World Academy of Science, Engineering and Technology
International Journal of Energy and Power Engineering
Vol:8, No:12, 2014

Operation Strategies of Residential Micro Combined Heat and Power Technologies

Omar A Shaneb, Adell S. Amer

Abstract**—**Reduction of CO_2 emissions has become a priority for several countries due to increasing concerns about global warming and climate change, especially in the developed countries. Residential sector is considered one of the most important sectors for considerable reduction of CO_2 emissions since it represents a significant amount of the total consumed energy in those countries. A significant CO_2 reduction cannot be achieved unless some initiatives have been adopted in the policy of these countries. Introducing micro combined heat and power (µCHP) systems into residential energy systems is one of these initiatives, since such a technology offers several advantages. Moreover, µCHP technology has the opportunity to be operated not only by natural gas but it could also be operated by renewable fuels. However, this technology can be operated by different operation strategies. Each strategy has some advantages and disadvantages.

This paper provides a review of different operation strategies of such a technology used for residential energy systems, especially for single dwellings. The review summarizes key points that outline the trend of previous research carried out in this field.

Keywords**—**Energy management, µCHP systems, residential energy systems, sustainable houses, operation strategy.

I. INTRODUCTION

MICRO combined heat and power (µCHP) refers to producing both heat and electricity simultaneously on the site of end user [2]. µCHP technology (≤ 10 kWe) is a fast growing in several countries since it has to a number of advantages such as increased efficiency and reduced overall emissions. Furthermore, if this technology is operated by renewable fuels, such as hydrogen or biomass fuels it will be greener. The best technologies that could be used as µCHP unit a for a µCHP system are: internal combustion engine (ICE), Stirling engine (SE) and fuel cell (FC) [3]. Residential µCHP technology based on either an ICE, a SE or a FC has been developed by a number of companies [4]. For instance, a 1.0 kWe solid oxide fuel cell has been recently developed by Ceres Power and it is ready for mass production [5].

The adoption of such technologies has the potential to play a significant role in the transition to a future sustainable energy system with low CO_2 emissions. However, there are some challenges facing the adoption of µCHP technologies such as the high capital cost and the integration within the LVDN/µG. Integrating µCHP systems within residential energy systems is considered as the most difficult issue to address, since it depends on several dynamic variables such as variation in heat demand HD to electricity demand ED. In order to reach an optimum operation, these dynamic variables have to be considered.

µCHP technologies are usually operated according to a predetermined conventional strategy, either according to heat led operation strategy HLOS or electricity led operation strategy ELOS [6], [7].

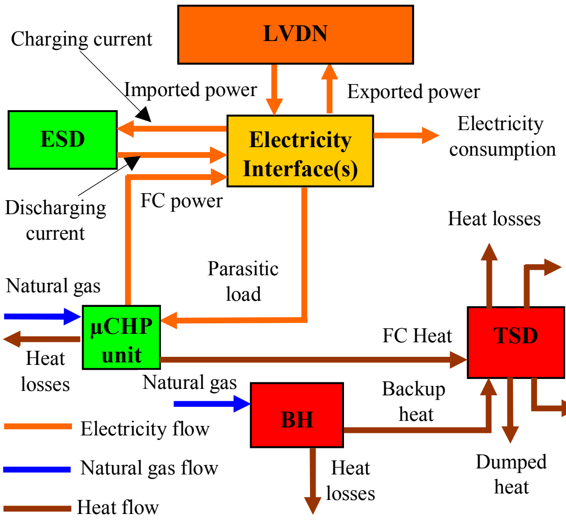

Fig. 1 A conceptual arrangement of a residential µCHP system [7]

It is not an easy task to perfectly exploit the energy produced from the µCHP unit; this is because of the mismatch between the building's HD and ED, particularly for single dwellings. For instance, when a µCHP unit is operated according to HLOS in a summer season, ED may not be met since there is a low HD during that season. On the contrary, using this strategy in winter would most likely lead to extra produced electricity during the period of peak HD. Therefore, it is advantageous to the system to be integrated with a thermal storage device TSD to store thermal energy once it is not needed in order to use it when less heat is generated. As a result, a µCHP unit might be connected to the low voltage distribution networks/micro-grid (LVDN)/(µG) to compensate any difference between the demand and the generation. Instead, an electrical storage device ESD or a TSD could be integrated into the system to store the excess energy [8]. Conversely, multi-family, commercial, or institutional applications can benefit from the demand diversity, which occurs due to the multiple demands served; this reduces the

O. A. Shaneb is with the College of Industrial Technology, Misurata, Libya (phone: +218-92-768-90-47; fax: +218-51-2615314; e-mail: omar_shaneb@yahoo.com).

A. S. Amer is with the College of Industrial Technology, Misurata, Libya (phone: +218-91-159-23-30; fax: +218-51-2615314; e-mail: ad_sa_am@yahoo.com).

Open Science Index, Energy and Power Engineering Vol:8, No:12, 2014 publications.waset.org/9999957.pdf

need for storage devices [9]. Therefore, a µCHP system for a single dwelling, which is considered in this review, may consist of: a µCHP unit, a TSD, an ESD, a backup heater BH. It is also preferable to be connected to the LVDN/µG in order to export/import power, as illustrated in Fig. 1.

Recent research conducted by one of the authors has shown that depending on a single strategy for the operation of a µCHP system is not always the best choice whereas a hybrid strategy could achieve better performance [7]. In addition, it is known that both ED and HD fluctuate daily and seasonally, which makes the use of a pre-determined operation strategy less useful due to not being responsive to such dynamic fluctuations. For instance, using an ELOS could lead to a waste of heat when there is little HD and the TSD is fully charged. Instead, using an appropriate optimal online operation strategy, which aims for the most efficient operation of the µCHP system, is expected to perform better than conventional operation strategies [4].

LP techniques, which have the advantage of rapid calculation, are widely used for solving decision making problems. LP has been used for the optimization of energy systems with different purposes and applications [10]-[16]. A generic online LP optimizer (LPO) for residential µCHP systems that accounts for a backup heater and a TSD has been developed [16]. The generic of this optimizer allows for it to be used for operating any µCHP units in residential energy systems. Finally, concluding remarks have been made.

II. OPERATION STRATEGIES FOR µCHP SYSTEMS

An operation strategy OS can be defined as a strategy for activating, deactivating or turning down a unit of the µCHP system [17]. In other terms, an OS is the way of operating the µCHP system and managing the flow of thermal and electrical energy within and to/from the system. The purpose of managing the µCHP system is to attain definite beneficial goals of the householder, the supplier or the LVDN/µG such as operation costs reduction [18]. Therefore, any OS should have the ability to answer certain questions with the aim of achieving specific goal/goals; the main questions are listed below:

- When should the µCHP unit be activated/deactivated?
- When should the µCHP unit be ramped up/down?
- When should the TSD be charged/discharged and at what rate?
- When should the BH be turned on/off?
- When should the ESD be charged/discharged and at what rate?
- How much electricity should be exported/imported and when?

These questions cannot be easily answered since managing such a system is complex due to several reasons such as variation in HD and ED according to climate, occupants and building type and variation in prices of, gas, imported and exported electricity

Oss are used and described in existing literature can be classified into two main categories as follows:

A. Conventional Operation Strategies

Conventional OSs of energy systems are relatively simple straightforward strategies and can easily be implemented and controlled through a conventional control technique. Conventional control techniques or proportional integral derivative (PID) control techniques are widely used in industrial applications since it is simple and robust [19]. PID control is simply based on measuring the actual signal and comparing it to a reference signal; and according to the difference between them control actions are taken. Although HLOS and ELOS are the only two OSs applied for µCHP systems available in the market; however there are several conventional OSs used and described in existing literature as follows [4]:

1. Heat Led Operation Strategy

HLOS is based on meeting HD by operating the µCHP unit and then meeting any shortage with a BH [20], [21]. Technical constraints should be considered during operation of the system. For instance, the output power of the µCHP unit is constrained by the unit's ability for modulation to meet low HD [22]. This OS is the most prominent for operating the µCHP units available in the market, especially SEs because it has a high heat to power ratio [6]. However, when a HLOS is used, a considerable amount of electricity will be exported during periods of high HD and low ED [23]. Consequently, it cannot be guaranteed that the cumulative amount of exporting electricity be absorbed by the grid once the mass deployment of µCHP units are operated according to this strategy.

2. Electricity Led Operation Strategy

ELOS is based on operating the µCHP unit, within the operating limits, to meet the maximum possible amount of the ED while any shortage can be imported from the LVDN/µG [24]. The same strategy may also be implemented to meet the needs of the electricity supplier [17] by operating the µCHP unit via a smart meter for certain periods. The system in this strategy should be integrated with a TSD to store heat when there is no HD or when HD is less than the produced heat. In addition, the µCHP system should also be integrated with a BH in order to compensate any shortage in meeting the HD [20].

3. Time Led Operation Strategy

Time led operation strategy TLOS can be classified into three main strategies [9]. The first one is a constant output strategy, where activating the µCHP unit according to the 'on' times will be specified by the user and the HD inside the house. The 'off' time specified by the user will control the operation of the system, which will be constant at its rated power output. The µCHP unit may be operated at a constant output for only one period daily or for more than one period and any extra electricity is exported to the LVDN/µG, while any deficiency can be imported from the LVDN/µG. In this case, the µCHP unit will be operated during periods of high demand to ensure that most of the electricity delivered is used to meet demands [24]. However, HD does not always coincide with ED, so the system should be integrated with a BH and a TSD in order to absorb any extra produced heat during the period of operation. The second one is a restricted constant output strategy, where activating the µCHP unit is restricted to two cases: (i) when HD is greater than the recovered thermal power of the µCHP unit; (ii) when HD is smaller than the recovered thermal power of the µCHP unit and the temperature of the TSD is less than its maximum value. As a result, the transient HD can be exactly met by the thermal output of the µCHP system while start/stop times of the µCHP unit will be more frequent [17]. The third one is a restricted time led with part-load capability, where the µCHP unit can also be operated at part-load during periods of modest HD. This reduces deactivating times of the µCHP unit and improves the system's ability to match the HD without producing extra heat. However, a reduction in electricity output will occur because electrical efficiency at part-load is reasonably low, especially when an ICE is used as a µCHP unit.

4. Least Cost Operation Strategy

In least cost operation strategy LCOS, the mode of operation chosen at any moment is the one leading to minimum operating cost of meeting a given HD and ED taking into consideration any technical constraints of the system [25]. As a result, the TSD is charged/discharged according to optimal cost while electricity was imported and exported according to a combination of fuel prices, prices of imported/exported electricity and their interaction with the profiles of electrical/overall efficiency [26].

5. Emission Operation Strategy

Recently, an emission operation strategy EOS, which aims to minimize emissions, has been proposed for a combined cooling heat and power system (CCHP) [27]. This strategy is proposed due to the international concern regarding global warming and climate change. It is based on operating the unit according to its contribution to reducing CO2 emissions regardless the cost of operation. For example, when a certain amount of electricity is required inside the dwelling, the decision to import electricity from the µG or to operate the µCHP unit to provide this electricity would be taken according to which mode of operation results in the minimum estimated CO2 emissions. In EOS, the emission of pollutants is estimated according to the emission factors for electricity and fuel. Then, the emissions ratio (ER) is defined as ER= EP1/EP2, where EP1 is the emission of pollutants to the building using the separate cooling and heating systems, and EP2 is the emission of pollutants to the building using the CCHP system. The CCHP unit should only operate if ER is greater than or equal to one. The same principle can be applied to µCHP systems.

B. Non-Conventional Operation Strategies

Non conventional OSs are the strategies aiming to search for the optimal or near-optimal working condition of the system [28]. Non-conventional OSs used for hybrid/multiple energy systems are classified into two main categories: optimization-based and rules-based operation strategies as follows [29]:

1. Optimization-Based Operation Strategies

OSs based on optimization techniques are performed over a fixed demand profile and hence a global optimal solution can be determined [30]. These OSs are based on searching, according to a certain objective function, for optimal parameters that lead to optimal performance of a system such as LP, NLP and dynamic programming (DP). DP is one of the most popular and effective methods in an offline operation strategy when the entire profile is know a priori [31], [32], since it is a time consuming technique [33]; so it is not suitable for operation of a µCHP unit. LP, which has been used by the author, is relatively faster and less time consuming. Furthermore, LP is based on linearization of relationships, which simplify the complicated mathematical relationships. As a result, it can be said that LP technique has several advantages to be applied in the field of online operation of µCHP systems as described below [10].

The LP model is designed to optimally operate a residential µCHP system, where the electrical output of the µCHP unit is daily determined on an hourly basis. As such, the model involves determining optimal values for 24 decision variables: the hourly electrical output of the µCHP unit (kWe) for a whole day. These decision variables are determined according to an objective function to minimize the daily operation cost. Online operation of a residential µCHP system has been formulated as an LP minimization model. The model is named LP optimizer LPO; Fig. 2 shows an overview of the LPO.

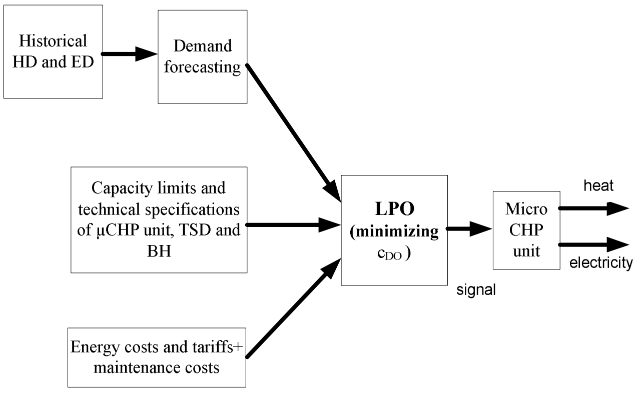

Fig. 2 Overview of the LPO [10]

The online LPO has the deliver significant energy savings and operation cost savings in practice. It has also the ability to significantly reduce the annual CO_2 emissions. It is suggested that the online LPO could be embedded within the control systems of µCHP technologies.

2. Rules-Based Operation Strategies

Rules-based OSs are those strategies which generally use artificial intelligent techniques. In order to improve Oss, it is important that some parameters of the systems should be taken into consideration online instead of priori decisions.

It is viewed as a complicated task to design such a model for operation of µCHP systems, especially for single dwellings, by means of conventional techniques due to: non linear behavior of the system, multiple objectives, uncertainties and multiple inputs. Firstly, the system comprises non-linearity such as the values of electrical efficiency and heat to power ratio under partial load. Secondly, the operation of such a system is based on uncertain variables such as conflicting HD and ED. For example, at early morning in winter, there is a high demand for heat while there is little demand for electricity. Conversely, in summer HD could be negligible in some periods compared to ED. Thirdly, the OS of such a system would take decisions of operation according to multiple measured inputs such as HD, ED and amount of stored heat in the TSD. Furthermore, a µCHP system consists of subsystems such as TSD and BH, which are highly interconnected. As a result, operation of the µCHP systems would probably perform better when an artificial intelligent AI technique is used since this technique deals with such complexities inherent in these systems [4].

AI techniques can solve complicated practical problems in various areas and they offer some advantages over the conventional PID controller [34], [35]. These techniques have the ability to: learn from examples, handle noisy and incomplete data, and manipulate non-linear problems [36]. In addition, AI techniques can be trained, and once they are trained can further perform prediction and generalization at high speed [37]. This feature is of significant importance since it enables the OS of µCHP system to learn particular consumption patterns of a specific house. AI techniques have been developed and deployed in many applications such as engineering, economics and marine because of their symbolic reasoning, flexibility and explanation capabilities [36]. They have also been applied in control of complex systems, modeling, optimization and forecasting [37].

AI systems comprise areas such as artificial neural networks (ANNs), fuzzy logic (FL), multi agent system (MAS) and various hybrid systems, which combine two or more techniques together. FL technique has several advantages over the other AI techniques, so it has been applied for the operation of a µCHP system as described below.

The objective of the real time fuzzy logic operation strategy FLOS is to decide the electrical output power of the µCHP unit, which would minimize the operation costs and CO_2 emissions. The main principle of the FLOS is to maximize the energy utilization by delivering the maximum possible energy from the µCHP unit while insuring that no heat is dumped. This principle can guarantee minimizing the total amount of primary energy used and CO_2 emissions because of the inherent efficiency of the µCHP unit. As a result, minimization of the total amount of primary energy used will necessarily result in minimization of operation costs once an encouraging exporting price or feed-in-tariff FIT is considered. The real time FLOS has been formulated in a generic form to allow its use for any µCHP system and any demand pattern. This generic form enables the FLOS to work effectively with different incentive mechanisms that could be applied for installing µCHP technologies [38].

The real time FLOS has been designed in away to regulate the output power of the µCHP unit using three input variables: HD, ED and the instantaneous temperature of the water inside the TSD. These three input variables have been considered the most influential input variables through studying and understanding the fundamental behavior of the main devices of the µCHP system. Fig. 3 shows an overview of the real time FLOS [38].

Once the µCHP unit is operated according to the output of the real time FLOS, the flow of thermal and electrical power (i.e. storing heat, backup heating, exporting and importing electricity) is determined according to the following stated rules. The µCHP unit is firstly used to meet the ED and HD. However, when the amount of electrical output from the µCHP unit is greater than the ED, the surplus electricity can be exported to the LVDN. Conversely, the LVDN can supply the dwelling with any shortage in electricity. Any extra produced heat will be diverted to the TSD and used when it is needed. However, if the thermal output does not satisfy the demand and there is not enough stored heat, a BH is used [1]-[3].

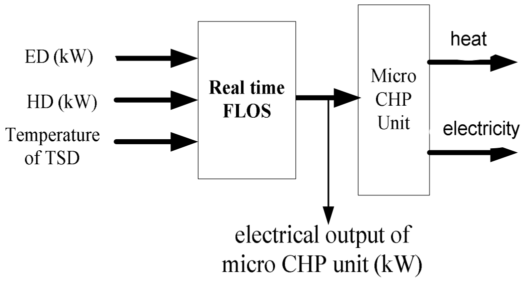

Fig. 3 Overview of the real time FLOS [38]

The real time FLOS has been designed to have three inputs and one output. The inputs are the ED (kW), the HD (kW) and the instantaneous temperature of the water inside the TSD (^{o}C) while the output is the instantaneous value of electrical output power required by the µCHP unit (kWe).

When considering the practical implementation of real time µCHP OSs, the FLOS has a number of attractive features: namely FLOS:

- does not rely on a forecasting system or historical data,
- can be easily embedded in a real time control unit.
- has a fast execution time.

Given the combination of operationally outperforming other strategies in terms of reducing CO_2 emissions and operation cost, and the features mentioned, FLOS represents a promising solution for µCHP real time operation. Thus, FLOS should be considered for further investigation and possible adoption by µCHP technology developers.

III. CLOSING REMARKS

Selection of appropriate µCHP technologies is a key factor in the pursuit of efficient residential energy provision.

Open Science Index, Energy and Power Engineering Vol:8, No:12, 2014 publications.waset.org/9999957.pdf

However, regardless of which μCHP technology is selected for use within a residential energy system, a number of OSs may be considered including HLOS, ELOS, TLOS, CLOS, real time FLOS, online LPO and EOS.

The use of existing and emerging μCHP technologies along with TSE and ESD, coupled with contemporary OSs and techniques, hold considerable promise for residential applications. More specifically, the effective integration of these technologies into residential energy systems offers potential savings in operation costs and CO_2 emissions, especially when the use of renewable fuels becomes commonplace.

OSs of μCHP systems in the residential sector, especially in single dwellings, have been explored. Adopting of an optimal OS has the potential to encourage the penetration of μCHP technology, especially FCs, in the residential sector as this technology is capable of improving the economic and environmental value of this sector. Furthermore, the application of such OSs could encourage mass production of μCHP units, particularly FCs, because these strategies would significantly reduce the operation costs of the system and CO_2 emissions.

Given the combination of operationally outperforming other strategies in terms of reducing CO2 emissions and operation cost, and the features mentioned, FLOS represents a promising solution for μCHP real time operation. Thus, FLOS should be considered for further investigation and possible adoption by μCHP technology developers.

The LPO could be used for single dwellings which have a relatively predictable demand because it depends on forecasting and requires historical demand data. However, the FLOS could be used for dwellings which have non predictable demand such as renting houses because this OS does not rely on demand forecasting.

REFERENCES

[1] J. Cockroft and N. Kelly, "A comparative assessment of future heat and power sources for the UK domestic sector," Energy Conversion and Management, vol. 47, pp. 2349-2360, Sep. 2006.

[2] M. De Paepe and D. Mertens, "Combined heat and power in a liberalised energy market," Energy Conversion and Management, vol. 48, pp. 2542-2555, Sep. 2007.

[3] O. A. Shaneb, et al., "Micro combined heat and power technologies and control for residential applications," International Journal of Renewable Energy Technology, vol. 1, pp. 325-347, Mar. 2010.

[4] P. Taylor, "Active Network Management as an enabler for the proliferation of domestic combined heat and power," in 12th International Stirling Engine Conference, Durham, UK, 2005.

[5] O. A. Shaneb and P. Taylor, "An evaluation of integrated fuel cell and energy storage systems for residential applications," in The 44th UPEC conference, Glasgow-UK, 2009.

[6] O. A. Shaneb and P. C. Taylor, "Evaluation of alternative operating strategies for residential micro combined heat and power," in IEEE Energy Conference, Manama-Bahrain, pp. 143-148, Dec. 2010.

[7] H. Onovwiona and V. Ugursal, "Residential cogeneration systems: review of the current technology," Renewable and Sustainable Energy Reviews, vol. 10, pp. 389-431,Oct. 2006.

[8] M. Newborough, "Assessing the benefits of implementing micro-CHP systems in the UK," Proceedings of the Institution of Mechanical Engineers, Part A: Journal of Power and Energy, vol. 218, pp. 203-218, June. 2004.

[9] O. Shaneb, P. Taylor and G. Coates, "Optimal Online Operation of Residential μCHP Systems using Linear Programming," Energy and Buildings, vol. 44, pp. 17-25, Jan. 2012.

[10] Kong, et al., "Energy optimization model for a CCHP system with available gas turbines," Applied thermal engineering, vol. 25, pp. 377-391, Feb. 2005.

[11] H. J. Ehmke, "Size optimization for cogeneration plants," Energy, vol. 15, pp. 35-44, Jan. 1990.

[12] A. Hawkes and M. Leach, "Modeling high level system design and unit commitment for a micro grid," Applied energy, vol. 86, pp. 1253-1265, July- Aug. 2009.

[13] N. A. Tibi and H. Arman, "A linear programming model to optimize the decision-making to managing cogeneration system," Clean Technologies and Environmental Policy, vol. 9, pp. 235-240, Nov. 2007.

[14] G. Sundberg and D. Henning, "Investments in combined heat and power plants: influence of fuel price on cost minimized operation," Energy Conversion and Management, vol. 43, pp. 639-650, Mar. 2002.

[15] S. Gamou, et al., "Optimal unit sizing of cogeneration systems in consideration of uncertain energy demands as continuous random variables," Energy Conversion and Management, vol. 43, pp. 1349-1361, Aug. 2002.

[16] A. Peacock and M. Newborough, "Impact of micro CHP systems on domestic sector CO2 emissions," Applied thermal engineering, vol. 25, pp. 2653-2676, Dec. 2005.

[17] A. Hawkes and M. Leach, "The capacity credit of micro-combined heat and power," Energy Policy, vol. 36, pp. 1457-1469, Apr. 2008.

[18] T. Thanh and K. K. Ahn, "Nonlinear PID control to improve the control performance of 2 axes pneumatic artificial muscle manipulator using neural network," Mechatronics, vol. 16, pp. 577-587, Nov. 2006.

[19] Van der Veen, R. , Balancing market performance in a decentralized electricity system in the Netherlands, Thesis report master SEPAM, Technology University Delft, Oct. 2007.

[20] H. Aki, et al., "Operational strategies of networked fuel cells in residential homes," Power Systems, IEEE Trans on, vol. 21, pp. 1405-1414, July. 2006.

[21] Hawkes, A.D. and Leach, M.A., 'On policy instruments for support of micro combined heat and power', Energy Policy, Vol. 36, pp. 2973-2982, Aug. 2008.

[22] J. Harrison, et al., "MICRO CHP implications for energy companies," Cogeneration and on-Site Power Production, vol. 1, Mar. 1999.

[23] H. I. Onovwiona, et al., "Modeling of internal combustion engine based cogeneration systems for residential applications," Applied thermal engineering, vol. 27, pp. 848-861, Apr. 2007.

[24] A. Hawkes and M. Leach, "Cost-effective operating strategy for residential micro-combined heat and power," Energy, vol. 32, pp. 711-723, May. 2007.

[25] M. Houwing, and I. Bouwmans, "Agent-based modeling of residential energy generation with micro-CHP" Proceedings of the second international conference on integration of renewable and distributed energy resources, Napa, CA, USA, Dec. 2006.

[26] N. Fumo, P.J. Mago, and M.L. Chamra, "Emission operational strategy for combined cooling, heating, and power systems", Applied Energy, Vol. 86, No. 11, pp. 2344-2350, Nov. 2009.

[27] M. Geidl, "Integrated modeling and optimization of multi-carrier energy systems," PhD Thesis, Swiss Federal Institute of Technology (ETH), (2007).

[28] S. Caux, et al., "On-line fuzzy energy management for hybrid fuel cell systems," International Journal of Hydrogen Energy, vol. 35, pp. 2134-2143, Mar. 2010.

[29] C. C. Lin, et al., "Power management strategy for a parallel hybrid electric truck," Control Systems Technology, IEEE Trans. on, vol. 11, pp. 839-849, Nov. 2003.

[30] S. Delprat, et al., "Control of a parallel hybrid powertrain: optimal control," Vehicular Technology, IEEE Trans. on, vol. 53, pp. 872-881, May. 2004.

[31] S. Kutter and B. Baker, "An iterative algorithm for the global optimal predictive control of hybrid electric vehicles,", pp. 1-6, Sept. 2011.

[32] Z. Ouyang and S. Shahidehpour, "A hybrid artificial neural network-dynamic programming approach to unit commitment," Power Systems, IEEE Trans. on, vol. 7, pp. 236-242, Feb. 1992.

[33] M. Tanrioven and M. Alam, "Impact of load management on reliability assessment of grid independent PEM fuel cell power plants," Journal of power sources, vol. 157, pp. 401-410, June. 2006.

[34] P. Srinivasan, "Dynamic Modeling and Control of a Proton Exchange Membrane Fuel Cell as a Distributed generator," Master Thesis, Ohio State University, USA, 2003.
[35] A. Mellit, et al., "Artificial intelligence techniques for sizing photovoltaic systems: A review," Renewable and Sustainable Energy Reviews, vol. 13, pp. 406-419, Feb. 2009.
[36] S. A. Kalogirou, "Artificial intelligence for the modeling and control of combustion processes: a review," Progress in Energy and Combustion Science, vol. 29, pp. 515-566, Sept 2003.
[37] O. Shaneb, P. Taylor and G. Coates, “Real Time Fuzzy Logic Operation of Residential µCHP Systems”, Energy and Buildings Journal, Vol. 55, Issue (12), pp. 141-150, Dec. 2012.

Omar A. Shaneb was born in 1970. He is a lecturer of mechanical and industrial engineering at the College of Industrial Technology, Misurata-Libya. He received his PhD in Economic, Optimization and Management of Energy Systems from Durham University, UK, in 2012. He received his Master degree in industrial engineering from the College of Industrial technology, Libya in 2001 and he has received his Bachelor degree in Mechanical Engineering from The college of Engineering, Hoon-Libya in 19991. He has previously worked for the Libyan General Company for Electricity. He has an experience of more than nineteen years in teaching experimental and theoretical courses. His research interests include integration& operation of energy systems and economics& management and optimization of engineering systems.

Adell S. Amer is a lecturer of mechanical and industrial engineering at the College of Industrial Technology, Misurata-Libya. He received his MEng. in Advanced Manufacturing Engineering from Swinburne University, Australia, in 2012. He has an experience of more than ten years in teaching experimental and theoretical courses.