ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 1, January 2016

Comparative Analysis of Biogeography-Based Optimization and Fuzzy Logic in Load Frequency Control

Hatef Farshi[1], Khalil Valipour[2]

M.Sc., Department of Electrical Engineering, Mohaghegh Ardabili University, Ardabil, Iran[1]

Assistant Professor, Department of Electrical Engineering Department, Mohaghegh Ardabili University, Ardabil, Iran[2]

ABSTRACT: Load Frequency Control (LFC) is one of the vital parts in power system design, automation, operation and stability.In this paper, we compare two different controllers,the Biogeography-Based Optimization (BBO) based PID controller and Fuzzy Logic Controller (FLC), in LFC problem of two area interconnected hydrothermal power system. The hydro and thermal areas are comprised with an electric governor and reheat turbine, respectively.Also, 1% Step Load Perturbation (SLP) has been considered in any individual area. The mentioned power system with the proposed approach is simulated in MATLAB/SIMULINK and the responses of frequency and tie-line power deviation for these two controllers in each area were shown and compared. The simulation results show that FLC achieves better responses in comparison with BBO based PID controller.

KEYWORDS: Load Frequency Control (LFC), PID controller, Bio-geography Based Optimization (BBO), Fuzzy Logic Controller (FLC), Step Load Perturbation (SLP), Integral Square Error (ISE)

I. INTRODUCTION

Modern power systems are interconnected units which the electrical power is transferred between them. Load Frequency Control (LFC) plays a great role in power system operation and stability because of its duty to preserve frequency and transferred power in their scheduled value, in normal condition and in the case of a very slight perturbation of the load. Generally LFC is a control system with three main purposes as follows:

- Preserving system frequency in nominal value or close to it.
- Preserving the transferred power in a scheduled value.
- Preserving each unit generation in an economically suitable value [1]-[4].

The first and second aims of LFC is frequency regulation to nominal value and preserving power transfer between the control areas by changing output of selected generators. The third aim is to distribute the needed change between generations of the units, so the operation cost will decrease.

When the load increases (decreases), the turbine's velocity will decrease (increase) until the governor could coordinate the incoming steam with the new load. The less changes of the velocity will result in less error.

One way to restore nominal values of the velocity or the frequency is to add a controller (PI, PID, fuzzy logic and artificial neural network controller) to the system. These controllers will detect the average value of error and overcome the deviation.

Since the power system load change is continuous, generation control is set to automatic state to restore nominal values of frequency.

It is obvious that frequency is related to active power (P) and any change of power is influenced by system frequency. An optimal power system should tolerate sudden changes of load and preserve voltage and frequency in an acceptable range [5]-[8].

Lots of investigations have been done on the LFC of power system in the latest decades that represent its important effect on power system generation, operation, stability, reliability and power quality. References [6], [7] and [8] are 3 review articles which show and discuss lots of articles about LFC problem.

DOI:10.15662/IJAREEIE.2015.0501001

II. SYSTEM MODELLING

A. Two-area LFC Model

Generally, power system consists of several subsystems interconnected through tie lines. The investigated LFC system, in this paper, consists of two hydro-thermal areas. Area 1 is reheat thermal system and area 2 is hydro system. The hydro area is comprised with an electric governor and thermal area is comprised with reheat turbine. 1% step load perturbation is considered in both thermal and hydro area.

The generalized model of two-area interconnected power system is shown in figures 1.
Also, nomenclature for various symbols is given after appendix.

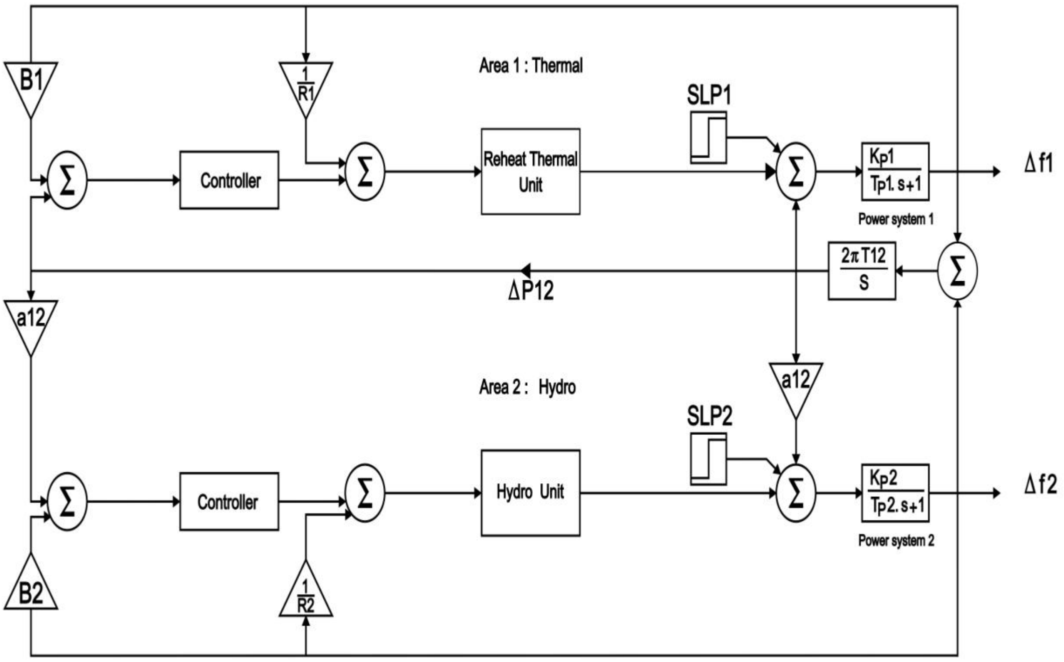

Fig. 1. Investigated two-area power system.

B. Thermal Unit

The thermal unit of investigated two-area power system consists of governor and steam turbine with reheater. Dynamic model of this thermal area is shown in figure 2.

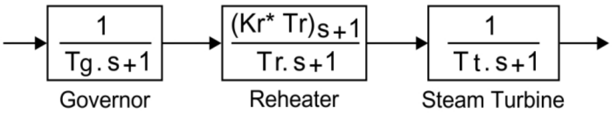

Fig. 2. Dynamic model of thermal area.

C. Hydro Unit

The hydro area of investigated power system includes electric governor and hydro turbine. Dynamic model of this hydro area is shown in figure 3.

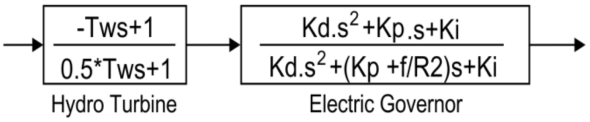

Fig. 3. Dynamic model of hydro area.

III. BBO BASED PID CONTROLLER

BBO is an evolutionary algorithm that uses the mathematical models and concepts of the biogeography. These models describe migration of species between habitats in an ecosystem and how species arise or disappear. BBO, introduced by Dan Simon in 2008 [9], is a population-based global optimization algorithm inspired by the science of biogeography. In BBO, each possible solution is considered as a habitat and their features that characterize habitability are called Suitability Index Variables (SIV). The goodness of each solution is called its Habitat Suitability Index (HSI), where a high HSI of an island means good performance on the optimization problem, and vice versa.

The method to generate the next generation in BBO is by immigrating solution features to other islands, and receiving solution features by emigration from them.

The immigration rate and emigration rate of the jth island can be formulated as follows [10]:

$$\lambda_{S_j} = I_m\,(1 - \frac{S_j}{S_{max}}) \qquad (1)$$

$$\mu_{S_j} = \frac{E_m\,.\,S_j}{S_{max}} \qquad (2)$$

Where λ_{S_j} and μ_{S_j} are the immigration and emigration rates; I_m is the maximum possible immigration rate; E_m is the maximum possible emigration rate; S_j is the number of species; and S_{max} is the maximum number of species.

Mutation operator modifies a habitat's SIV randomly based on mutation rate. The mutation rate m_{S_j} is expressed as (3).

$$m_{S_j} = m_{max}\,(\frac{1-P_{S_j}}{P_{max}}) \qquad (3)$$

Where m_{max} is the maximum mutation rate; P_{max} is the maximum species count probability; P_{S_j} is the species count probability which is given by (4).

$$P_{S_j} = \begin{cases} -\left(\lambda_{S_j} + \mu_{S_j}\right)P_{S_j} + \mu_{(S+1)_j}P_{(S+1)_j}\,S = 0 \\ -\left(\lambda_{S_j} + \mu_{S_j}\right)P_{S_j} + \lambda_{(S-1)_j}P_{(S-1)_j} + \mu_{(S+1)_j}P_{(S+1)_j}\,1 \ll S \ll S_{max} - 1 \\ -\left(\lambda_{S_j} + \mu_{S_j}\right)P_{S_j} + \lambda_{(S-1)_j}P_{(S-1)_j}\;\; S = S_{max} \end{cases} \qquad (4)$$

Where $\mu_{(S+1)_j}$ and $\lambda_{(S-1)_j}$ are the emigration and immigration rates for the jth habitat contain (s+1) and (s-1) number of species, respectively.

The implementation of this algorithm is briefly listed in the following process:

- Define the problem, variables and select BBO parameters (number of habitats, immigration rate (λ), mutation rate (m), and emigration rate (μ))
- Initialize the habitats
- Modify habitats (migration) based on λ, μ
- Mutation
- If termination criteria is reached, End. Otherwise go to step 3 for next iteration [10],[11].

In spite of many complicated control theories and techniques, more than 90% of control strategies still use PID controllers. This is mainly because of structural simplicity, high reliability, good stability and the convenient ratio between performances and cost of PID controller [12],[13].

A typical structure of a PID controller includes three separate elements: the proportional, integral and derivative values. So, BBO technique is used to optimize the PID parameters by Integral Square Error (ISE) criteria (Equation 5) in this paper.

$$J = \int (\Delta f1^2 + \Delta f1^2 + \Delta Ptie^2) \qquad (5)$$

ΔPtie and Δf are tie-line power and frequency deviations, respectively.

The effect of PID controller parameters on a closed loop system is summarized in the table 1.

Table 1.Effect of PID parameters.

Parameter	**Rise time**	**Overshoot**	**Settling time**	**Steady state error**
kp	Decrease	Increase	Small change	Decrease
ki	Decrease	Increase	Increase	Eliminate
kd	Small change	Decrease	Decrease	No change

IV. FUZZY LOGIC CONTROLLER

Since power system dynamic characteristics are complex and variable, conventional control methods cannot provide good results. Intelligent controller can be replaced with conventional controller to get fast and good dynamic response in load frequency problems. FLC can be more useful in solving large scale of controlling problems in comparison with conventional controllers. FLC is designed to minimize fluctuation on system outputs (Δf1, Δf2 and ΔPtie). There are many studies on LFC of power system with fuzzy logic controller like [14],[15].

A FLC consist of three sections namely fuzzifier, rule base and defuzzifier as shown in figure 4.

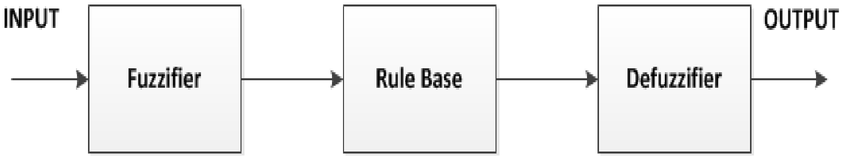

Fig. 4. Fuzzy logic scheme.

The ACE and its derivation are inputs of FLC. Two inputs signals are converted to fuzzy numbers first in fuzzifier. Then, fuzzy rules which shown in table 2 are applied and, finally, fuzzy resultants representing the controller output are converted to the crisp values using the central of area (COA) defuzzifier scheme.

Five membership functions are used in both inputs and output of this fuzzy system which are as follows: Positive Big (PB), Positive Small (PS), Zero (Z), Negative Small (NS), Negative Big (NB), Small (S), Medium (M), Big (B), very Big (VB), Very Very Big (VVB).

Table 2. Fuzzy rules.

		d (ACE)				
		NB	**NS**	**Z**	**PS**	**PB**
ACE	**NB**	S	S	M	M	B
	NS	S	M	M	B	VB
	Z	M	M	B	VB	VB
	PS	M	B	VB	VB	VVB
	PB	B	VB	VB	VVB	VVB

Figure 5 shows this fuzzy system briefly.

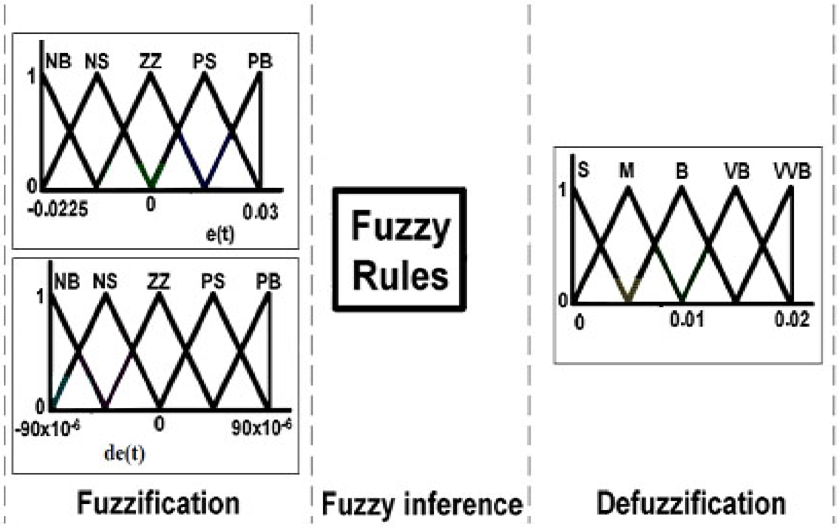

Fig. 5. Fuzzy inference system for LFC.

V. RESULTS AND ANALYSIS

In this paper, BBO based PID and FLC are used in two-area LFC model. 1% SLP is considered in both thermal and hydro area. PID parameters obtained by BBO technique are shown in table 3.

Table 3. PID controllers' parameters.

	BBO
kp1	0.492908
ki1	0.730713
kd1	0.358271
kp2	0.428614
ki2	0.176308
kd2	0.137494

Dynamic responses of frequency deviation by these two methods are shown in figures 6 and 7.

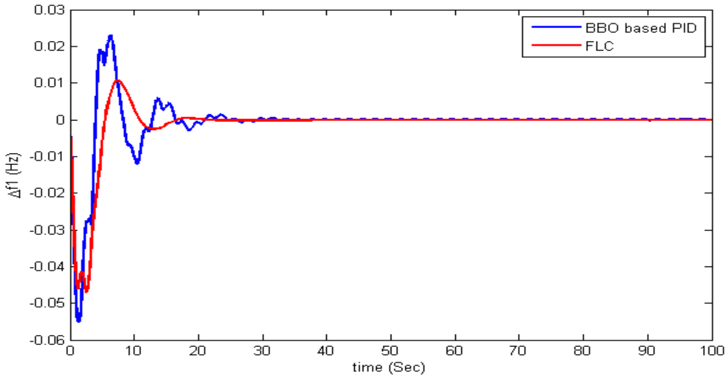

Fig. 6. Frequency deviation in area 1.

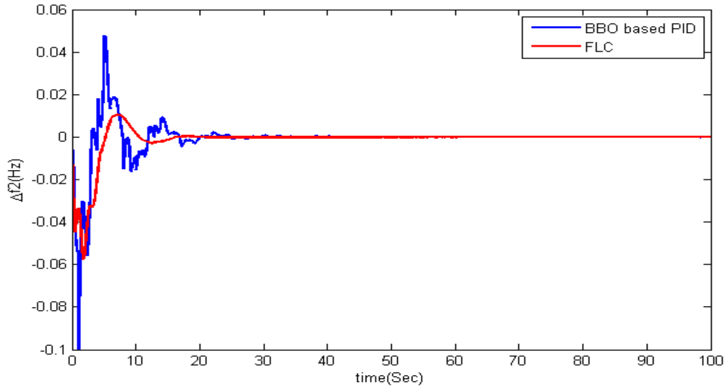

Fig. 7. Frequency deviation in area 2.

Also, dynamic responses of tie-line power deviation are shown in figure 8.

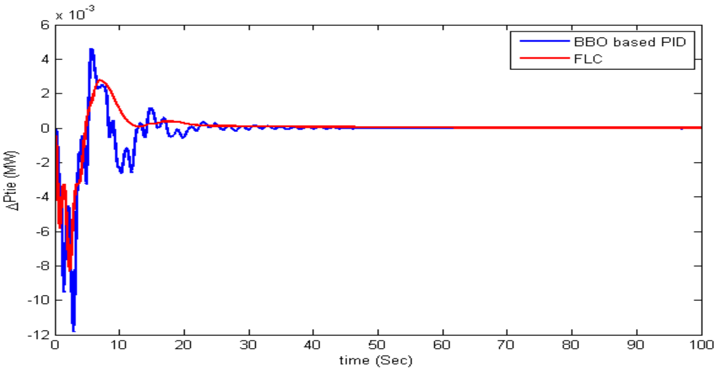

Fig. 8. Tie-line power deviation.

Cost function of BBO is shown in figure 9.

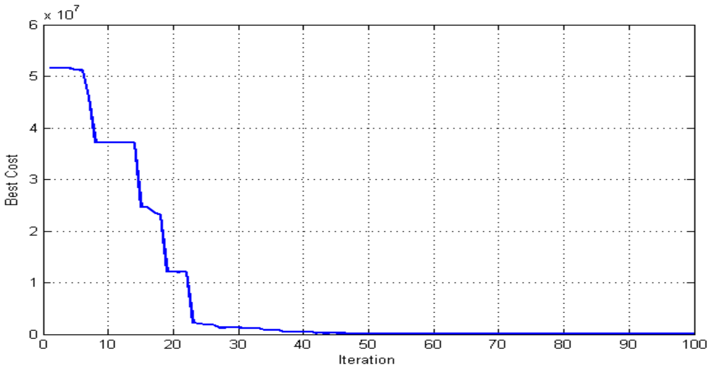

Fig. 9. BBO cost function.

The detailed information for frequency and tie-line power deviation of area 1 and 2 is shown in table 4 for two mentioned methods.

Table 4. Detailed information for frequency and tie-line power deviation.

		BBO	**FLC**	**FLC vs. BBO**
Δf1	Settling Time	23.8365	15.3382	35%
	Overshoot	0.0230	0.0108	53%
	Undershoot	-0.0553	-0.0472	11%
Δf2	Settling Time	22.3873	15.1520	32%
	Overshoot	0.0479	0.0105	78%
	Undershoot	-0.0997	-0.0577	42%
ΔPtie	Settling Time	25.1076	21.8900	12%
	Overshoot	0.0046	0.0028	40%
	Undershoot	-0.0118	-0.0083	30%

By observing the above tables, we can conclude the FLC is more robust than BBO based PID controller.

In Δf1, Δf2 and ΔPtie, the settling time of FLC has about 35%, 32% and 12% improvement in comparison with BBO, respectively. Also, Overshoot response of FLC has about 53%, 78% and 40% improvement. There are almost 11, 42 and 30 percent improvement for undershoot of it, too.

VI. CONCLUSIONS

In this paper, the PID controller has employed for LFC of two-area interconnected hydro-thermal power system and its parameters have determined by a metaheuristic algorithm (BBO). Furthermore, FLC has used in this power system. Then, LFC model by these two mentioned controllers has simulated in MATLAB/SIMULINK and their results have compared with each other. It has shown in section 5 that FLC has superiority in comparison with BBO based PID controller.

APPENDIX

Parameter	**Value**
f	60 Hz
i	1, 2
Pri	2000MW
Hi	5sec
D1	8.33*10-3 Pu MW/ Hz
D2	12.5*10-3 Pu MW/ Hz
T12	0.086 Pu MW/radians
Ri	2.4 Hz/Pu MW
Tg	0.08 sec
Kr	0.5
Tr	10 sec
Tt	0.3 sec
Bi	0.424
Tp1	20 sec
Tp2	13 sec
Kp1	120 Hz/Pu MW
Kp2	80 Hz/Pu MW
Kd	4
Kp	1
Ki	5
Tw	1 sec
a12	-1
SLP	0.01

NOMENCLATURES

f :Nominal system frequency
i:Subscript referred to area i
Pri:Area rated power

Hi:Inertia constant
D1:ΔPD1/ Δf1
D2:ΔPD2/ Δf2
T12:Synchronizing coefficient
Ri:Governor speed regulation parameter
Tg:Steam governor time constant
Kr:Steam turbine reheat constant
Tr:Steam turbine reheat time constant
Tt:Steam turbine time constant
Bi:Frequency bias constant
Tp1:2Hi/f*D1
Tp2:2Hi/f*D2
Kp1:1/D1
Kp2:1/D2
Kd:Electric governor derivative gain
Kp:Electric governor proportional gain
Ki:Electric governor integral gain
Tw:Water starting time
Δ*fi*:Frequency deviation of area i
Δ*Ptie(*Δ*P12)*:Tie-line power deviation
ACEi:Area control error of area i (BiΔfi±ΔPtie)
a12:−Pr1/Pr2
J:Cost index
SLP:Step load perturbation

REFERENCES

[1] H. Shabani, B. Vahidi, M.A. Ebrahimpour, "A robust PID controller based on imperialist competitive algorithm for load-frequency control of power systems", ISA Transactions, Vol. 52, pp. 88–95, 2013.
[2] H. Saadat, "Power system analysis", USA: McGraw-Hill; 1999.
[3] Kundur, "Power system stability and control", New York: Mc-Grall Hill; pp. 601–623, 1994.
[4] H. Bevrani, T. Hiyama, "Intelligent automatic generation control", Taylor & Francis Group, USA, pp.11–36, 2011.
[5] D.G. Padhan, S. Majhi, " A new control scheme for PID load frequency controller of single -area and multi-area power systems", ISA Transactions, Vol. 52, pp. 242–251, 2013.
[6] H. Shayeghi, H.A. Shayanfar, A. Jalili, "Load frequency control strategies: A state-of-the-art survey for the researcher", Energy Conversion and Management, Vol. 50, pp. 344–353, 2009.
[7] Ibraheem, P. Kumar P, Kothari," Recent philosophies of automatic generation control strategies in power systems", IEEE Transaction on Power System, Vol. 20, pp. 346–357, 2005.
[8] S.K. Pandey, S.R. Mohanty, N. Kishor, " A literature survey on load–frequency control for conventional and distribution generation power systems", Renewable and Sustainable Energy Reviews, Vol. 25, pp. 318–334, 2013.
[9] D. Simon, "Biogeography-Based Optimization", IEEE Transaction on Evolutionary Computation, Vol. 12, No. 6, 2008.
[10] P.K. Ammu, K.C. Sivakumar, R. Rejimoan, "Biogeography-Based Optimization - A Survey", International Journal of Electronics and Computer Science Engineering, Vol. 2, No. 1, pp. 154–160, 2013.
[11] H. Kumar, S. Ushakumari, "Biogeography based Tuning of PID Controllers for Load Frequency Control in Microgrid", International Conference on Circuit, Power and Computing Technologies, pp. 797–802, 2014.
[12] L. Santos Coelho, V.C. Mariani, "Firefly algorithm approach based on chaotic Tinkerbell map applied to multivariable PID controller tuning", Computers and Mathematics with Applications, Vol. 64, pp. 2371–2382, 2012.
[13] R. Kumar Sahu, S. Panda, S. Padhan, "A hybrid firefly algorithm and pattern search technique for automatic generation control of multi area power systems", Electrical Power and Energy Systems, Vol. 64, pp. 9–23, 2015.
[14] H. Guolian, Q. Lina, Z. Xinyan, Z. Jianhua, " Application of PSO-Based Fuzzy PI Controller in Multi-area AGC System after Deregulation", IEEE Conference on Industrial Electronics and Applications, Vol. 7, pp. 1417–1422, 2012.
[15] S.P. Ghosal, "Optimization of PID gains by particle swarm optimization in fuzzy based automatic generation control", Electrical Power and Energy Systems, Vol. 72, pp. 203–212, 2004.

BIOGRAPHY

Hatef Farshiwas born in Meshkin Shahr, Iran, 1990. He received the B.Sc. degree of electrical engineering from Islamic Azad University-Ardabil Branch in 2013. He is currently the M.Sc. student at department of electrical engineering in Mohaghegh Ardabili University.His research interests include application of artificial intelligence in power systems, power system dynamics, renewable energy and distributed generation.

Dr. Khalil Valipourwas born in Ardabil, Iran. Currently, he is anassistant professor at electrical engineering department of Mohaghegh Ardabili University. His research interests are power system dynamics, power system modeling in the transients' states, electrical machines and transformers design, reactive power control, protective relays and renewable energy management.