

Intelligent Automation System for Smart Grid Renewable Energy Generation on Climatic Changes

Joy Iong-Zong Chen¹, Kong-Long Lai²

¹Professor, Department of Communication Engineering, Da-Yeh University, Chang-Hua, Taiwan

²Department of Electrical Engineering, Da-Yeh University, Chang-Hua, Taiwan

Email id: ljchen@mail.dyu.edu.tw

Abstract

Nature oriented power generation systems are considered as renewable energy sources. Renewable energy generations are safe to the environment and nature, in terms of minimal radiation and pollution. The space requirement, operational and maintenance cost of renewable energy generation stations are also comparatively lesser than the conventional generating stations. The new form of micro grid energy stations of 230Volt supply attract the small commercial users and the domestic users. The smart grid energy generation is widely employed in the place where the conventional energy supply is not available. Due to its simple construction process, the smart grid renewable energy stations are employed on certain national highways as charging stations for electric vehicles and as a maintenance centre. The motive of the proposed work is to alert the smart grid system with an intelligent algorithm for making an efficient energy generation process on various climatic changes. This reduces the energy wastage in the primary smart grid station and makes the system more reliable on all conditions. The performance of the proposed approach is compared with a traditional smart grid system which yielded a satisfactory outcome.

Keywords: Smart grid control, climatic operation, renewable energy efficiency, power quality, energy wastage reduction



1. Introduction

The electrical power supply which are generated from solar, wind, biomass and hydro energy are termed as renewable energy sources. The solar energy is a power source, generated from sunlight with the help of solar photovoltaic devices. Few years ago, the photovoltaic cells were used in the digital calculators and watches as an alternative power supply [1]. The concept of adding solar cells to form a solar panel and the group of solar panel results in a solar panel array which has the ability to produce electricity by an entire domestic operation. In the recent years, the solar power stations are constructed with a huge volume of solar panel arrays in acres of land for generating electricity for a mass application [2, 3]. The solar energy stations are free from air pollution and can be placed even on a house ceiling for domestic applications. However, the energy generated by the solar power stations are not constant due to change in receipt of sunlight on various weather situations. Figure 1 explores the construction of solar panel array for a domestic application.



Figure 1. Rooftop installation of solar panel array for domestic applications

The kinetic energy produced from the moving air is utilized in the wind power station for generating electricity. A wind turbine is a primary requirement for generating power from

the moving wind and such wind turbines are kept over at a certain height from the land surface with the help of hard metal tower units [4]. Similarly, the wind turbines are connected with hollow blades for observing the wind movement to generate rotational movement to the wind turbines. Therefore an electrical power will be produced in the wind turbine by the principle of electromagnetism [5]. There is also change in electrical power generation in wind energy station due to the change in air motion in the environment. Figure 2 indicates the major units involved in the wind power stations.



Figure 2. Major units of wind power station

The amount of electrical power generated in a wind station is controlled by turbine capacity and blade length. The output power generated from the wind mills are also calculated by the dimension of the turbine rotor to the cube of wind speed [6]. In simple terms, the wind power generation increases to a factor of 8 when the air speed doubles at a time. The commercial wind power station units ranges from 1.6MW to 8MW.

Biomass is a renewable energy source created from plant and animal wastages. Direct combustion, chemical and biological conversion are the methods involved in generation of biomass sources [7, 8]. In most case of biomass power station, steam turbines are employed for generating electrical power from the heat produced by the direct combustion of biomasses.

Therefore the space requirement and construction of a biomass power station is slightly complicated than a wind mill and the solar power station [9, 10]. Similarly, the biomass station is not pollution free, and requires a pollution control unit in its operation. A simple constructional view of biomass power station is shown in Figure 3.

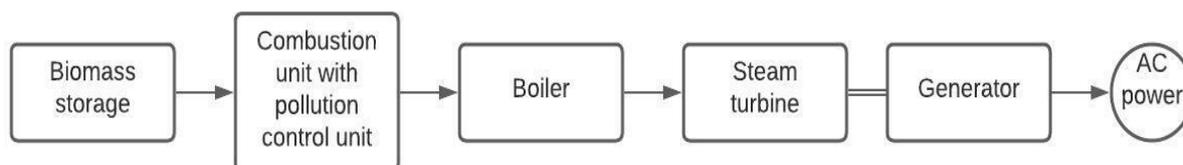


Figure 3. Construction of biomass power station

Hydroelectric power station work in the same manner of a windmill, where the electricity is produced by the kinetic energy generated from a water flow. A hydro turbine is employed in this station for converting the kinetic energy into electrical power [11, 12]. The major limitation of the hydropower power station is the choice of its location, which can be placed only near the dams or rivers. In some cases, the hydropower stations are placed near the canals for utilizing the kinetic energy produced by it. Pumped storage hydropower stations are also employed in recent years, where a low power pump is fixed for moving water from various sources to a huge storage tank [13]. However, the efficiency of pumped storage hydropower station is comparatively less with respect to the traditional models and it may be enabled in the place where the demand for the electricity is very high. Table 1 specifies a comparative view of various renewable power stations.

Table 1. Comparative analysis of renewable energy stations

Energy Sources	Solar	Wind	Biomass	Hydro
Emissions	Low	Low	High	Low
Space requirement	Medium	Low	High	Medium

Construction cost	Low	Low	High	Very High
Maintenance	Low	Low	Very High	High
Power stability	Bad	Bad	Good	Better

2. Literature Work

An improved stacked gated recurrent unit-recurrent neural network was developed to predict the power generation requirement on smart grip application based on the load requirement. The network was designed to operate on both uni-variate and multi-variate conditions. The work requires the historical information on the monitoring and operational data of the smart grid architecture for the training process. The training algorithm is refined in the work with an adjustable momentum for adjusting the variables on control process when there is a change in load conditions [14]. The machine learning algorithms are widely employed in recent years for the prediction of coronary artery diseases also. All kind of prediction algorithms work on the same procedure like data preprocessing, feature selection, training and prediction of estimations [15]. A decentralized stochastic programming approach was proposed to observe the uncertainty in the load variations on domestic renewable energy generation. To minimize the computational load of the proposed approach, a multi-core CPU was employed in the work [16].

Privacy protection is yet a difficulty in processing big data for prediction applications, therefore an effective perturbation algorithm based on optimal geometric transformation was framed to analyse the attack resistance, scalability and accuracy on various dataset analysis. The experimental result indicates that the work achieves better performances than the traditional approaches [17]. Similarly, a fingerprint biometric system was employed for data security in cloud architectures. Here the biometric system was employed based on effective

chaotic model. The experimental analysis states that the proposed work achieves betterment in false detection accuracy and matching [18].

A probability and cumulative density function based technique was designed to monitor the performances of solar and wind renewable energy systems. The technique was also further extended to estimate the non-linearity of the system with a demand response program engaged with an incline block tariff. From the observed estimation a multi-objective genetic algorithm was placed to make a better energy optimization process. The technique predicts the pollution emission, operational cost and supply availability of the connected smart grid systems [19]. The estimations from the smart grids can be observed with an IoT sensor for making a wireless communication. The observations from the IoT sensors can be forwarded to the cloud environment when the system is employed with a WiFi shield. This reduces the computational complexity in the base stations [20].

A particle swarm optimization based algorithm was proposed to minimize the energy generation cost in a load distribution system. The local search capability of the system is improved by making a multiple swarm to the proposed architecture. The performances of the proposed algorithm was compared to the traditional particle swarm optimization model, artificial bee colony and genetic algorithms. The simulation experiment indicates that the proposed system performs better in handling load dispatch issue and reduces the energy generation cost to a certain extent [21]. The recent advancement in smart grid applications allow user to control the power generation with a mobile application having a front end monitoring system with an IoT application and a back end analysis system for suggesting the required operational control [22]. A reliable blockchain based encryption application can also be employed in the cloud network for adding security to the collected data. However, the computational complexity of such encryption models are comparatively high and it can be applied where the memory space requirement is not a problem [23].

An adaptive fuzzy neural network approach was structured with shunt hybrid filters to maintain the power quality in smart and microgrid applications. The simulation experiment

was conducted in Simulink tool in comparison with the adaptive fuzzy back stepping and adaptive fuzzy sliding control and found satisfied with the proposed approach efficiency [24]. A multi-objective integrated optimization framework was employed in a greenhouse micro grid for optimizing the energy generation process. The energy management platform based on model predictive control was incorporated in the system for forecasting the required electricity power on the climatic changes [25].

A demand side management system was employed for managing the smart grid operation in peak load conditions in an efficient way. Here the system is merged with a load shifting algorithm for determining the hour wise load changing patterns on domestic connections. Therefore the experimental work saves energy generation of 9.6KW in summer and winter climates [26]. A combination of levy whale optimization and modified crow search optimizer algorithm was designed to make a hybrid controller for a smart grid application. The controller observes the real and reactive power of the circuit to maintain the power quality [27]. A mixed integer linear programming model was suggested to manage the energy operation problem in a seaport smart grid. The experimental result indicated a remarkable improvement in saving the energy generation cost over the conventional approaches [28].

3. Proposed Methodology

An intelligent automation system is designed to regulate the power generation of smart grids on various climatic changes. The smart grid system analysed in the work contains a solar photovoltaic array setup along with a wind mill and hydro power plant. All these three renewable energy generations require various natural resources like sunlight, wind and water for their operation. Change in environmental climate makes an unstable state to the required natural resources for the renewable energy generation. Therefore an intelligent automation system is proposed in the work to regulate the power generation process with estimation of the climatic changes and required energy consumption. The block diagram of the proposed work is shown in Figure 4.

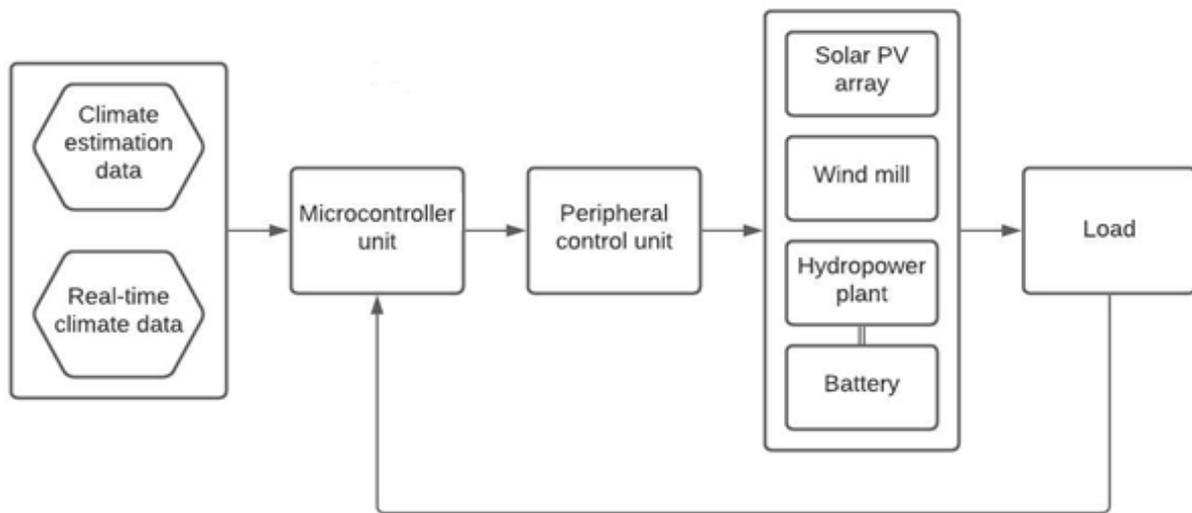


Figure 4. Architecture of the proposed smart grid operating system

The climate estimation data and real-time climate monitoring data play a major role in the operation of selecting an appropriate renewable energy system for power generation process. The climate estimation data are incorporated in the system from a web server and the real-time climate monitoring data are taken into account by the help of sensors enabled in the work. Based on the availability of solar power and wind movement, the system enables the solar PV array and wind mill for power generation. The system also enables the hydropower generation unit during rainy situation. The hydropower plant utilized in the proposed work is a pumped line hydropower plant consisting of a storage tank to save rain water. The storage tank is also connected with a pump system for delivering water to the storage tank when there is no natural water resource available from rain. The pumped line hydropower plant will be enabled when there is a high energy demand in the connected utilization system.

The energy requirement of the water pump is taken from the battery source charged directly from solar PV array and wind mill at the time of less energy utilization by the connected loads. Therefore the system is created to maintain the power efficiency and load distribution to the connected loads in a better way. The solar PV array employed in the work is designed to generate 2KW power supply and the wind mill enabled in the grid system has

the ability to generate 5KW power supply. Similarly, a 2KW hydropower plant is also included in the work for maintaining the power demand at critical times.

4. Performance Analysis

The proposed model is designed to enable solar power supply when the load estimation is under 2KW with adequate sunlight. The system enables the wind mill only when the load is beyond 3KW with adequate wind flow. The operation of hydropower plant (2KW) is enabled only when there is no adequate wind flow available for power generation by wind mill. The system also enables hydropower plant in the night time when there is no adequate wind flow and sunlight for power generation. The experimental analysis of the traditional control system on the smart grid is shown in Table 2. The projection indicates that the energy efficiency of the traditional control system ranges from 72% to 100% and the average energy efficiency of the traditional model reaches up to 91.1%.

Table 2. Performance of the traditional control module in smart grid

Time	Conventional System (Manual)			Total power generated (KW)	Supplied to load (KW)	Supplied to battery (KW)	Energy efficiency (%)	Average energy efficiency
	Solar (KW)	Wind (KW)	Hydro (KW)					
13:00	2	0	0	2	1.5	0	75	91.10%
13:30	2	0	0	2	1.8	0.1	95	
14:00	2	0	0	2	2	0	100	
14:30	0	2.5	0	2.5	1.8	0	72	
15:00	1	2	0	3	2.9	0.1	100	
15:30	1.5	0	1	2.5	2.5	0	100	
16:00	0	2.8	0.2	3	3	0	100	
16:30	0	4	0	4	3.2	0.2	85	
17:00	0	5	0	5	4	0.2	84	
17:30	0	3	0.5	3.5	3.5	0	100	

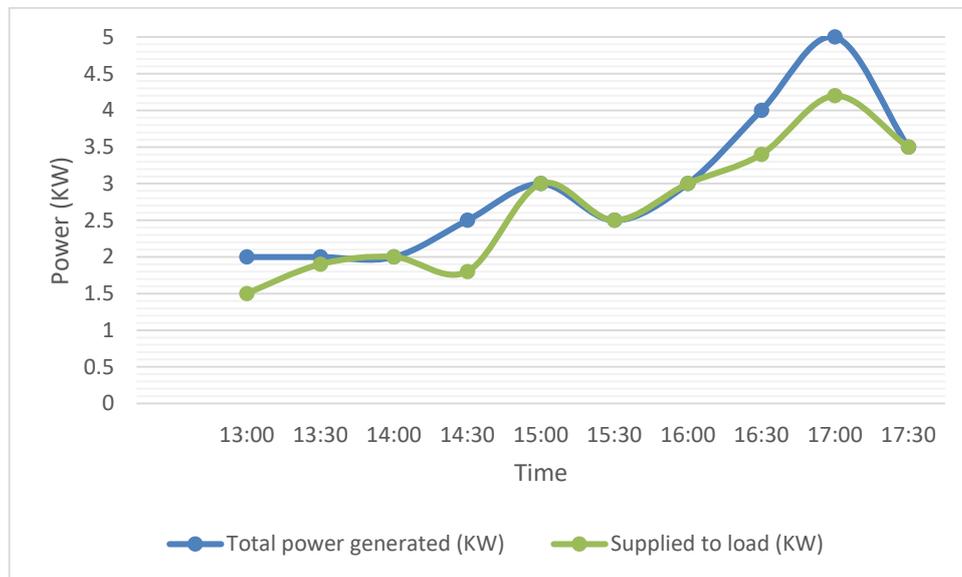


Figure 5. Power analysis of the traditional system

Table 3. Performance of the proposed control module in smart grid

Time	Observed load (KW)	Proposed System (Automated)			Total power generated (KW)	Supplied to load (KW)	Supplied to battery (KW)	Energy efficiency (%)	Average energy efficiency
		Solar (KW)	Wind (KW)	Hydro (KW)					
13:00	2	0	1.5	0.5	2	2	0	100	97.20%
13:30	1.7	2	0	0	2	1.7	0.1	90	
14:00	1.6	1.5	0	0.1	1.6	1.6	0	100	
14:30	2.3	2	0	0.3	2.3	2.3	0	100	
15:00	2.8	0	3.5	0	3.5	2.8	0.5	94.29	
15:30	3.2	0	3	0.2	3.2	3.2	0	100	
16:00	1.5	1.8	0	0	1.8	1.5	0.2	94.44	
16:30	3	2	0	1	3	3	0	100	
17:00	3.8	0	4.5	0	4.5	3.8	0.4	93.33	
17:30	4	0	3.4	0.6	4	4	0	100	

The differences among the generated power and the utilized power is shown in Figure 5. It indicates a huge difference among the generated power and supplied power at 13:00, 14:30, 16:30 and 17:00 hours due to unavailability of an automatic control system. Especially, the system suffers to maintain its efficiency at the time of wind mill operation. The betterment of incorporating an automated control system to a smart grid station is shown in Table 3.

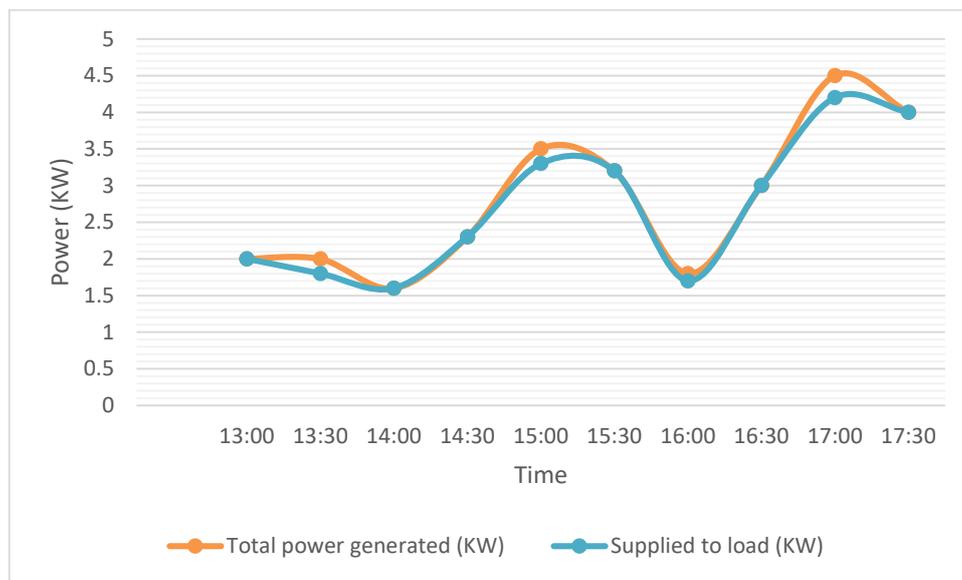


Figure 6. Power analysis of the proposed system

The average energy efficiency observed from the proposed control system reaches up to 97.2%. The load distribution difference among the generated power and the supplied power is shown in Figure 6. It indicates a minimum difference in the powers at 13:30, 15:00 and 17:00 hours. The energy efficiency of the proposed system at various time condition ranges from 90% to 100% which is comparatively better than the traditional control system.

Conclusion

Smart grid systems are usually affected with poor power regulation and poor operational efficiency. Therefore the smart grid systems are connected with a control device based on the real-time power measurement and the generated power measurement. However,

such systems could not maintain the accuracy beyond certain limits. Hence an intelligent control approach based on climatic changes estimation is proposed in the work to regulate the energy generation and distribution process. The system receives climatic change information from the real-time monitoring sensors and web servers for estimating the operation of solar, wind and hydropower plant. Similarly, the energy demand requirements of the connected system is also considered into account for estimating the power generation. The experimental report indicates that the proposed system achieves an average energy efficiency of 97.2% at various load conditions.

References

- [1] Rabaia, Malek Kamal Hussien, Mohammad Ali Abdelkareem, Enas Taha Sayed, Khaled Elsaid, Kyu-Jung Chae, Tabbi Wilberforce, and A. G. Olabi. "Environmental impacts of solar energy systems: A review." *Science of The Total Environment* 754 (2021): 141989.
- [2] Nirmal, D. "High performance flexible nanoparticles based organic electronics." *Journal of Electronics and Informatics* 1, no. 1 (2019): 99-106.
- [3] Shakya, Subarna. "A Self Monitoring and Analyzing System for Solar Power Station using IoT and Data Mining Algorithms." *Journal of Soft Computing Paradigm* 3, no. 2 (2021): 96-109.
- [4] Raju, Leo, V. Balaji, S. Keerthivasan, and C. Keerthivasan. "Internet of things and blockchain based distributed energy management of smart micro-grids." In *International Conference on Computer Networks, Big data and IoT*, pp. 590-596. Springer, Cham, 2019.
- [5] Sadorsky, Perry. "Wind energy for sustainable development: Driving factors and future outlook." *Journal of Cleaner Production* 289 (2021): 125779.
- [6] Ravikumar, S., H. Vennila, and R. Deepak. "Study on Hybrid Wind-Solar Power Generation System with THD Minimization Using Improved Rider Optimization Algorithm." In *International Conference on Mobile Computing and Sustainable Informatics*, pp. 481-488. Springer, Cham, 2020.

- [7] Johnson, Telma, and V. Shijoh. "Novel State Disturbance Based Multi-level Inverter with Sliding Mode Control." In *Data Intelligence and Cognitive Informatics*, pp. 689-698. Springer, Singapore, 2021.
- [8] Zafar, Muhammad Wasif, Avik Sinha, Zahoor Ahmed, Quande Qin, and Syed Anees Haider Zaidi. "Effects of biomass energy consumption on environmental quality: the role of education and technology in Asia-Pacific Economic Cooperation countries." *Renewable and Sustainable Energy Reviews* 142 (2021): 110868.
- [9] Akhtar, Iram, Mohammed Asim, Raj Kumar Yadav, Piyush Agarwal, and Sheeraz Kirmani. "Design of Effective Grid-Connected Solar System." In *International Conference on Inventive Computation Technologies*, pp. 606-614. Springer, Cham, 2019.
- [10] Wang, Haoxiang. "Fault Diagnosis in Hybrid Renewable Energy Sources with Machine Learning Approach." *Journal of Trends in Computer Science and Smart technology (TCSST)* 3, no. 03 (2021): 222-237.
- [11] Nayak, Manas Ranjan, Manoj Saha, and Chinmay Kumar Nayak. "Optimal Participation of Hybrid Renewable Energy Sources in Standalone Microgrid." In *International Conference on Intelligent Computing, Information and Control Systems*, pp. 144-153. Springer, Cham, 2019.
- [12] Bashar, Abul, and S. Smys. "Integrated Renewable Energy System for Stand-Alone Operations with Optimal Load Dispatch Strategy." *Journal of Electronics* 3, no. 02 (2021): 89-98.
- [13] Haas, Jannik, Luis Prieto-Miranda, Narges Ghorbani, and Christian Breyer. "Revisiting the potential of pumped-hydro energy storage: A method to detect economically attractive sites." *Renewable Energy* 181 (2022): 182-193.
- [14] Xia, Min, Haidong Shao, Xiandong Ma, and Clarence W. de Silva. "A stacked GRU-RNN-based approach for predicting renewable energy and electricity load for smart grid operation." *IEEE Transactions on Industrial Informatics* 17, no. 10 (2021): 7050-7059.
- [15] Haoxiang, Wang, and S. Smys. "Big Data Analysis and Perturbation using Data Mining Algorithm." *Journal of Soft Computing Paradigm (JSCP)* 3, no. 01 (2021): 19-28.

- [16] Chen, Joy Iong Zong, and P. Hengjinda. "Early Prediction of Coronary Artery Disease (CAD) by Machine Learning Method-A Comparative Study." *Journal of Artificial Intelligence* 3, no. 01 (2021): 17-33.
- [17] Wang, Yue, Hao Liang, and Venkata Dinavahi. "Decentralized stochastic programming for optimal vehicle-to-grid operation in smart grid with renewable generation." *IET Renewable Power Generation* 15, no. 4 (2021): 746-757.
- [18] Manoharan, J. Samuel. "A Novel User Layer Cloud Security Model based on Chaotic Arnold Transformation using Fingerprint Biometric Traits." *Journal of Innovative Image Processing (JIIP)* 3, no. 01 (2021): 36-51.
- [19] Ullah, Kalim, Ghulam Hafeez, Imran Khan, Sadaqat Jan, and Nadeem Javaid. "A multi-objective energy optimization in smart grid with high penetration of renewable energy sources." *Applied Energy* 299 (2021): 117104.
- [20] Sungheetha, Akey, and Rajesh Sharma. "Real Time Monitoring and Fire Detection using Internet of Things and Cloud based Drones." *Journal of Soft Computing Paradigm (JSCP)* 2, no. 03 (2020): 168-174.
- [21] Vijayakumar, T., and R. Vinothkanna. "Efficient energy load distribution model using modified particle swarm optimization algorithm." *Journal of Artificial Intelligence* 2, no. 04 (2020): 226-231.
- [22] Butt, Osama Majeed, Muhammad Zulqarnain, and Tallal Majeed Butt. "Recent advancement in smart grid technology: Future prospects in the electrical power network." *Ain Shams Engineering Journal* 12, no. 1 (2021): 687-695.
- [23] Joe, C. Vijesh, and Jennifer S. Raj. "Deniable Authentication Encryption for Privacy Protection using Blockchain." *Journal of Artificial Intelligence and Capsule Networks* 3, no. 3 (2021): 259-271.
- [24] Das, Soumya Ranjan, Prakash K. Ray, Arun K. Sahoo, Krishna Kant Singh, Gaurav Dhiman, and Akansha Singh. "Artificial intelligence based grid connected inverters for power quality improvement in smart grid applications." *Computers & Electrical Engineering* 93 (2021): 107208.

- [25] Ullah, Israr, Muhammad Fayaz, Muhammad Aman, and DoHyeun Kim. "An optimization scheme for IoT based smart greenhouse climate control with efficient energy consumption." *Computing* (2021): 1-25.
- [26] Praveen, Mande, and GV Sivakrishna Rao. "Ensuring the reduction in peak load demands based on load shifting DSM strategy for smart grid applications." *Procedia Computer Science* 167 (2020): 2599-2605.
- [27] Kannayeram, G., N. B. Prakash, and R. Muniraj. "Intelligent hybrid controller for power flow management of PV/battery/FC/SC system in smart grid applications." *International Journal of Hydrogen Energy* 45, no. 41 (2020): 21779-21795.
- [28] Iris, Çağatay, and Jasmine Siu Lee Lam. "Optimal energy management and operations planning in seaports with smart grid while harnessing renewable energy under uncertainty." *Omega* 103 (2021): 102445.

Author's biography

Joy Iong-Zong Chen is currently a full professor in the Department of Communication Engineering Dayeh University at Changhua Taiwan. Prior to joining Dayeh University, he worked at the Control Data Company (Taiwan) as a technical manager from Sep.1985 to Sep. 1996. His research interests include wireless communications, spread spectrum technical, OFDM systems, and wireless sensor networks. He has published a large number of SCI Journal papers on the issues addressed by the physical layer for wireless communication systems. Moreover, he also majors in developing some applications of the IOT (Internet of Thing) techniques and Dr. Joy I.-Z. Chen owned some patents authorized by the Taiwan Intellectual Property Office (TIPO).

Kong-Long Lai is currently working as professor in the Department of Electrical Engineering, Da-Yeh University, Changhua, Taiwan. His area of research includes Information and communication technologies, Antenna design and RF propagation, Autonomic, & Dependable computing, Green Computing, Computational Complexity and Networks.