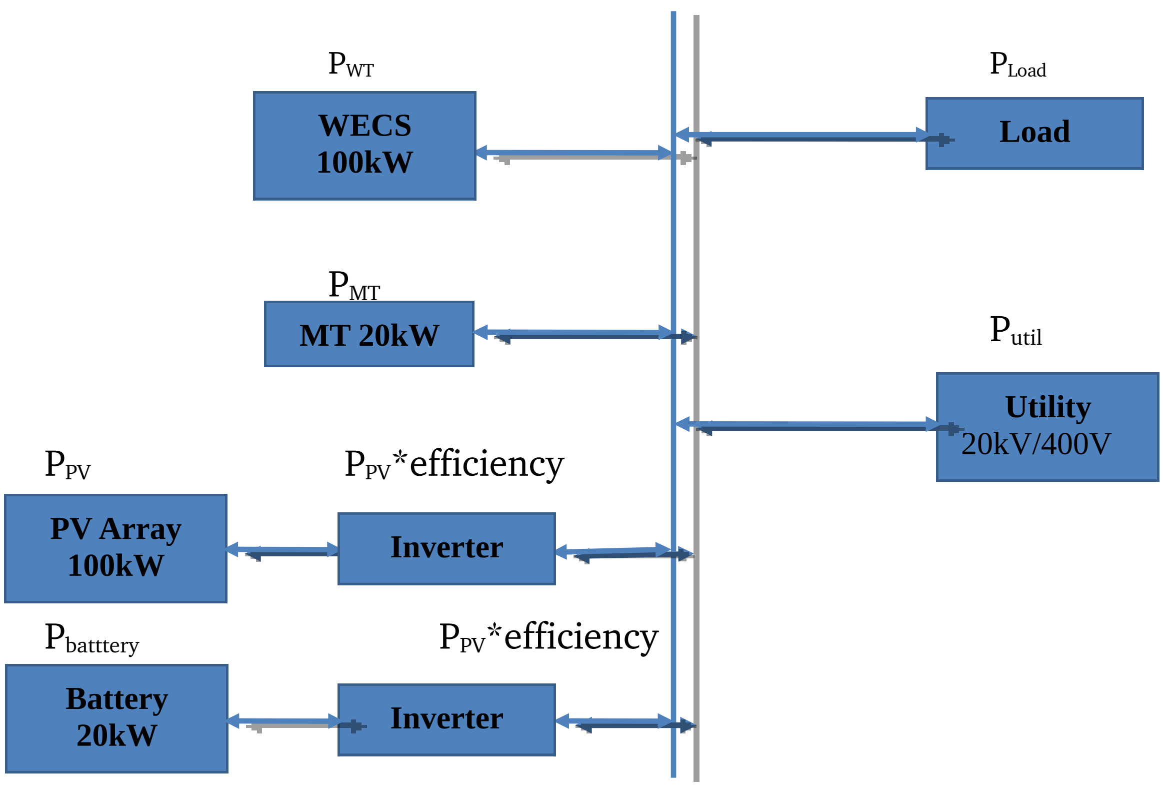
Real Time Energy Management of a Wind-Micro-turbine-PV Energy System with Storage Unit connected to Utility optimized by use of Particle Swarm Optimization

Abstract

Energy sustainability of energy systems is a multi-objective, multi-constraint problem, where the energy system requires the capability to make rapid and robust decisions regarding the dispatch of electrical power produced by generation assets. This process of control for energy system components is known as energy management. The application of particle swarm optimization (PSO), which is a biologically inspired direct search method, to find real-time optimal energy management solutions for a stand-alone Wind – Micro-turbine – PV energy system, is presented. Results demonstrate that the proposed PSO-based energy management algorithm can solve an extensive solution space while incorporating many objectives such as: minimizing the cost of generated electricity, maximizing MT operational efficiency and minimizing utility's charge. Promising simulation results indicate the suitability of PSO for realtime energy management



AC Bus 400V

<u>Models of Microgrid</u> [27]

- ✓ <u>Microturbine</u>

Emission SO_2 = 720/10^6 kg/Wh

Emission CO_2 = 0.0036/10^6 kg/Wh

Emission NO_x = 0.1/10^6 kg/Wh

$\mathbf{P_{MTrated}}$ = 20KW, maximum power output which could be given by microturbine

Total Emission = (Emission SO_2 + Emission CO_2 + Emission NO_x) * $P_{current}$

Where,

$\mathbf{P_{MT}}$ is the power output which could be given by microturbine to the Grid,

$$\mathbf{0 \leq P_{MT} \leq P_{MTrated}}$$

- ✓ <u>WECS</u>

Cut on speed= 4 m/s

Corner Speed=14 m/s

Cut out speed=25 m/s

Swept Area = pi (Rotor Diameter/2)^2

P(I) = ½ (Swept Area) v(I)^3 rho (capacity factor)

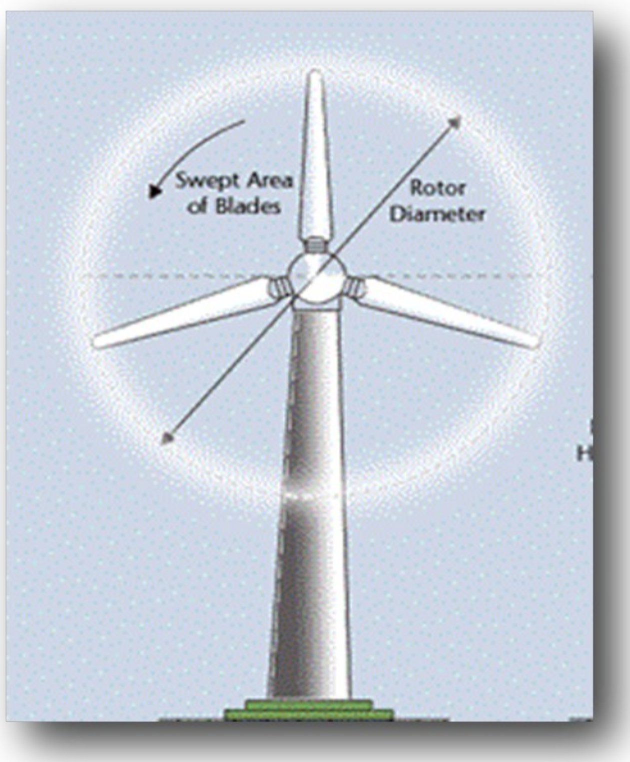
Where,

Rho: the density air (rho=0.1 kg/m^3)

Swept Area: this refers to the area in square feet of the rotor. It is also called the 'Capture Area'

Rotor Diameter: this number is listed on most wind turbine spec sheets. It is simply the diameter the blades cover

Capacity Factor: ratio of its actual output over a period of time, to its potential output if it were possible for it to operate at full nameplate capacity



✓ <u>PV array</u>

The power output of a PV module depends on the number of cells in the module, the type of cells, and the total surface area of the cells. All modules are rated by manufacturers in terms of their peak power (Wp) under standard test conditions: ie. 1000W/m^2 of sunlight ('peak sun'), T = 25 °C, and air mass of 1.5. The type of the cell is used in this study is Crystalline Silicon. Open circuit voltage V_g=1.12 eV and shot circuit current Isc = 5.75 A. Firstly, I compute Current/Temperature coefficient [26]:

$$K_0 = \frac{I_{sc}(T_2) - I_{sc}(T_1)}{T_2 - T_1}$$

K_0, current / temperature coefficient [A/K]

Then the photo-current depending the Temperature T_1:

$$I_L(T_1) = I_{sc}(T_{1,nom}) \frac{G}{G(nom)}$$

Finally,

$$I_L(T_1) = I_L(T_1) + K_0(T - T_1)$$

Then the saturation current of diode depending the Temperature T_1:

$$I_0(T_1) = \frac{I_{sc}(T_1)}{e^{\frac{qV_{oc}(T_1)}{nkT_1}} - 1}$$

Where,

k = 1.38e-23, Boltzmann constant

q = 1.60e-19, Electron

n = 1.2, Quality factor for the diode (crystalline)

Finally,

$$I_0 = I_0(T_1) \frac{T^{\frac{3}{n}}}{T_1} e^{\frac{qV_g(T_1)}{nk\left(\frac{1}{T} - \frac{1}{T_1}\right)}}$$

And the final current of the solar cell:

$$I = I_L - I_0\left(e^{\frac{q(V+IR_s)}{nkT}} - 1\right)$$

Where,

R_s, Resistance of the source

$$R_s = -\frac{dV}{dI_{V_{oc}}} - \frac{1}{X_V}$$

Where,

$\frac{dV}{dI_{V_{oc}}}$ is the slope at V_{OC} and X_V

$$X_V = \frac{q}{nkT_1} e^{\frac{qV_{oc}(T_1)}{nkT_1}}$$

Power output of the cell:

$$P_{cell} = V_g I$$

However, this is not the power output which will be used. Maximum power tracking is used in order to find the the operating point $A(V_{max},I_{max})$ at which the power dissipated in the resistive load is maximum:

$$P_{max} = V_{max}, I_{max}$$

Finding the maximum power tracking of each cell, aims to find the maximum power tracking of the whole PV array. But each PV array is connected with others PV arrays and create a PV module which is connected to the grid via an inverter. The inverter has an efficiency 0.9 in this study. As a result of that the PV module's power output is 90% of the actuall power output which was produced.

✓ Battery

Using commercial features, 25Ah of a battery can give power output 300Watt-hours with constant voltage 12Volts. Also 25Ah corresponds to 100% state of charge (SOC). In order to create a realistic grid, an inverter is connected to the battery to convert direct current to alternating and the efficiency is 90%. This study initialize the battery with SOC=50%. 420 Watt-hours is a minor amount of power in order to cover load demands. Hence, a group of batteries serial-connected were needed in this study.

Total amount of batteries with maximum power output limit p_{bmax} applying at a time dT:

$$K = \frac{pbmax}{\frac{Vb * Ahinit * nb}{dT}}$$

Total initial Ampere-hours:

$$Ah_{total} = Ahinit\, K$$

Ampere-hours that will be consumed after applying power output p_{bnew} :

$$Ah\_cur\_con = \left(\frac{pbnew}{pbmax}\right) Ahinit$$

Ampere-hours consumed until now:

$$Ah\_con = \left(\frac{(\sum pbold)}{pbmax}\right) Ahinit$$

Ampere-hours remained after consumed A_{h_con}:

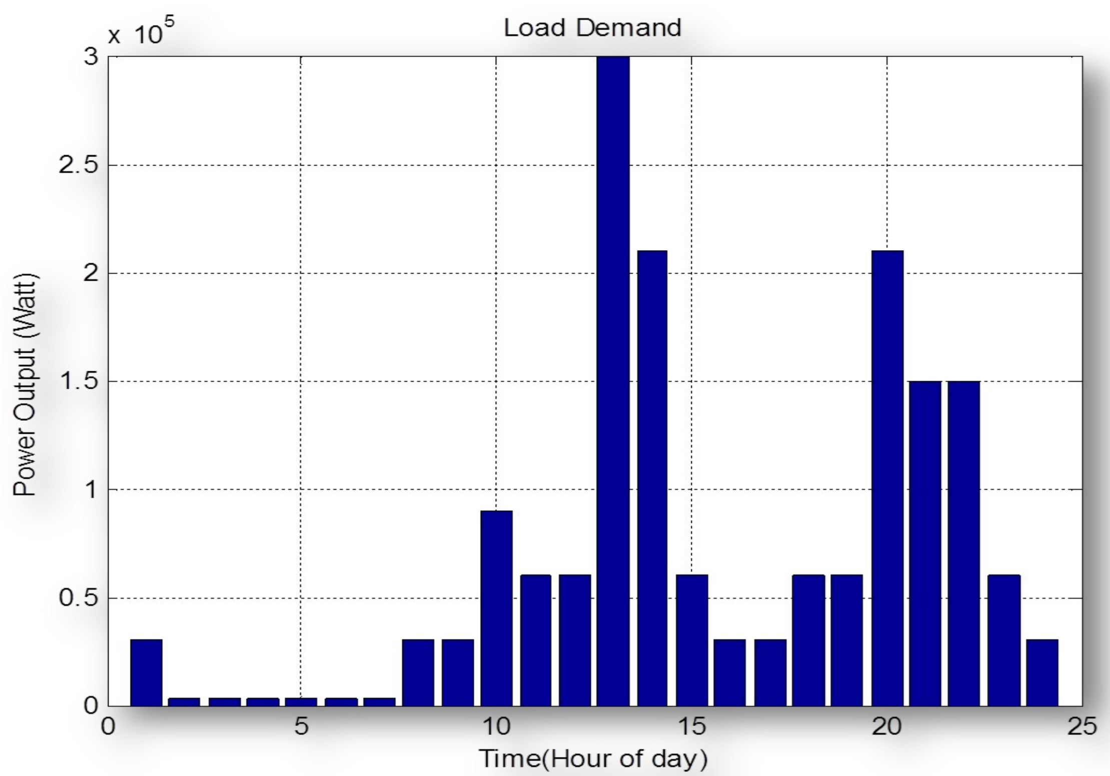
$$Ah\_remain = Ahinit - Ah\_con;$$

State of charge of Battery (SOC) after current power consumption:

$$soc = \frac{(Ahinit - Ah_{con} - Ah\_cur\_con)}{Ahinit}$$

✓ Load & Utility [25]

The load demand diagram is similar to the referenced paper “Methodology for optimal sizing of stand-alone photovoltaic/wind-generator systems using genetic algorithms, Solar Energy” and the size of the load is multiplied by 300 Watt-hours.



➢ **Objective Function**

1. Microturbine (MT) Cost Function [20]

The MT cost function can expressed as follows:

- $\sum_{t=1}^{t=24} Ft, MT \;=\; C_{MT} F_{MT} \sum_{t=1}^{t=24} P_{t,MT}\; \Delta T \;+\; \sum_{t=1}^{t=24} OM_{t,MT} \;+\; \sum_{t=1}^{t=24} SC_{t,MT}$

Where,

$F_{t,MT}$, total operating cost of the MT

C_{MT}, fuel cost of the MT unit ($/m^3). Cost of natural gas (fuel): 0.36

F_{MT}, fuel consumption rate (m^3/kWh), F_{MT} =0.0009 was used in this study

$P_{t,MT}$, decision variable representing the real power output from the MT(W)

ΔT, energy management time step which is set at 1 hour

$OM_{t,MT}$, operation and maintenance cost of the MT unit ($)

$SC_{t,MT}$, start-up cost of the MT unit ($)

The operations and maintenance is assume to be proportional with the produced energy:

$$\sum_{t=1}^{t=24} OM_{t,MT} \;=\; K_{oc} \sum_{t=1}^{t=24} P_{t,MT}\; \Delta T$$

K_{OC} is taken as 0.000006 $/Wh for the MT. The start-up cost of the MT depends on the length of time the unit has been turned off before starting up once again:

$$\sum_{t=1}^{t=24} SC_{t,MT} \;=\; \sum_{t=1}^{t=24} \left(\sigma_{MT} \;+\; \delta_{MT} \left(\frac{1 - e - \tau_{off,MT}}{\tau_{MT}} \right) \right) \left(1 \;-\; u_{(t-1),MT}\right)$$

If cold start-up of the MT requires power to run the MT's auxiliary systems, then the WECS or battery is required to provide this cold start-up power. In this study, the MT's hot start-up time is 30 s, cold start-up time is 200 s, and its cooling time constant is 520 s. In general, for optimization studies that include MT, hot and cold start-up costs should be included, however, in this particular case, the value of these parameters do not affect the optimization results, because the fuel cost of the MT is always higher than the total cost of operating the WECS.

2. Utility Cost Function

The Utility cost function can expressed as follows:

$$\sum_{t=1}^{t=24} F_{t,util} = C_{util} \sum_{t=1}^{t=24} P_{t,util}$$

Where,

C_{util} charge of the power utility unit offers (\$/Wh). C_{util} = 0.0001 \$/Wh

$P_{t,MT}$ representing the real power output from the utility unit (Wh)

In our case, the maximum available power from the MT is 20 kW and the lower limit is zero, i.e., the MT can be turned OFF when the output power from the WECS is enough to meet the demanded power. Once the MT is switched ON , it has to operate continuously for a certain length of time before being switched OFF . Also, a certain OFF time period has to be achieved, meaning that the MT must be OFF for a certain period before being restarted. Violation of such constraints can shorten the unit's life time. These constraints are formulated as continuous run/stop time constraints as follows:

1) Evaluate whether the MT may be shut OFF by comparing the ON-time of the MT in the previous steps of the energy management with the MT's minimum up-time (MUT)

$$\text{if } (T^{on} - MUT) \geq 0,$$
$$\text{then } T^{on} = 0,\ u_{t,MT} = 0$$

2) Evaluate whether the MT may be started up by comparing the OFF-time of the MT in the previous time steps with the MT's minimum down-time (MDT)

$$\text{if } (T^{off} - MDT) \geq 0,$$
$$\text{then } T^{off} = 0,\ u_{t,MT} = 1$$

Where,

T^{on} and T^{off}, are the time length the MT has been ON or OFF, respectively. In this study, MUT = 600s and MDT = 300s.

$$\min \textit{Objective Function} = \sum_{t=1}^{t=24} F_{t,MT} + F_{t,util}$$

- **<u>Proposed Real Time EMS</u> [20]**

1. Strategy

The strategy for the proposed energy management, which accounts for multiple simultaneous objectives for the hybrid energy system, is described below. The battery has three states; charging, discharging, and inactive. The primary objectives of the EMS are as follows:

1) minimize the cost of energy generation;
2) maximize battery life by monitoring and controlling its state of charge (SOC) and process of charge/discharge
3) maximize the use of excess available wind power in a useful dump load when the battery is fully charged in an attempt to increase system utilization [8]
4) when the MT is in operation, adjust its operating point to near its rated power to increase its operation efficiency and reduce its environmental impact [24]
5) maximize the average available stored energy in the battery (i.e., higher battery SOC), hence improving system reliability

2. Algorithm: PSO Optimization

- To apply PSO to the WECS-PV-MT energy management problem at hand, $P_{t,MT}$ and $P_{t,Battery}$ are selected as decision variables to be optimized by PSO . $P_{t,MT}$ is then computed using the equality:

$$P_{t,MT} + P_{t,WT} + P_{PV} + P_{Battery} = P_{t,Load} - P_{t,util}$$
$$0 \leq P_{t,WT} \leq P_{t,WT}^{max}$$

Where,

$P_{t,WT}^{max}$ is the rated power output of the wind turbine

For $1 \leq t \leq 24$

- To optimize the problem in each step, initial swarms are defined as follows:

$$P_{t,MT} = rand()\ (P_{t,MT}^{max} - P_{t,MT}^{min}) + P_{t,MT}^{min}$$

$$P_{t,Battery} = rand()\ (P_{t,\ Battery}^{max} - P_{t,\ Battery}^{min}) + P_{t,\ Battery}^{min}$$

$$\text{For } 1 \leq t \leq 24$$

rand() represents uniform random numbers between 0 and 1, $P_{t,MT}^{max}$ is the maximum power from the MT and $P_{t,Battery}^{max}$ is the maximum power from the Battery which is proportional to its state of charge.

Where,

$P_{t,Battery} \geq 0$, if battery is on discharging mode
$P_{t,Battery} \leq 0$, if battery is on charging mode

Then, the output power of the Utility can be calculated as follows:

$$P_{t,util} = P_{t,Load} - (P_{t,MT} + P_{t,WT} + P_{PV} + P_{Battery})$$

$$\text{For } 1 \leq t \leq 24$$

- Two energy management scenarios are considered:

Case 1, no Optimization, WECS-PV-MT: In this case, the WECS power will supply the load and if excess power is available, it will be used to charge the storage battery if it is not fully . Otherwise, the WECS output power is charged SOC 100% limited to that required by the load. The MT will be used when the combination of WECS, PV and battery power is not sufficient to supply the load. Therefore, the WECS maximum power dispatch as well as the PVs maximum power dispatch are governed by the following equation:

$$\text{if } P_{t,WT}^{avail} + P_{t.PV} > P_{t,Load} \text{ AND } SOC_t = 100\% \rightarrow P_{t,WT}^{max} + P_{t.PV} = P_{t,Load}$$

$$\text{else : } P_{t,WT}^{max} = P_{t,WT}^{avail}$$

Where,

$\mathbf{P_{t,WT}^{max}}$ is the power output that is needed to cover the rest of $P_{t,Load}$
$\mathbf{P_{t,WT}^{avail}}$ is the rated power output of the windturbine

Case 2, Optimized, WECS-PV-MT -Dump Load: This is the preferred energy management strategy, where the maximum available power is extracted from the WECS and PV at all times. If the sum of available wind power and available pv power is more than load demand and the storage battery is full, the excess available power of the WECS and PV is supplied to a useful dump load.

In the PSO algorithm, the values of initial guesses used for the objective functions are assigned randomly between the boundaries. The best possible answer will then be selected and the swarms' positions will be updated, for each decision variable according to position and velocity. The following equality constraints are applied at each iteration to check swarms' positions and modify objective function appropriately:

$$\text{if } (SOC_t \leq 20\%) \text{ AND } (P_{Battery} < \text{chrpwr\_min OR } P_{Battery} > \text{range\_min\_pbatt}),$$

$$\text{then } Obective_t = \infty$$

Where,

chrpwr_min is the maximum power can be used to charge the battery

range_min_pbatt is the minimum power could be offered to the battery on charging mode

$$\text{if } (SOC_t > 20\%) \text{ AND } (P_{Battery} > \text{range\_max\_pbatt OR } P_{Battery} \leq \text{range\_min\_pbatt}),$$

$$\text{then } Obective_t = \infty$$

Where,

range_max_pbatt is the maximum power can be offered by the battery to the grid

range_min_pbatt is the minimum power could be offered to the battery on discharging mode

The constant value chrpowr_min = -16000 Watt-hours in this study. The battery must not be charged instantaneously, in order to maintain its "life" long.

The constant value range_min_pbatt =0 Watt-hours, it is referred to the minimum power could be offered to the battery on charging mode. The constant value range_max_pbatt = 20000 Watt-hours in this study.

$$\text{if } (P_{MT} < \text{ range\_min\_mt OR } P_{MT} > \text{range\_max\_pbatt})$$

$$\text{then Obective}_t = \infty$$

The initial battery SOC is 50%. It is our demand, SOC to be equal or greater than than the initial SOC, at the end of the day, inorder to develop a sustainable microgrid.

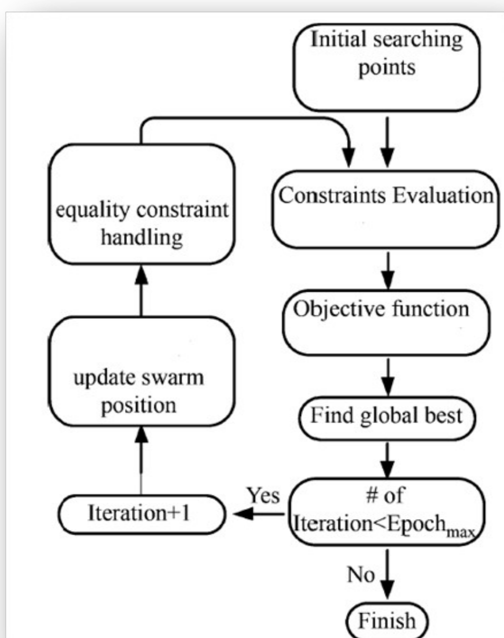
$$\text{if } (SOC_{tFINAL,Battery} \leq SOC_{tINITIAL,Battery})$$

$$\text{then Obective}_t = \infty$$

Where,

$SOC_{tFINAL,Battery}$ is the final SOC of the battery
$SOC_{tINITIAL,Battery}$ is the initial SOC of the battery

The constant value range_max_mt = 20000 Watt-hours, as those Watt-hours can be offered by the microturbine to the grid in this study. The constant value range_min_mt = 0, as the power of microturbine cannot take negative values.



The above equality constraints ensure that improper selections for $P_{t,MT}$ and $P_{t,Battery}$ values are adjusted into the space of appropriate dispatch assignments and that Objective function handles values within the appropriate boundaries. For the initial searching points, 50 swarms and 10000 iterations are used. These values are chosen by experience, caution must be taken to ensure that the solution converges within the maximum number of iterations.

- **<u>Some worth-noticing results are following</u>**

  - ✓ **Connected to the Utility buy-sell**

  - **Battery P_{rated} = 20kWh**
    PV P_{rated} = 200kWh
    Windturbine P_{rated} = 100kWh
    Microturbine P_{rated} = 20kWh

The Figure 1 below shows the convergence of the particle swarm optimization algorithm used in this study. The objective function described above takes the minimum value ≈ -102.5 \$ for a specific set of power outputs of the microturbine, battery unit and utility. The optimization algorithm was run for 400 generations(iterations) although as it is obvious that the convergence succeeded on the first 5 iterations.

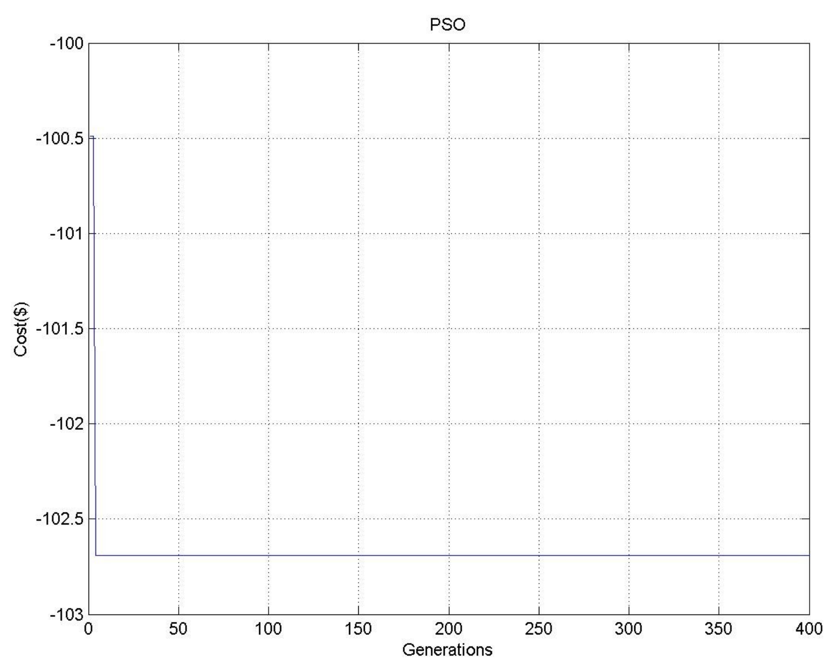


Figure 1

The set of power outputs which gives the minimum objective function are presented below. It is worth-noticed that between 10:00am and 15:00pm in which the load demand was increased, utility and WT aimed to cover the residential needs, due to the fact that PV module was not able enough to serve the demands. Between 20:00pm and 22:00pm the load demand was increased again, but none of the renewable energy sources could enough. The Grid was obligated to buy again from the utility. Microgrid bought enough power from the utility to cover the load demand, at those two time intervals however it is clear from the Figure 2 that MG sold more power to the utility than the amount which bought. As a result of that reader can figure out the negative value of the objective.

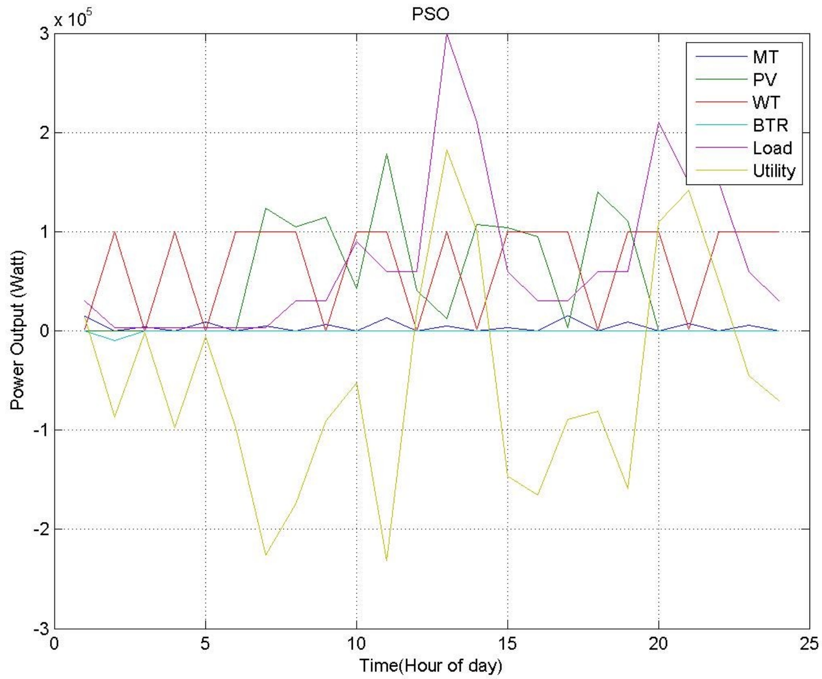


Figure 2

- **Battery P_{rated} = 60kWh**
  PV P_{rated} = 300kWh
  Windturbine P_{rated} = 300kWh
  Microturbine P_{rated} = 60kWh

The difference from the previous one is that power output of RES, MT and storage unit (battery) is greater. It is expected MG to be able to cover the load demand without buying from the utility. Hence, the gain will be larger than the gain from the previous example. Taking a look in Figure 3 it is obvious that gain was increased up to 500%.

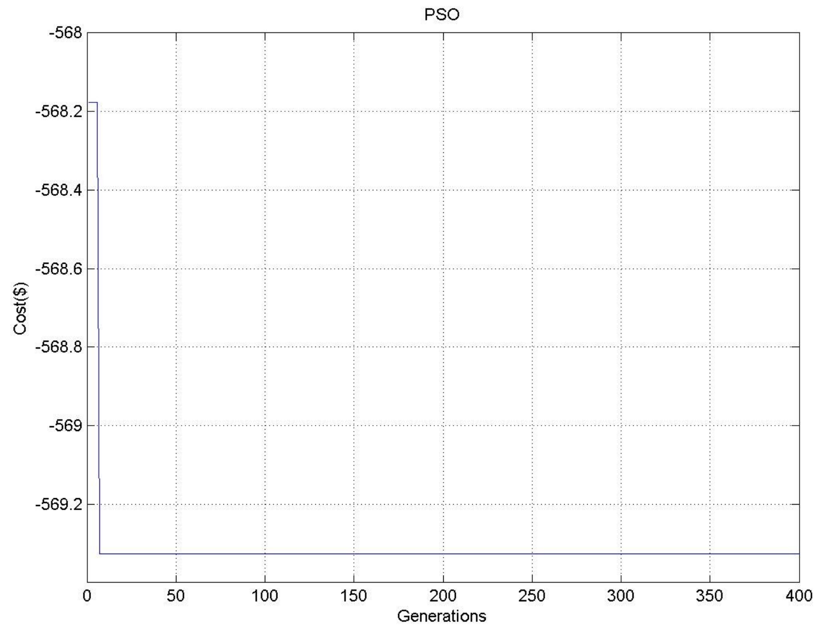


Figure 3

Indeed the MG needed to buy a minor quantity of power from the utility just between 21:00-22:00.

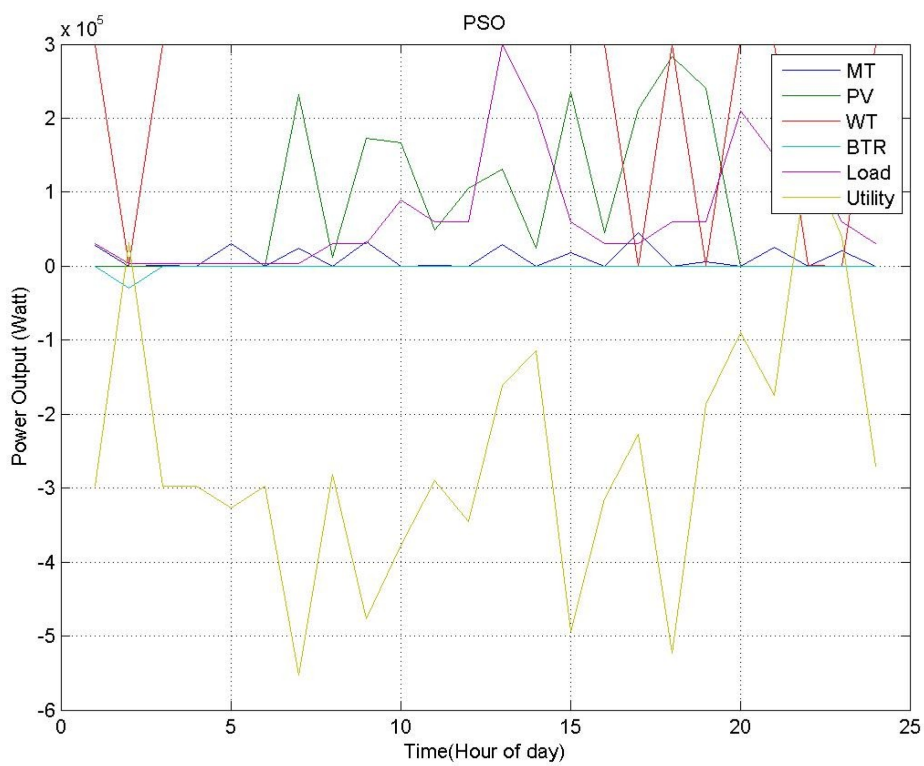


Figure 4

✓ **Connected to the Utility buy-not sell**

- **Battery P_{rated} = 20kWh**
  PV P_{rated} = 200kWh
  Windturbine P_{rated} = 100kWh
  Microturbine P_{rated} = 20kWh

The general expectation in Figure 5 that is that the gain will be decreased due to the fact that MG cannot sell the utility, perhaps no gain will be earned.

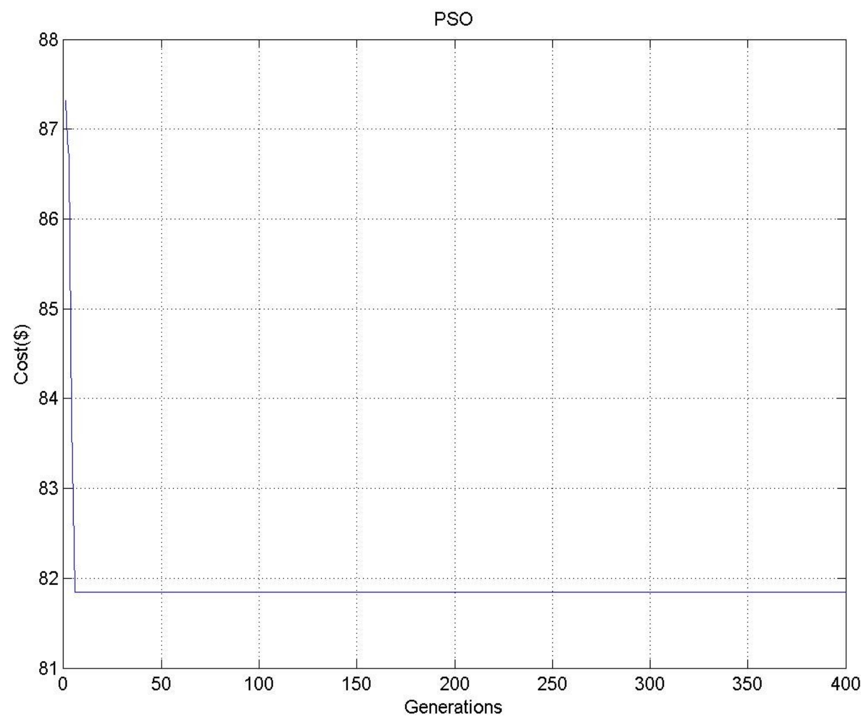


Figure 5

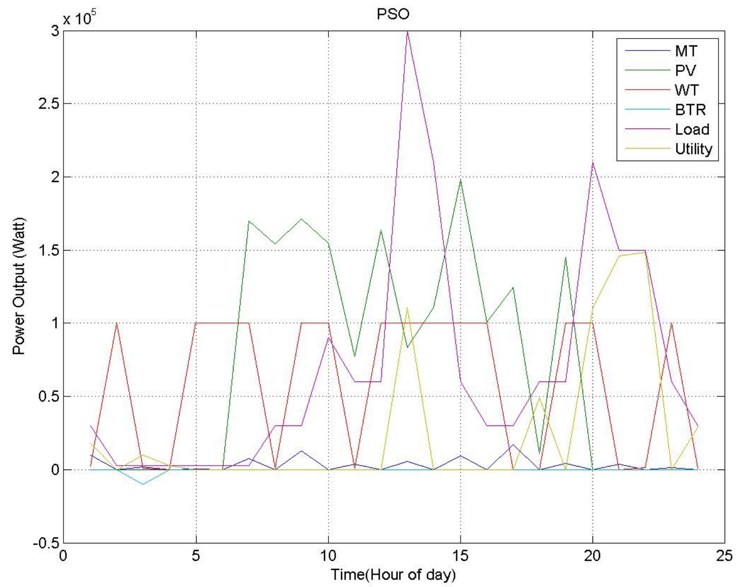


Figure 6

- **Battery P_{rated} = 60kWh**
  PV P_{rated} = 300kWh
  Windturbine P_{rated} = 300kWh
  Microturbine P_{rated} = 60kWh

The general expectation in Figure 7 is that the gain will be increased under normal circumstances due to the fact that power outputs of the power supply units were increased too.

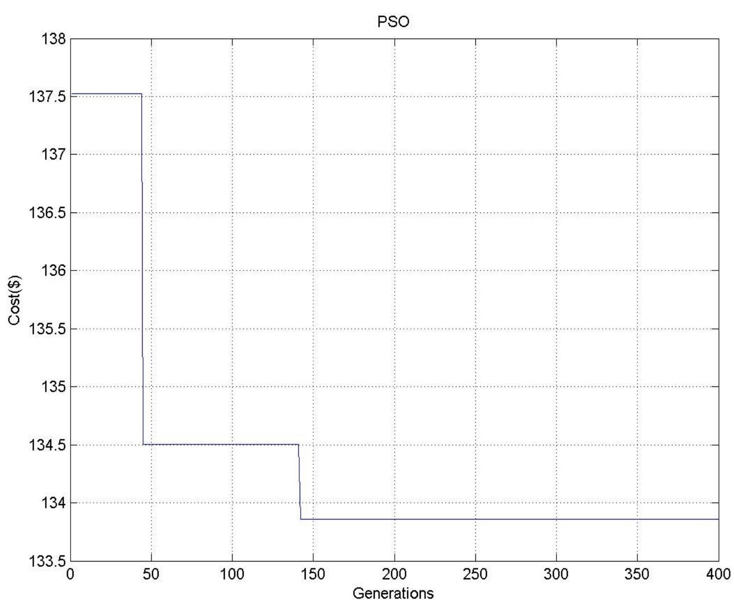


Figure 7

However as we can see in Figure 8 that RES and storage unit could not cover peak load demands at specific hours due to current conditions. Hence, MT aimed to serve the demands. As a result, the cost increased a bit more than the previous example.

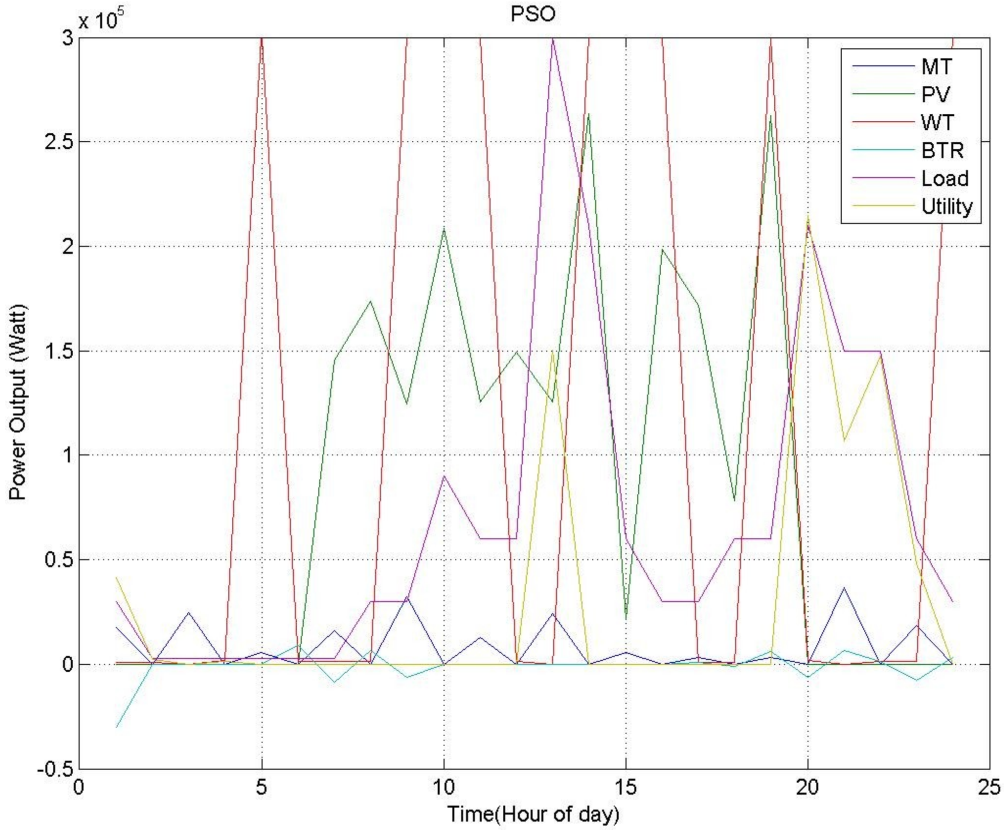


Figure 8

- ✓ **Disconnected from the Utility**

- **Battery P_{rated} = 20kWh**
  PV P_{rated} = 200kWh
  Windturbine P_{rated} = 100kWh
  Microturbine P_{rated} = 20kWh

The general expectation is that the gain will be increased than the previous example. Buying from the utility is much more expensive than operating and maintaining a MT. Indeed, it is obvious in Figure 9 that that cost functions is under the levels of the previous one. Details are presented in Figure 10.

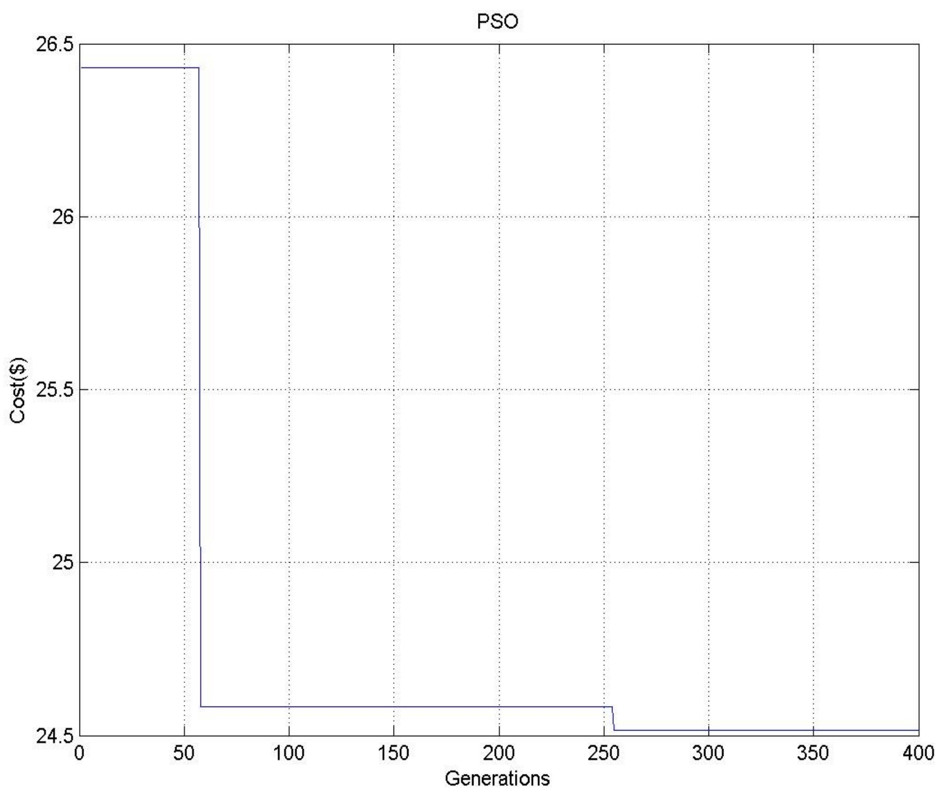


Figure 9

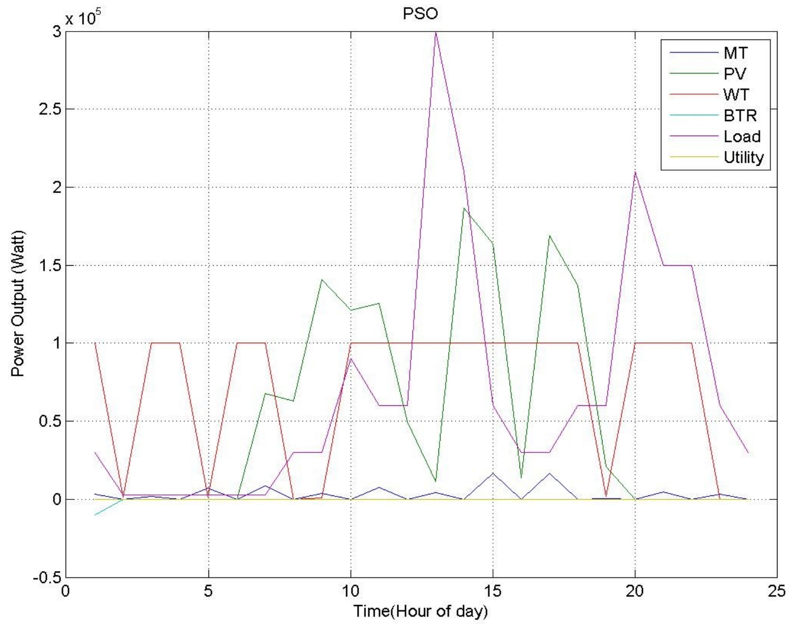


Figure 10

- **Battery P_{rated} = 60kWh**
  PV P_{rated} = 300kWh
  Windturbine P_{rated} = 300kWh
  Microturbine P_{rated} = 60kWh

The general expectation in Figure 11 is that the gain will be increased under normal circumstances due to the fact that power outputs of the power supply units were increased too.

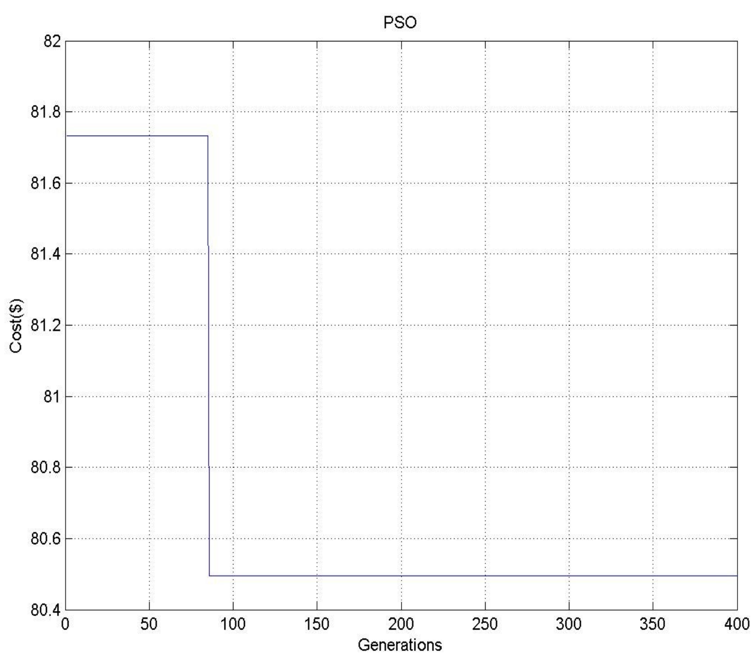


Figure 11

However as in the previous example we can see in Figure 12 that RES and storage unit could not cover peak load demands at specific hours due to current conditions. Hence, MT aimed to serve the demands. As a result, the cost increased a bit more than the previous example.

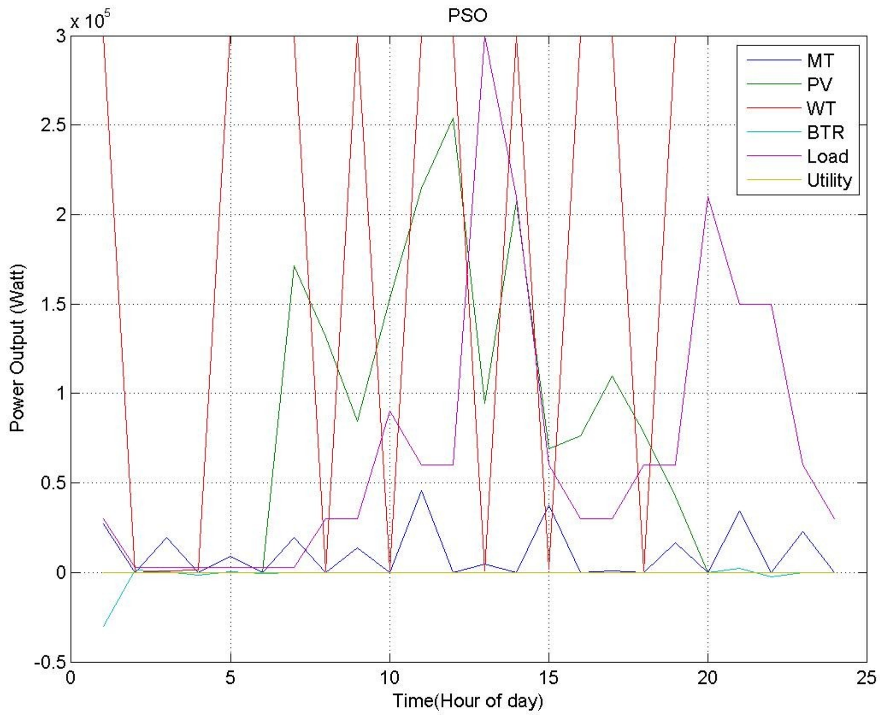


Figure 12

- **Bibliography**

1. Ashoke Kumar Basu, Microgrids: Planning of fuel energy management by strategic deployment of CHP-based DERs – An evolutionary algorithm approach, Inte national Journal of Electrical Power & Energy Systems, Volume 44, Issue 1, January 2013, Pages 326-336, ISSN 0142-0615, http://dx.doi.org/10.1016/j.ijepes.2012.07.059 http://www.sciencedirect.com/science/article/pii/S014206151200419X)

2. Faisal A. Mohamed, Heikki N. Koivo, Multiobjective optimization using Mesh Adaptive Direct Search for power dispatch problem of microgrid, International Journal of Electrical Power & Energy Systems, Volume 42, Issue 1, November 2012, Pages 728-735, ISSN 0142-0615, http://dx.doi.org/10.1016/j.ijepes.2011.09.006 http://www.sciencedirect.com/science/article/pii/S0142061511002092)

3. Waleed Al-Saedi, Stefan W. Lachowicz, Daryoush Habibi, Octavian Bass, Power flow control in grid-connected microgrid operation using Particle Swarm Optimization under variable load conditions, International Journal of Electrical Power & Energy Systems, Volume 49, July 2013, Pages 76-85, ISSN 0142-0615, http://dx.doi.org/10.1016/j.ijepes.2012.12.017. http://www.sciencedirect.com/science/article/pii/S0142061513000264

4. Taher Niknam, Rasoul Azizipanah-Abarghooee, Mohammad Rasoul Narimani, An efficient scenario-based stochastic programming framework for multi-objective optimal micro-grid operation, Applied Energy, Volume 99, November 2012, Pages 455-470, ISSN 0306-2619, http://dx.doi.org/10.1016/j.apenergy.2012.04.017. http://www.sciencedirect.com/science/article/pii/S0306261912003030

5. George Kyriakarakos, Dimitrios D. Piromalis, Anastasios I. Dounis, Konstantinos G. Arvanitis, George Papadakis, Intelligent demand side energy management system for autonomous polygeneration microgrids, Applied Energy, Volume 103, March 2013, Pages 39-51, ISSN 0306-2619, http://dx.doi.org/10.1016/j.apenergy.2012.10.011. http://www.sciencedirect.com/science/article/pii/S0306261912007155)

6. Mousa Marzband, Andreas Sumper, Albert Ruiz-Álvarez, José Luis Domínguez-García, Bogdan Tomoiagă, Experimental evaluation of a real time energy management system for stand-alone microgrids in day-ahead

markets, Applied Energy, Volume 106, June 2013, Pages 365-376, ISSN 0306-2619, http://dx.doi.org/10.1016/j.apenergy.2013.02.018. http://www.sciencedirect.com/science/article/pii/S0306261913001268

7. Eleonora Riva Sanseverino, Maria Luisa Di Silvestre, Mariano Giuseppe Ippolito, Alessandra De Paola, Giuseppe Lo Re, An execution, monitoring and replanning approach for optimal energy management in microgrids, Energy, Volume 36, Issue 5, May 2011, Pages 3429-3436, ISSN 0360-5442, http://dx.doi.org/10.1016/j.energy.2011.03.047 http://www.sciencedirect.com/science/article/pii/S0360544211002155

8. Amjad Anvari Moghaddam, Alireza Seifi, Taher Niknam, Mohammad Reza Alizadeh Pahlavani, Multi-objective operation management of a renewable MG (micro-grid) with back-up micro-turbine/fuel cell/battery hybrid power source, Energy, Volume 36, Issue 11, November 2011, Pages 6490-6507, ISSN 0360-5442, http://dx.doi.org/10.1016/j.energy.2011.09.017. http://www.sciencedirect.com/science/article/pii/S0360544211006141

9. Taher Niknam, Faranak Golestaneh, Ahmadreza Malekpour, Probabilistic energy and operation management of a microgrid containing wind/photovoltaic/fuel cell generation and energy storage devices based on point estimate method and self-adaptive gravitational search algorithm, Energy, Volume 43, Issue 1, July 2012, Pages 427-437, ISSN 0360-5442, http://dx.doi.org/10.1016/j.energy.2012.03.064 http://www.sciencedirect.com/science/article/pii/S0360544212002678

10. Taher Niknam, Faranak Golestaneh, Mehdi Shafiei, Probabilistic energy management of a renewable microgrid with hydrogen storage using self-adaptive charge search algorithm, Energy, Volume 49, 1 January 2013, Pages 252-267, ISSN 0360-5442, http://dx.doi.org/10.1016/j.energy.2012.09.055 http://www.sciencedirect.com/science/article/pii/S0360544212007347

11. Sirus Mohammadi, Babak Mozafari, Soodabeh Solimani, Taher Niknam, An Adaptive Modified Firefly Optimisation Algorithm based on Hong's Point Estimate Method to optimal operation management in a microgrid with consideration of uncertainties, Energy, Volume 51, 1 March 2013, Pages 339-348, ISSN 0360-5442, http://dx.doi.org/10.1016/j.energy.2012.12.013 http://www.sciencedirect.com/science/article/pii/S0360544212009255

12. J.A. Peças Lopes, Silvan A. Polenz, C.L. Moreira, Rachid Cherkaoui, Identification of control and management strategies for LV unbalanced microgrids with plugged-in electric vehicles, Electric Power Systems Research, Volume 80, Issue 8, August 2010, Pages 898-906, ISSN 0378-7796, http://dx.doi.org/10.1016/j.epsr.2009.12.013 http://www.sciencedirect.com/science/article/pii/S0378779610000039

13. J. Vasiljevska, J.A. Peças Lopes, M.A. Matos, Integrated micro-generation, load and energy storage control functionality under the multi micro-grid concept, Electric Power Systems Research, Volume 95, February 2013, Pages 292-301, ISSN 0378-7796, http://dx.doi.org/10.1016/j.epsr.2012.09.014 http://www.sciencedirect.com/science/article/pii/S0378779612002969

14. Hugo Morais, Péter Kádár, Pedro Faria, Zita A. Vale, H.M. Khodr, Optimal scheduling of a renewable micro-grid in an isolated load area using mixed-integer linear programming, Renewable Energy, Volume 35, Issue 1, January 2010, Pages 151-156, ISSN 0960-1481, http://dx.doi.org/10.1016/j.renene.2009.02.031 http://www.sciencedirect.com/science/article/pii/S0960148109001001

15. George Kyriakarakos, Anastasios I. Dounis, Konstantinos G. Arvanitis, George Papadakis, A fuzzy logic energy management system for polygeneration microgrids, Renewable Energy, Volume 41, May 2012, Pages 315-327, ISSN 0960-1481, http://dx.doi.org/10.1016/j.renene.2011.11.019 http://www.sciencedirect.com/science/article/pii/S0960148111006215

16. H.M. Khodr, N. El Halabi, M. García-Gracia, Intelligent renewable microgrid scheduling controlled by a virtual power producer: A laboratory experience, Renewable Energy, Volume 48, December 2012, Pages 269-275, ISSN 0960-1481, http://dx.doi.org/10.1016/j.renene.2012.05.008 http://www.sciencedirect.com/science/article/pii/S0960148112003217

17. George Kyriakarakos, Anastasios I. Dounis, Konstantinos G. Arvanitis, George Papadakis, A fuzzy cognitive maps–petri nets energy management system for autonomous polygeneration microgrids, Applied Soft Computing, Volume 12, Issue 12, December 2012, Pages 3785-3797, ISSN 1568-4946,

http://dx.doi.org/10.1016/j.asoc.2012.01.024
http://www.sciencedirect.com/science/article/pii/S1568494612000646

18. Zhang, Y.; Gatsis, N.; Giannakis, G.B., "Robust Energy Management for Microgrids With High-Penetration Renewables," *Sustainable Energy, IEEE Transactions on* , vol.PP, no.99, pp.1,10, 0
URL: http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=6510507&isnumber=5433168

19. Chaouachi, A.; Kamel, R.M.; Andoulsi, R.; Nagasaka, K., "Multiobjective Intelligent Energy Management for a Microgrid," *Industrial Electronics, IEEE Transactions on* , vol.60, no.4, pp.1688,1699, April 2013
http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=6157610&isnumber=6361304

20. Palma-Behnke, R.; Benavides, C.; Lanas, F.; Severino, B.; Reyes, L.; Llanos, J.; Saez, D., "A Microgrid Energy Management System Based on the Rolling Horizon Strategy," *Smart Grid, IEEE Transactions on* , vol.4, no.2, pp.996,1006, June 2013
URL: http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=6417004&isnumber=6517533

21. Ross, M.; Hidalgo, R.; Abbey, C.; Joós, G., "Energy storage system scheduling for an isolated microgrid," *Renewable Power Generation, IET* , vol.5, no.2, pp.117,123, March 2011
URL: http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=5729377&isnumber=5729375

22. Chaouachi, A.; Kamel, R.M.; Andoulsi, R.; Nagasaka, K., "Multiobjective Intelligent Energy Management for a Microgrid," *Industrial Electronics, IEEE Transactions on* , vol.60, no.4, pp.1688,1699, April 2013
URL: http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=6157610&isnumber=6361304

23. Kanchev, H.; Di Lu; Colas, F.; Lazarov, V.; Francois, B., "Energy Management and Operational Planning of a Microgrid With a PV-Based Active Generator for Smart Grid Applications," *Industrial Electronics, IEEE Transactions on* , vol.58, no.10, pp.4583,4592, Oct. 2011

URL: http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=5720519&isnumber=6005674

24. Pourmousavi, S.A.; Nehrir, M.H.; Colson, C.M.; Caisheng Wang, "Real-Time Energy Management of a Stand-Alone Hybrid Wind-Microturbine Energy System Using Particle Swarm Optimization," *Sustainable Energy, IEEE Transactions on* , vol.1, no.3, pp.193,201, Oct. 2010
URL: http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=5530418&isnumber=5563518

25. Eftichios Koutroulis, Dionissia Kolokotsa, Antonis Potirakis, Kostas Kalaitzakis, Methodology for optimal sizing of stand-alone photovoltaic/wind-generator systems using genetic algorithms, Solar Energy, Volume 80, Issue 9, September 2006, Pages 1072-1088, ISSN 0038-092X, http://dx.doi.org/10.1016/j.solener.2005.11.002
http://www.sciencedirect.com/science/article/pii/S0038092X05003713

26. Francisco M. González-Longatt "Model of Photovoltaic Module in Matlab™" URL:
http://academia.edu/875827/Model_of_Photovoltaic_Module_in_Matlab

27. http://en.wikipedia.org/wiki/Wind_turbine