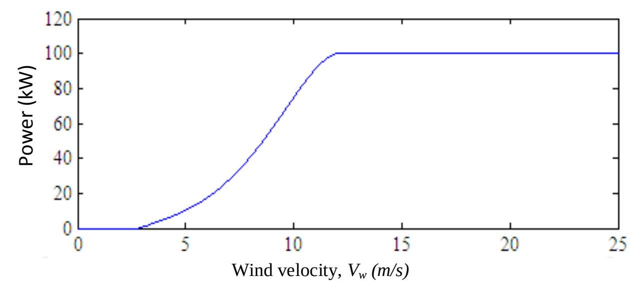

Figure 6. Power curve of a *100 kW* turbine

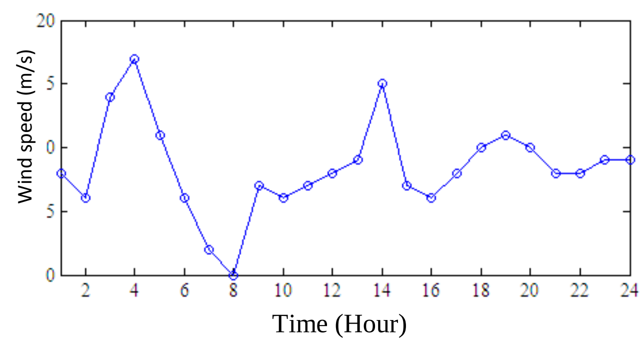

Figure 7. The input wind speed as used in the model

D. ***Solar Photovoltaic (PV) System***

The output power of solar photovoltaic depends on environmental conditions, such as solar radiation and temperature, resulting in a non-linear and time-variant power source. Depending in the solar radiation and load current, the output power of the PV module will be changed that follows the equation (10) [29],

$$P_{PV} = \eta A\phi\left[1 - 0.005(T_a + 25)\right] \quad (10)$$

Where, S is the area of PV array (m^2), φ presents the solar irradiation *(W/m²)* and T_a is ambient temperature *(^0C)*. Our Studied system has the following parameters: *A=2000m²,* *η=20%* and we assume temperature is constant *(T_a=25^{0}C)*. The solar irradiation data for 24 hour period used in this model is given in Fig.8.

If $\Delta P_L>0$, the remaining power will be given by the ESS or by the distributed generator (DEG, MTG, FC. Meanwhile, the charging and discharging of the ESS is properly monitored. The tuning of output power of DGs by genetic algorithm occurs in the following ways.

1. Initialization: The algorithm begins by creating an initial population. This population is normally randomly reproduced at any desired size.
2. Evaluation: The fitness value of chromosomes is now evaluated by calculating the cost function or objective function. Here, it is tried to find the minimum magnitude of the cost function.
3. Selection: Selection helps to discard the weak individuals and only keeps the best individuals called parents that contribute to the population at the next generation. There are a small number of selection methodologies but the primary concepts is the same, make it more likely the best adjuster individuals will be selected for our upcoming generation.
4. Crossover: In this stage, new individuals are created by combining prospective of chosen individuals. By combining two or more individuals it will create a fitter offspring from each of its parents.
5. Mutation: Mutation typically works by making very small changes at random to an individual's genome.
6. Termination: Now the next generation is started again from step two until it reaches a maximum number of generations.

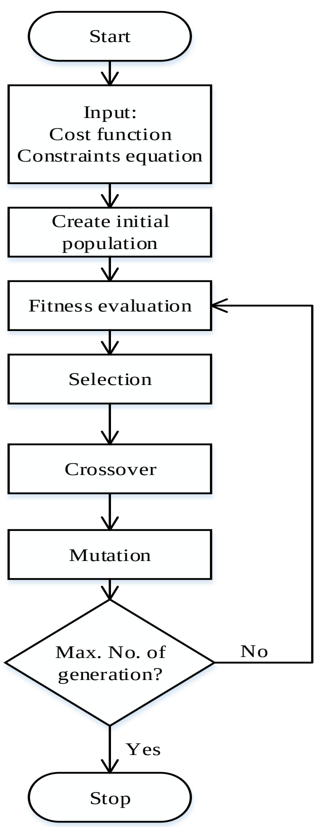

Figure 9. Flow chart for genetic algorithm

RESULTS AND DISCUSSION

The total load profile for the studied integrated system used for simulation purpose is shown in Fig.10. The scheduling time is 24 hours in a day with the scheduling time interim of 1 hour. The load demand varies between 430kW to 1500kW. The optimization model that is discussed in the past section is implemented to this time-varying load.

The total renewable power i.e. summation of total power from WTG and solar PV is shown in Fig.11. Also, WTG and solar PV power profile is given to the following figures according to their location in system. After observing the total load and renewable power of the system, the genetic algorithm is used to find out the optimum power generation of microsources subject to minimum operating cost according to control strategy. The various combination of produced power is shown from Fig.12 to Fig.15.

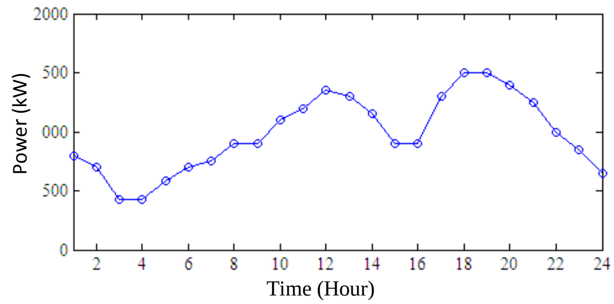

Figure 10. Total load profile of the simulated system

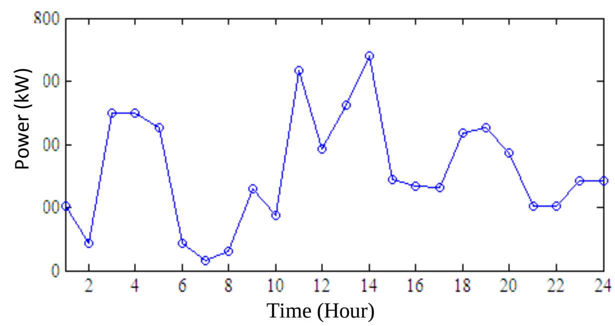

Figure 11. Total renewable power of the simulated system

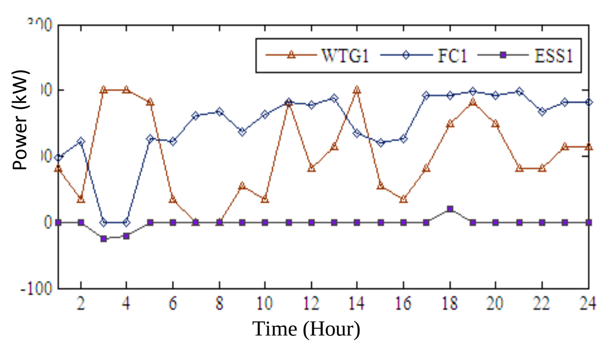

Figure 12. Power profile at MG 1

REFERENCES

[1] S. Chowdhury, S. P. Chowdhury, P. Crossley. *Microgrids and Active Distribution Networks: Renewable Energy Series 6.* London, United Kingdom: The Institution of Engineering and Technology, 2009.

[2] N. J. Gil, J. A. P. Lopes. Hierarchical Frequency Control Scheme for Islanded Multi-Microgrids Operation. *Lausanne Power Tech Lausanne*; 2007 July 1-5; Lausanne. IEEE; 2007. 473-478p.

[3] S. A. Gopalan, V. Sreeram, H.H.C. Iu, Z. Xu, Z.Y. Dong, K. P. Wong. Fault Analysis of an Islanded Multi-Microgrid. *Power and Energy Society General Meeting*. 2012 July 22-26; San Diego, CA.IEEE; 2012. 1-6p.

[4] W. Xi, Q. Xiaoyan, J. Runzhou, et al. Economic Operation of Multi-Microgrids Containing Energy Storage System. *International Conference on Power System Technology (POWERCON).* 2014 October 20-22; Chengdu. IEEE; 2014. 1712 – 1716p.

[5] D. Rua, J. A. Peças Lopes, J. Ruela. Communications Uncertainties in Isolated Multi-Microgrid Control Systems. *Power Systems Computation Conference (PSCC).* 2014 August 18-22; Wroclaw. IEEE; 2014. 1– 7p.

[6] S. A. Arefifar, Y. Abdel-Rady I. Mohamed, Tarek El-Fouly. Optimized Multiple Microgrid-Based Clustering of Active Distribution Systems Considering Communication and Control Requirements. *IEEE Transactions on Industrial Electronics*, vol. 62, no.2, pp. 711–723.

[7] Georgia E. Asimakopoulou, Aris L. Dimeas, Nikos D. Hatziargyriou. Leader-Follower Strategies for Energy Management of Multi-Microgrids. *IEEE Transactions on Smart Grid*. 2013 ; 4(4) : 1909 – 1916p.

[8] D. Rua, L. F. Moura Pereira, N. Gil, et al. Impact of Multi-Microgrid Communication Systems in Islanded Operation. *2nd IEEE PES International Conference and Exhibition on Innovative Smart Grid Technologies (ISGT Europe)*; 2011 December 5-7; Manchester. IEEE; 2011. 1– 6p.

[9] Y. Yang, W. Pei, H. Xiao, et al. Comprehensive planning of Multiple Microgrids with Self-Healing Consideration. *International Conference on Power System Technology (POWERCON);* 2014 October 20-22; Chengdu. IEEE; 3275–3281p.

[10] A. G. Madureira, J. C. Pereira, N. J. Gil, et al. Advanced Control and Management Functionalities for Multi-Microgrids. *European Transactions on Electrical Power.* 2011; 21(2): 1159–1177p.

[11] P. Li, X. Guan, J. Wu, et al. An Integrated Energy Exchange Scheduling and Pricing Strategy for Multi-Microgrid System. *TENCON 2013-2013 IEEE Region 10 Conference (31194);* 2013 October 22-25; Xian. IEEE; 2013. 1-5p.

[12] A. Kargarian, B. Falahati, Yong Fu, et al. Multiobjective Optimal Power Flow Algorithm to Enhance Multi-Microgrids Performance Incorporating IPFC. *IEEE Power and Energy Society General Meeting*; 2012 July 22-26; San Diego, CA. IEEE; 2012. 1-6p.

[13] D. Gregoratti, J. Matamoros. Distributed Energy Trading: The Multiple-Microgrid Case. *IEEE Transactions on Industrial Electronics.* 2015; 62(4): 2551–2559p.

[14] J. Vasiljevska, J.A. Pecas Lopes, M.A. Matos. Integrated Micro-Generation, Load and Energy Storage Control Functionality under the Multi Microgrid Concept. *Electric Power Systems Research.* Elsevier. 2013; 95: 292–301p.

[15] T. Logenthiran, D. Srinivasan, A. M. Khambadkone et al. Optimal Sizing of Distributed Energy Resources for Integrated Microgrids Using Evolutionary Strategy. *IEEE Congress on Evolutionary Computation (CEC); 2012 June* 10-15; Brisbane, QLD. IEEE; 2012. 1-8p.

[16] M. Mirhosseini Moghaddam et al., Optimal Energy Management for a Home Microgrid Based on Multi-Period Artificial Bee Colony, *25th IEEE Iranian Conference on Electrical Engineering (lCEE2017)*, Iran, 2017,1446-1451p, DOI: 10.1109/IranianCEE.2017.7985270.

[17] F. Si1, J. Wang et al., A Multi-Objective Optimization Strategy for Combined Heat and Power Systems of the Energy Internet, *2017 29th Chinese Control And Decision Conference (CCDC),* 28-30 May 2017, China, **DOI:** 10.1109/CCDC.2017.7978735.

[18] G. Chen, Z. Li, Z. Liu, A Distributed Solution of Economic Dispatch Problem in Islanded Microgrid Systems, *2016 IEEE Chinese Control and Decision Conference (CCDC),* 28-30 May 2016, China, 6804-6809p, **DOI:** 10.1109/CCDC.2016.7532223.

[19] N. Hatziargyriou. *Microgrids Architectures and Control*. United Kingdom: John Wiley and Sons Ltd; 2014.

[20] Ch. Wang, M. Liu, L. Guo. Cooperative Operation and Optimal Design for Islanded Microgrid. *IEEE PES Innovative Smart Grid Technologies (ISGT)*; 2012 January 16-20; Washington, DC. IEEE; 2012. 1-8p.

[21] F. Katiraei, C. Abbey. Diesel Plant Sizing and Performance Analysis of a Remote Wind-Diesel Microgrid. *IEEE Power Engineering Society General Meeting*; 2007; Tampa, FL. IEEE; 2007. 1-8p.

[22] Said H. El-Hefnawi. Photovoltaic Diesel-Generator Hybrid Power System Sizing. *Renewable Energy, Elsevier Science Ltd.* 1998; 13(1) : 33-40p.

[23] Diesel Service & Supply website [Internet]. (cited: 15th march 2015) Available from: http://www.dieselservice andsupply.com/.

[24] Capstone turbine corporation website [Internet]. (cited: 15th march 2015) Available from: http://www.capstoneturbine.com/

[25] F. A. Mohamed, H. N. Koivo. System Modelling and Online Optimal Management of Microgrid Using Mesh Adaptive Direct Search. *Electrical Power and Energy Systems, Elsevier.* 2010. 32(5) : 398-407p.

[26] F. Barbir, T. Gomez. Efficiency and Economics of Proton Exchange Membrane (PEM) Fuel Cells. *International Journal of Hydrogen Energy*. 1997; 22(10/11): 1027-1077p.

[27] N. Nikmehr and S. Najafi Ravadanegh, Optimal Power Dispatch of Multi-Microgrids at Future Smart Distribution Grids, *IEEE Transactions on Smart Grid*. 2015; 6(4): 1648 – 1657p, **DOI:** 10.1109/TSG.2015.2396992.

[28] Polaris America Turbines website [Internet]. (cited 20th march 2015) Available from: http://www.polarisamerica.com /turbines /100kw-wind-turbines/.

[29] D. J. Lee, L. Wang. Small-Signal Stability Analysis of an Autonomous Hybrid Renewable Energy Power Generation/Energy Storage System Part I: Time-Domain Simulations. *IEEE Transactions on Energy Conversion.* 2008; 23(1) : 311-320p.

[30] S. Chanana, A. Kumar. Operation and control of BESS using frequency-linked pricing in real-time market with high wind penetration. *International Journal of Energy Sector Management, Emerald.* 2011; 5(4) : 585-602p.

[31] H. Vahedi, R. Noroozian, S. H. Hosseini. Optimal Management of Microgrid Using Differential Evolution Approach. *7th International Conference on the European Energy Market (EEM)*; 2010 June 23-25; Madrid. IEEE; 2010. 1-6p.

[32] A. M. Azmy and I. Erlich. Online Optimal Management of PEM Fuel Cells Using Neural Networks. *IEEE Transactions on Power Delivery*.2005; 20(2) : 1051–1058p.