Maher G. M. Abdolrasol [1,*], Azah Mohamed [1], M A Hannan [2]

J. Electrical Systems 13-2 (2017): 285-294

Journal of Electrical Systems

Regular paper

Virtual Power Plant and Microgrids controller for Energy Management based on optimization techniques

This paper discuss virtual power plant (VPP) and Microgrid controller for energy management system (EMS) based on optimization techniques by using two optimization techniques namely Backtracking search algorithm (BSA) and particle swarm optimization algorithm (PSO). The research proposes use of multi Microgrid in the distribution networks to aggregate the power form distribution generation and form it into single Microgrid and let these Microgrid deal directly with the central organizer called virtual power plant. VPP duties are price forecast, demand forecast, weather forecast, production forecast, shedding loads, make intelligent decision and for aggregate & optimizes the data. This huge system has been tested and simulated by using Matlab simulink. These paper shows optimizations of two methods were really significant in the results. But BSA is better than PSO to search for better parameters which could make more power saving as in the results and the discussion.

Keywords: Virtual Power Plant, Microgrid, Energy Management System, Backtracking search algorithm, particle swarm optimization algorithm.

Article history: Received 19 March 2017, Accepted 2 May 2017

1. Introduction

Policies for distributed generation installation push to connection to girds instead of integration many distributed generations instilled by method called “fit and forget” this way makes the distributed generations is not visible to the grid network the energy generated through centralised generation instead of active management or representation to the system, that will cause the distributed generation to loss the network active support and security; consequently, each participated distributed generation need a centralised generation [1]. Every distributed generation in the system network either interruptible loads or renewable generator connected to the gird need to reduce energy and capacity supplied from centralised generators and as such can be observed as distributed energy resources. Considering the ability to enhance efficiency of the network and it is controllability [2-3].

Normally single distributed generation could not reach to energy markets, no visibility, but when aggregated number of distributed generations in one or more Microgrids would gain a visibility, controllability and impact similar to a transmission-connected generator in a form of virtual power plant (VPP) [4].

Single distributed generation will be able to have access and visibility will benefit from VPP market adds to that the gird operation and optimization of all the distributed

* Corresponding author: Maher G. M. Abdolrasol, Department of Electrical, Electronic and System Engineering, Faculty of Engineering and Built Environments, Universiti Kebangsaan Malaysia, Bangi, 43600, Selangor, Malaysia, E-mail: maher.abdolrasol@gmail.com

[1] Department of Electrical, Electronic and System Engineering, Faculty of Engineering and Built Environments, Universiti Kebangsaan Malaysia, Bangi, 43600, Selangor, Malaysia

[2] Department of Electrical Power Engineering, College of Engineering, Universiti Tenaga Nasional, Bandar Baru Bangi, 43650, Selangor, Malaysia

generations in the system will get a great profit. This paper is proposes a controller for energy management system (EMS) based on optimization techniques calls Backtracking search algorithm (BSA) and particle swarm optimization algorithm (PSO) respectively. Both optimization algorithms have been used to search for the optimal plan for EMS dealing VPP integrating renewable energy resources operate distribution system for 24 hours. By 100 iteration in the optimization process in order to run VPP system for hundreds times to search for the best objective in order to minimizing the power supplied from the main substations.

The rest of this paper is discussing the VPP and Microgrid, modelling of the system, then controller algorithms design with expiation of methodology of each technique finally, results and discussion of both optimization techniques.

2. Virtual power plant and Microgrids

VPP is a multi-technology unit, which contains together renewable and non-renewable generators in addition to energy storage system (ESS) linked with smart devices and communication and information technology systems. A VPP is essentially an accumulated section of energy savings and distributed generation activities delivering a set of outcomes that help to improve the energy efficiency of distributed generation. This makes it possible to scale up the implementation of distributed generation systems giving it recognition and equal status in energy sector investment processes. The motivation behind creating VPP technology is to coordinate the various types of energy resources to minimise the cost of power generation and maximise the profits received from the sale of that power.

A Microgrid is a small power system with a cluster of loads and distributed generators operating together through energy management software and devices [5]. A Microgrid is a cluster of local distributed energy resources and loads in such a way that an operation within the grid or in islanded mode is possible [5-6]. Usually it is connected at the low voltage level but sometimes also at the medium voltage level. The connected Microgrid appears as one node, generating or consuming power from the grid.

The concepts of Microgrids and VPP are usually considered for the integration of renewable energy resources. These two concepts have advantages. The motivation behind merger these concepts in a holistic manner to combine their strengths has not been thoroughly investigated in the literature. Perhaps, a single Microgrid is very small to contribute in energy markets. Including a Microgrid in a VPP could allow more profitable access to electricity markets. Thus, this project will attempt to address these shortcomings and investigate means of integrating Microgrids in a VPP concept as it is been recommended by IEEE standard [7]. This research is very important, as the consequences of this research will help utilities in scaling up the implementation and interconnection of distributed generations into existing networks. Fig.1 shows virtual power plant and Microgrids including distributed generators integration.

The main contribution for the proposed optimization algorithm in the EMS is to control and coordinate the power flows in each Microgrid come up with:

1) Cost effective: Decrease cost of the generation, buying energy from the grid and cost of the ESS.

2) *High reliability:* more reliability in the system to satisfy the consumers.

3) *Losses effective:* power losses reduction by means of constraints in to Distributed generations, system operation, loads, and the power-flow.

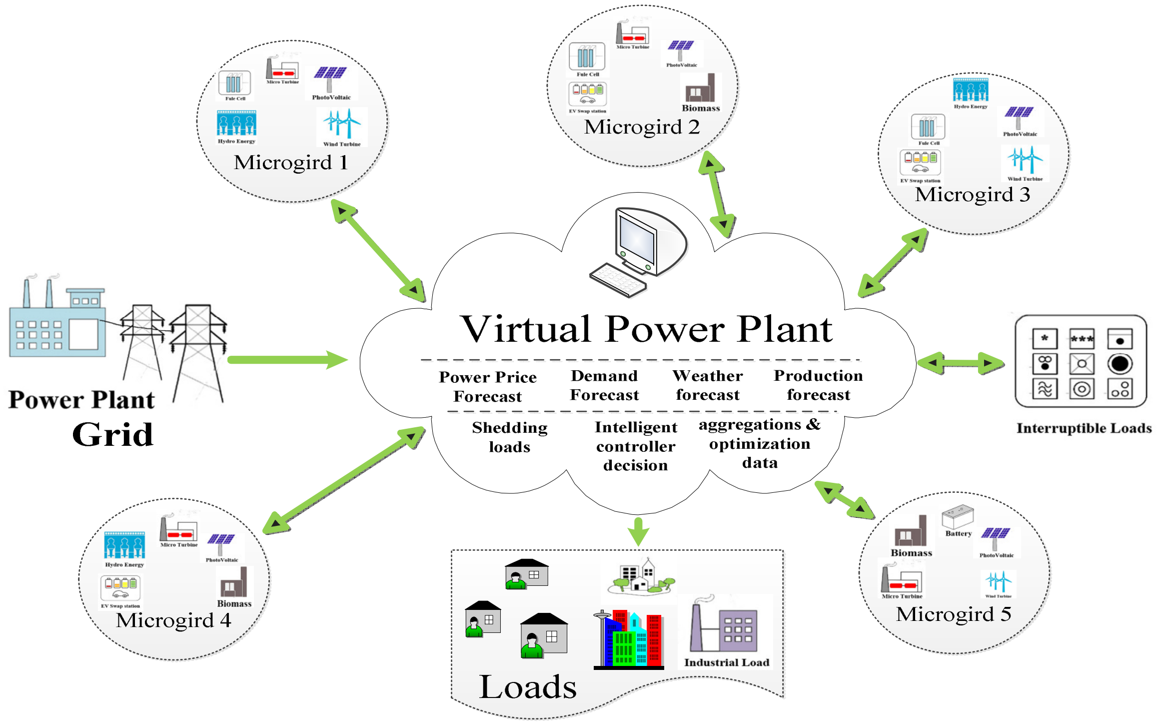

Fig. 1 Virtual power plant and Microgrids including distributed generators.

3. Modelling

The modelling is including a number of Microgrids in the VPP system. However, in this paper a single Microgrid considered as example of one Micorgird number three, it includes Hydro power, photovoltaic (PV), wind turbine (WT), solid oxide fuel cell (SOFC) and electrical vehicle (EV) Charge Hub as in Table 1.

Table 1: Microgrid sources type, capacity and fuel.

Source Type	Capacity	Fuel
Diesel Generator	3.5 MW	Diesel
Photovoltaic (PV)	1.2 MW	Solar Irradiance
Wind turbine (WT)	1.9 MW	Wind speed
Solid oxide fuel cell (SOFC)	0.8 MW	H_2
EV Charge Hub	1.1 MW	Charging

3.1. VPP Energy management system controller design

The EMS essentially is a set of transmitters, sensors, data acquisition, data control systems and data processing performed at distributed generation location. The EMS has a supervisory controller to do number of tasks for example statues ON and OFF, and rearranging temperature set points based on distributed generation circumstances [8]. The main duty for EMS is to create appropriate set points to permit each distributed generation in the system sharing its power in a clever way that economically optimised power dispatch will be maintained to fulfil certain load demand [9]. Since weather conditions always unstable due to variation of solar irradiation [10], wind speed and temperature situation make forecasting and fast online algorithms very important to take part of EMS to be is used to define the energy availability and to define the optimised power dispatch signals to the loads. This optimizations play vital part of finding the best set points for the system operation to reduce power consumption, although delivering excellent power to consumers. Fig.2 shows EMS and optimization algorithm control flow in the VPP system.

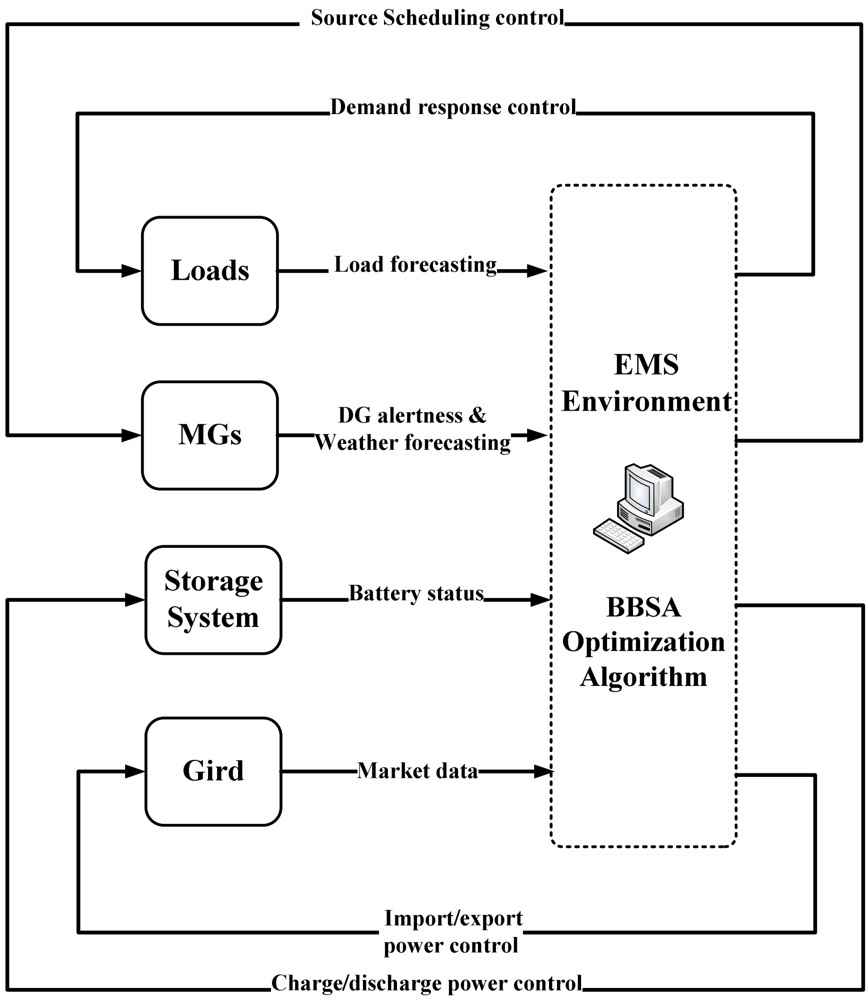

Fig.2 EMS based on an algorithm input and output control flow

In newly restructured electricity market, the GenCo and other market players (load serving entities, distribution companies) can sign long-term bilateral contracts to cover players needs that derives from the demand of their customers. These bilateral contracts cover the real physical delivery of electrical energy. The actors agree on different prices, quantities or different qualities of electrical energy. Also, duration of the contracts may differ, from medium-term (weekly, monthly) to long-term (yearly, few years). How much of their capacity and demand the GenCo and players will contract through bilateral contracts, and how much they will leave open for spot transactions, is their strategic and fundamental question. Basically, their reasons for contracting bilateral contracts are follows. Because of price volatility, the risk of market power and possible constraints in transmission network, the GenCo will estimate how much of its capacity will be contracted through bilateral contracts, and how much of capacity will be offered on the spot market.

4. Controller algorithm design

The controller optimization techniques comprise two separated techniques firstly, backtracking search algorithm and secondly, particle swarm optimization further details of each techniques explained as following two points:

4.1. BSA optimization techniques

BSA is an evolutionary computation technique as a solution for real-valued numerical optimization problems. It is principle is producing a random trial population includes two new crossovers and mutation operators. Primary BSA optimization developed by Pinar Civicioglu in 2013 [11] this technique produce a trial populations and dominates the search value which is the best populations and searching in the spaces borders to find the very sturdy exploration and exploitation capabilities [12-13]. In this paper back tracking search algorithm is presented with some consideration for the application by generating codes can control multi distributed generation in each Mircogird in the VPP system. Finding the best objective for the system with trial and error is an impossible mission but with optimization would be very easy. The target is to reduce the extreme power from the distribution system, contributing efficiently on proper time and proper price and using the sustainable resources. The BSA technique has several stages as in the flow chart in Fig.3.

$$T(t) = XT + 3 * rand(oldXT - XT) \quad (1)$$

4.1. PSO optimization techniques

Particle swarm optimization was introduced by Kennedy and Eberhart (1995, 2001); it has been effectively applied to optimize various continuous nonlinear functions [14]. PSO has a very simple theory and economic computational. PSO technique population is started randomly with particles and evaluated to calculate fitnesses composed with finding the particle best (best value of each individual so far) and global best (best particle in the whole swarm). Initially, each individual with its dimensions and fitness value is assigned to its particle best. The best individual among particle best population, with its dimension and fitness value is, on the other hand, assigned to the global best [15-16]. Fig.4. shows the flow char of PSO optimization algorithm.

The loop runs aims to meet the optimum solution. During this loop particle and global bests are determined to update the velocity first. At that time the current position of every particle is reorganized with the current velocity then performed the estimation again to compute the fitness of the swarm particles. However, the loop is ended with a discontinuing criterion prearranged in advance. In this paper a PSO principle of this algorithm is simulator to the normal PSO with some modification to make PSO codes control multi distributed generation in each Microgrid in the system. Finding the best set points for the system with trial and error is an impossible mission but with optimization would be very easy. The target is to reduce the extreme power from the main network, contributing in the distribution system efficiently on proper time and proper price and using the sustainable resources as much as fuel can be kept save to save the cost.

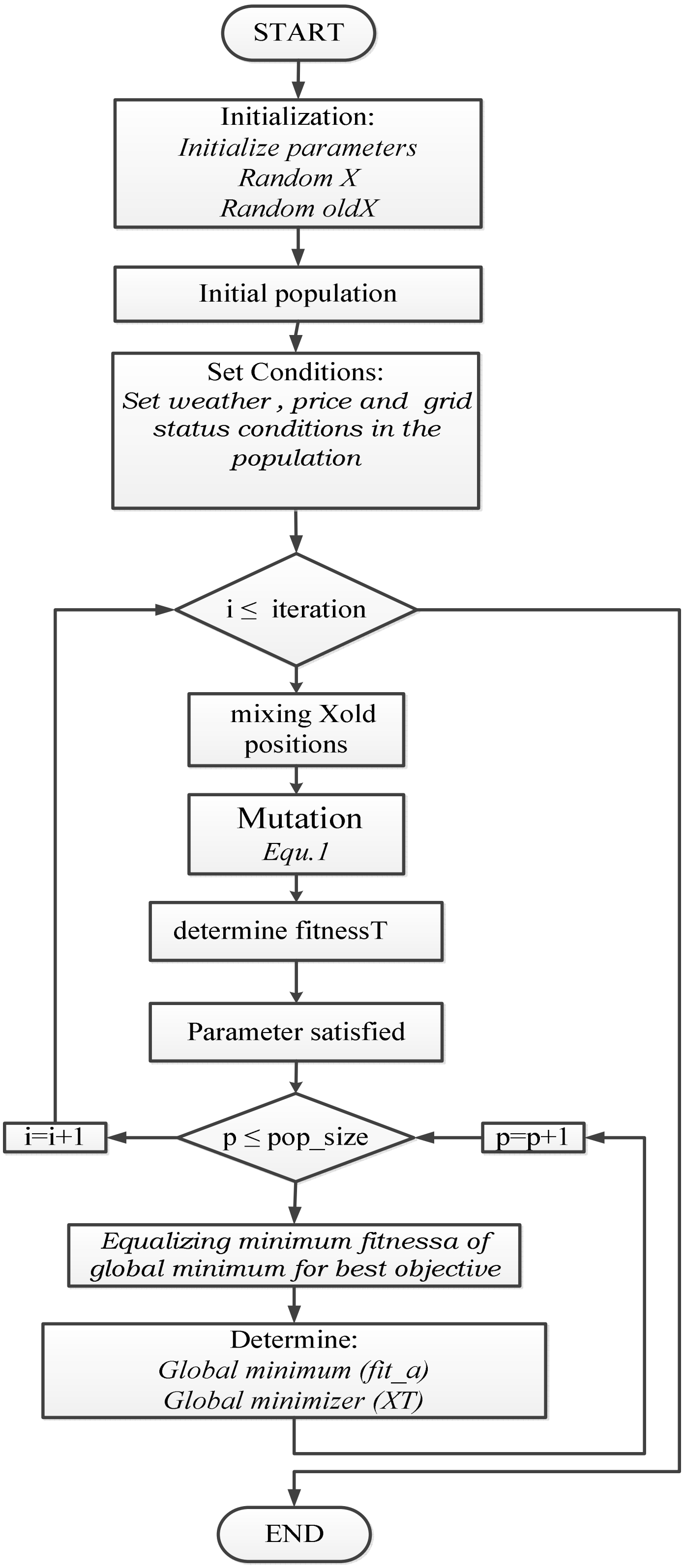

Fig.3 BSA algorithm flowchart.

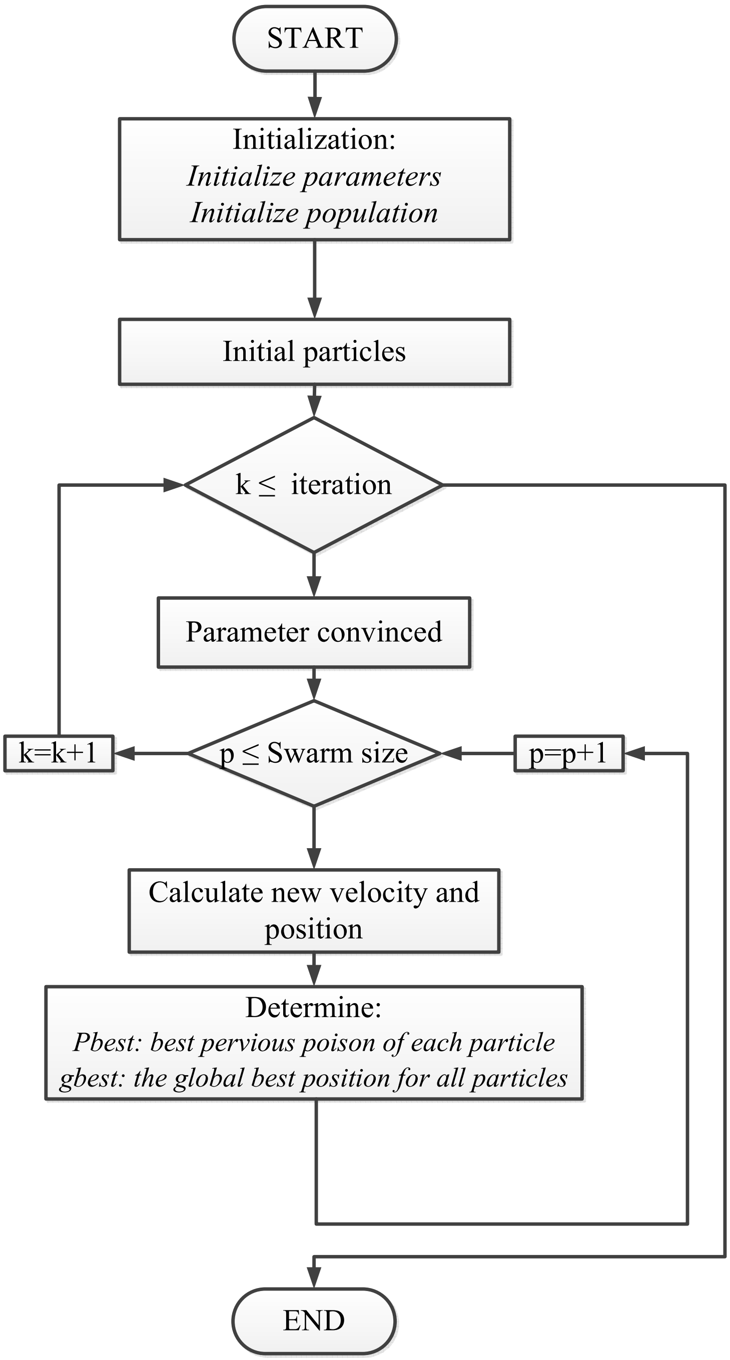

Fig.4. Flow chart for PSO algorithm.

5. Results and discussion

The results are showing BSA and PSO optimization techniques and their effect on a specific microgrid system in the VPP system. Fig.5. shows a fare comparison of the iteration obtained from the optimization of both objectives of BSA and PSO. The iteration runs for 100 iterations as observed form Fig.5. The PSO is settle after 10 iteration and stuck on local global minimum which is one of it is vital drawbacks while the BSA continue on reducing till reach 22 iteration to save too much power in compare to PSO. Fig.6. shows a selected Microgrid in VPP system after BSA optimization this Microgride includes diesels, photovoltaic, wind turbine, solid oxide fuel cell and ESS. Fig.6. shows each source status for 24 hours when connected mode or standby mode. And the exchange of each distributed generation source when the sun rises in morning PV will take place base on the controller set up priories composed with when the wind is available. The diesel utilized as backup will be used only during constrains conditions when other resources could not generate the power needed for the VPP system. Fig.7. is show the same Microgrid but using the PSO optimization also explains the function of each resource with different reaction based on the optimization. Fig.8. shows the distribution substation power comparison without optimization; with BSA and PSO for 24 hours the graph shows that BSA has the best objective in compare to PSO. A huge energy saved as showing in the system when it is compared to the conditions without any optimization thanks for the optimization techniques. This process to done in each controller to enhance greatly and In case of BSA optimization the power saved for the national grid approximatlly 47% in compare without optmization as shown in Fig. 8.

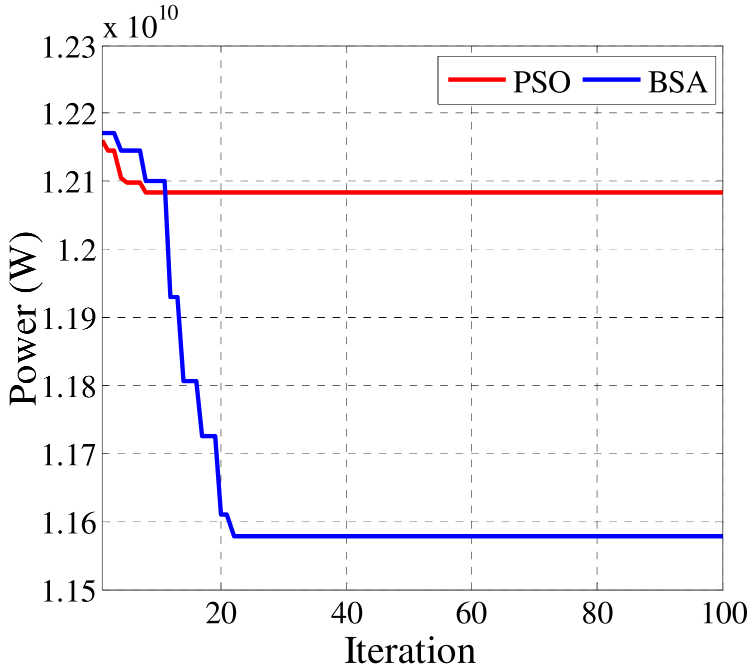

Fig.5. Iteration for objective power for BSA and PSO.

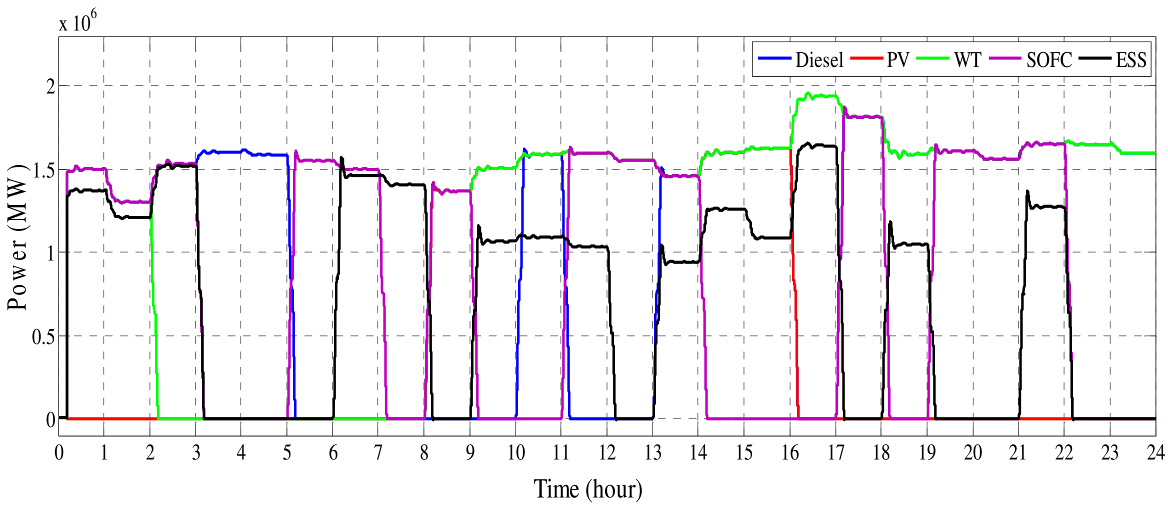

Fig.6. A single Microgrid in the VPP system using BSA optimization.

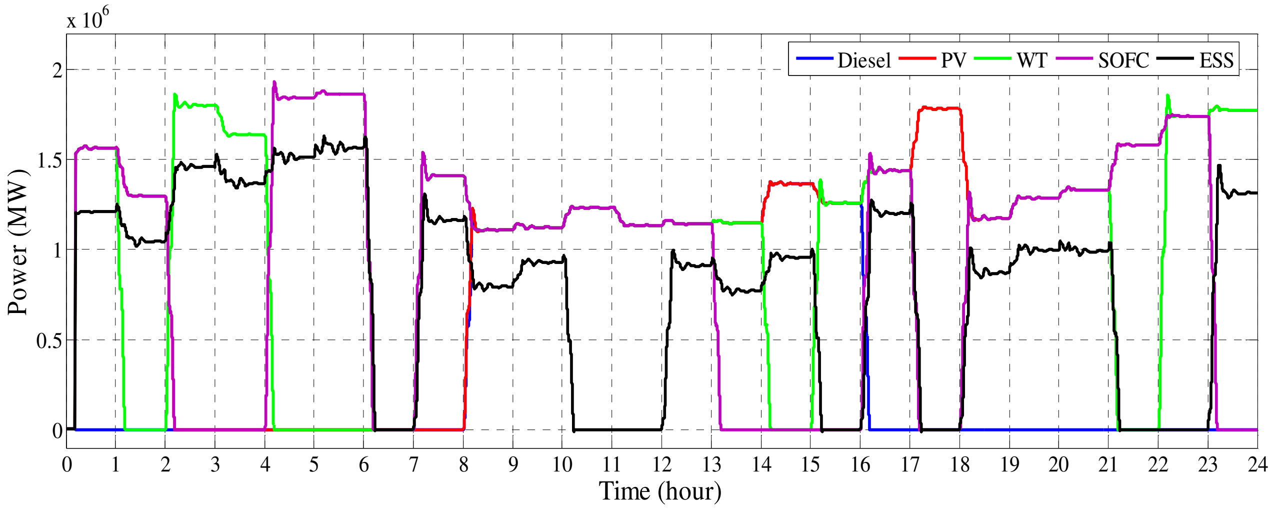

Fig.7. A single Microgrid in the VPP system using PSO optimization

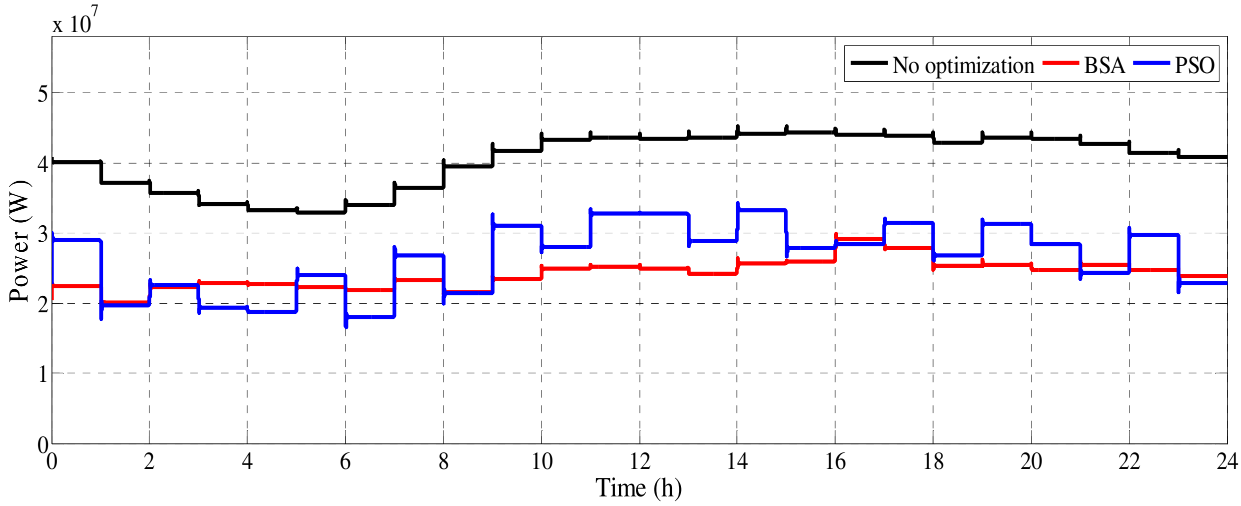

Fig.8. Distribution substation power comparison without optimisation, with BSA and PSO.

6. Conclusion

The potential of this research is instated of building new power plants a virtual power plant can be a very smart way which can save power cost and the environment. The Microgrid is very useful to give recognition for a small sources, but the VPP is add more credits to Microgrids by giving them a chance to be the effective part of energy supplies in the traditional distribution as VPPs. The optimization has been done on the VPP system to let each distributed generation to be in standby mode or contributing when it is needed by ON/OFF status. BSA and PSO optimization techniques are very effective as looks in the results. In case of BSA optimization the power saved for the national grid approximatlly 47% in compare without optmization. Results also show the renewable energies take a real part of the distribution system by showing results of a single Mircogird from number of Microgrids in the VPP system.

Acknowledgment

We would like to thank Universiti Kebangsaan Malaysia (UKM) for giving us a unlimited support by project number: DIP-2014-028.

References

[1] N. Ruiz, I. Cobelo and J. Oyarzabal, "A Direct Load Control Model for Virtual Power Plant Management," in IEEE Transactions on Power Systems, vol. 24, no. 2, pp. 959-966, May 2009.

[2] L. Hernandez et al., "A multi-agent system architecture for smart grid management and forecasting of energy demand in virtual power plants," in IEEE Communications Magazine, vol. 51, no. 1, pp. 106-113, January 2013.

[3] V. Kalkhambkar, B. Rawat, R. Kumar, R. Bhakar "Optimal Allocation of Renewable Energy Sources for Energy Loss Minimization" Journal of Electrical Systems;13(1):115-130, 2017.

[4] M. Rahimiyan and L. Baringo, "Strategic Bidding for a Virtual Power Plant in the Day-Ahead and Real-Time Markets: A Price-Taker Robust Optimization Approach," in IEEE Transactions on Power Systems, vol. 31, no. 4, pp. 2676-2687, July 2016.

[5] S. Parhizi, H. Lotfi, A. Khodaei and S. Bahramirad, "State of the Art in Research on Microgrids: A Review," in IEEE Access, vol. 3, no. , pp. 890-925, 2015.

[6] A. Belhamadia, M. B. Mansor, M. A Younis "Optimal Photovoltaic System Sizing of a Hybrid Diesel/PV System" Journal of Electrical Systems. 2017;13(1):86-94.

[7] IEEE Guide for Design, Operation, and Integration of Distributed Resource Island Systems with Electric Power Systems, IEEE Standard 1547.4, 2011, pp. 1–54.

[8] L. Meng, E. R. Sanseverino, A. Luna, T. Dragicevic, J. C. Vasquez, J. M. Guerrero, "Microgrid supervisory controllers and energy management systems: A literature review" Renewable and Sustainable Energy Reviews, Volume 60, July 2016, Pages 1263-1273, ISSN 1364-0321.

[9] M. Jin, W. Feng, P. Liu, C. Marnay, C. Spanos, MOD-DR: Microgrid optimal dispatch with demand response, Applied Energy, Volume 187, 1 February 2017, Pages 758-776, ISSN 0306-2619.

[10] P. Putera, S. A. Novita, I. Laksmana, M. I. Hamid, Syafii," Development and Evaluation of Solar-Powered Instrument for Hydroponic System in Limapuluh Kota, Indonesia" International Journal on Advanced Science, Engineering and Information Technology. Vol.5 (2015) No. 5ISSN: 2088-5334.

[11] P. Civicioglu, "Backtracking Search Optimization Algorithm for numerical optimization problems", Applied Math. Comp., vol. 219, pp. 8121–8144, 2013.

[12] J. A. Ali, M. A. Hannan and A. Mohamed, "Backtracking search algorithm approach to improve indirect field-oriented control for induction motor drive," 2015 IEEE 3rd International Conference on Smart Instrumentation, Measurement and Applications (ICSIMA), Kuala Lumpur, 2015, pp. 1-6.

[13] J. A. Ali, M A Hannan, A. Mohamed, and M. G.M. Abdolrasol," Fuzzy logic speed controller optimization approach for induction motor drive using backtracking search algorithm", Measurement, Vol. 78 PP. 49-62, Jan. 2016.

[14] P. Civicioglu, "Backtracking Search Optimization Algorithm for numerical optimization problems", Applied Mathematics and Computation, 219, 8121–8144, 2013.

[15] M. A. Hassan and M. A. Abido, "Optimal Design of Microgrids in Autonomous and Grid-Connected Modes Using Particle Swarm Optimization," in IEEE Transactions on Power Electronics, vol. 26, no. 3, pp. 755-769, March 2011.

[16] B. D. Argo, Y. Hendrawan, D. F. Al Riza, A. N. J. Laksono "Optimization of PID Controller Parameters on Flow Rate Control System Using Multiple Effect Evaporator Particle Swarm Optimization" International Journal on Advanced Science, Engineering and Information Technology. Vol.5 No. 2 ISSN: 2088-5334, 2015.