A Survey on the Provision of Smooth Transition Between Operation Modes in PV-BESS Microgrid

Burak Onar
Electronic and Automation Dep.
Anadolu OSB Vocational School, Başkent University
Ankara, Turkey
burakonar@baskent.edu.tr

Şevki Demirbaş
Electric and Electronic Engineering
Gazi University
Ankara, Turkey
demirbas@gazi.edu.tr

***Abstract*—The need for energy is increasing everyday, depending on rising in population and technology. However, electrical energy produced by conventional methods, obtained from fossil fuels, leads to serious problems in environmental pollution and energy resources decreasing worldwide as well. Therefore, it has increased orientation to alternative energy sources when all these situations are taken into account. The increase of alternative energy sources has raised the necessity of microgrid systems. However, it is known that a multifunctional types of electrical energy production systems such as the solar, wind, diesel generator, energy storage system are in a single roof. The microgrids operating principle works in both operating modes, both in island mode and grid connection. This components forming the complex structure will bring in a very difficulty in synchronously with each other. These challenges are critical to ensure the transitions between the operating modes. Because, along with the interruption of the grid connection, due to corruption such as the phase shift, voltage / frequency deviation, current harmonics can result in difficult situations that may result in grid collapse. In this study a survey has been implemented for the provision of smooth transition between operation modes in PV-BESS Microgrid. All possible situations are considered photovoltaic (PV) system which is critically important in renewable energy sources and microgrid design consisting of the battery energy storage system (BESS), which is critical for uninterrupted energy, is planned at the study.**

Keywords—microgrid, smartgrid, smooth transition, pv, bess.

I. Introduction

Today, the electrical energy has become indispensable in a very difficulty with its facilities. The tendency to exhaust fossil fuels, production methods that cause environmental pollution, economic effects and supply demanding relationships can be sorted as a few of them. Therefore, when all these problems are evaluated, a number of innovations are required in the production and consumption chain of energy. These innovations are increased by the trend to renewable energy sources at the beginning. The proliferation of alternative energy sources has led to the development and dissemination of microgrid systems that enable these energy sources to be managed from a single system. This alternative energy sources, such as solar energy system (SES), wind energy system (WES), micro-turbines (MT), hydro power plants (HEP), Thermal power plants (TES), Bio power plants, Bio Mass, as well as renewable or non-renewable energy sources, Diesel generators, such as energy storage systems (ESS) and uninterrupted power supplies (UPS) contributes to microgrid systems as a supporting system. As the micro mains is seen in Figure 1, it is a system that can be included in all these energy sources.

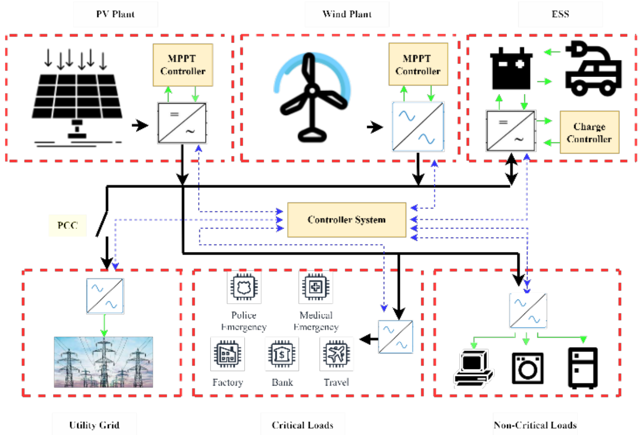

Fig 1. A simple control structure of the microgrid.

In recent years, the microgrid that replaces the research within the subjects, along with the renewable and non-renewable energy sources it has, Security, reliability, flexibility, convenience, seamless and quality power, minimum transmission loss and minimum cost features such as By keeping at the forefront, In the general framework, it has contributed to ensure a clean and reliable energy with the logic in place and in place. In addition, microgrids can work in two different operation modes, including grid connected or island mode. Designed microgrids In order to provide a continuous quality and reliable power, as It can feed the loads connected to the island mode, as well as renewable and non-renewable energy sources in which it can work in connection with the grid. As a result of all this, it can work with two different operating modes, including grid connected mode and island mode in microgrids.

However, all this is desirable to supply energy production resources with complex structure under a single roof and feed the load groups that are determined in synchronously with each other. With many advantages of microgrid structure, different type of production from each other, feed, production capacity such as the production resources with a different feature are asked to interact with each other to supply the same load groups. Therefore, there are many difficulties in this synchronization phase. These challenges can be sorted as the active power sharing in distributed production, harmonic compensation, unbalanced load compensation, reactive power compensation from grid connection mode to island mode or island mode to grid connection mode smooth transition [1]. The grids connection mode, which is located at the beginning of these challenges, the micro-mains system that can also operate the micro-mains system can be unintended to provide continuous, high quality and safe energy, due to the interruption of the mains connection to the island mode as a result of the interruption of the mains connection due to environmental and systemic factors. In addition, the intentional island mode, planned grid connection by cutting the island mode is also available in working conditions that provide continuity of the system. This is an important condition for micro networks to continue to provide sufficient power of loads. Under normal operation, the micro grid operates in constant current mode to provide power from the main grid of each district production system [2]. However, it should be examined in the island mode with the cutting of the microgrids grid connection. Therefore, the voltage can be switched to the Control Mode. In this mode, it provides constant voltage to the microgrid. Therefore, the microgrid that can work in both operation modes are systematically unexpected in many difficulties with the sudden grid break. One of the biggest problems encountered in both operating modes of microgrid is the transition status of the planned or unplanned island mode, the main focus of our study is the transition status to unplanned island mode. It will occur during the transition between the operating modes, voltage and frequency fluctuations, current harmonics, active and reactive power imbalances and it will be caused to errors that are difficult to go to the system crash by facing a lot of problems such as not overlap the phase angles. The main challenges that may occur during unplanned islanding; i) The microgrid frequency shift that may affect its determination, ii) Large voltage deviations that may occur at the inverter exit between the operating modes, iii) Active power, reactive power harmonics may occur due to deviations that may occur in current and voltage [3].

A lot of research was conducted in the literature by considering all this occurring. In recommended study in [4], challenges are mentioned between network connection mode and island mode. It is suggested that virsual synchronous generator (VSG) and Droop Control Methods can be a good solution to reduce the frequency deviation during the microgrid transition. In [5], it has proposed the Droop Control method in the proposed study, it does not need an external communication between the inverters in the grid connection mode and island mode. However, with the cutting of the grid connection, the grid current must be compensated. Accordingly, it has been monitored by a definition under the name of the shipment unit to ensure properly the passage has been monitored. In addition to this in the proposed study in [6], the use of the main grid interactive PWM algorithm was proposed to provide the inverter control to ensure non-continuous energy for precision and critical loads if there is an error on the grids. With the recommended control method, it can easily switching from current control mode to voltage control mode. The Droop Control Method is widely used to ensure smooth transition between the operating modes of the microgrid [7]. The greatest advantage of this is that it doesn't need an external communication. In the proposed study, it does not change the parameters of the nominal during the operation in microgrid island mode. But with H-infinitive and Model Prediction Control (MPC) control methods used in the proposed study, smoothly transition provided between both operating modes. In addition, MPC's from network connection mode to island mode in transition, reducing grid tracing error, having a quick transition time and in terms of economy has provided significant advantages. There are 2 different operating modes, including the most stunning feature of microgrid systems on grid connection mode and island mode. Thus, in the proposed operation in [8], the current controlled voltage source inverter (CC-VSI) and voltage controlled voltage source inverters (VC-VSI), by applying a single - phase microgrid, it has been contributed to smooth transition which is used between both operating modes. A microgrid is located in different types of distributed production. It can be listed here as renewable energy sources such as PV, Wind and MT. Thus maximum power is always transferred to the local grid. On the other hand, VC-VSIs and Droop Control techniques are always preferred in battery and other energy storage technologies. In the proposed study of [9], the Droop Control Plan is preferred to ensure the smooth transition between both operating modes, while the AC microgrids are recommended as a local Control plan to obtain the average power sharing. However, the droop control plan has been ignored in the grid connection mode. The recommended operation in [10] has been proposed Control strategy of VSI for Seamless transition among the island mode and grid connected. However, Droop Control method has been used without any communication between both operating modes. In addition, in the microgrid system, it has been preferred to facilitate intermediate connection with the main grid to provide seamless transitions with the assistance of the dispatch unit defined. [11] In the proposed study, VSI was preferred for parallel working conditions, while the Droop Control method was preferred due to lack of communication. Especially the reason for VSI is to keep system security at high level. The distributed production units can provide microgrid connections with the interface of power electronics with VSI. In [12], a control level is preferred as 3 layers applied to the microgrid system in the proposed study. The first level is the fastest of the spindle seconds. The second layer is slower than the first one. The third is the slowest control level. In longer periods, it is focused on energy and power management. Each of these levels is preferred for a purpose. To maintain the determination of each distributed unit of first level. The second level produces the effect of dynamic loads, generators and inertia effect on the load side. Thus, it improves voltage and frequency deviations. The third level is focused on energy and power management. In general, the current study has focused on the frequency decision in the microgrid. In [13], the current control of the operating modes is presented in the proposed study depending on a new plan. In addition, the phase locking loop (PLL) and PI-based controller helps the correct estimate of the phase angle during the inverter switching. In [14], a new plan has been adopted for seamless transition between Network Connection Mode and Island Mode. In the proposed method, the island mode was examined with PLL and the phase angle error was determined through PLL during the re-synchronization stage to the grid.

When the studies in the literature were examined, many different methods were encountered. The middle object of all of them is intended to ensure that transitions to planned or unplanned island mode between the distributed production units and the main grids in microgrids. As a result, in recent years, it is planned to be carried out to ensure the problems of transitions between the operating modes in microgrid systems that are replaced in the foreground. The distributed production units, which are replaced in microgrids systems, the solar

(PV), battery energy storage systems (BESS) and the main grid will also be made. This system will be ensured that both grid connection and island mode. In addition, a new study is planned to ensure smooth transitions between the operating modes.

II. Smooth Transition Between the Operating modes of the microgrid

A. Grid Connected Operation of Microgrid

The microgrid system is formed by using many components such as solar, wind, electric vehicles, diesel generators, energy storage system and load groups. The microgrid will be appropriate to work in both the grid connection and island mode in line with the target and principles of providing reliable, quality and uninterrupted power. It is a supportive point in both an angular reference and reliability angle. In general, the grid connected micro grids are connected to the main grids parallel [15]. However, the voltage and frequency are synchronized. Thus, both the quality of power is improved. There is a system security provided. It is preferable to use PLL usually in voltage and frequency synchronization [2]. In both operating modes, the system has a lot of difficulties with the breakage of the grid connection.

B. The Microgrid's Operation in Island Mode

The main principle of the microgrid system can continue to operate in island mode when faced with some unwanted situations of microgrid that operation grid connection. There are 2 different situations in switching to island mode [15]. In the first permitted range, the voltage and frequency is examined or the island mode giving an instruction to move to the island connection position from the grid connection location of the system. In general, grid tracking or compensation for the grid current is performed when these procedures are carried out.

C. Problems During the Transition Between Operation Modes

Microgrid, operations to be both the grids connection mode and the island mode in two different operation modes. Hence by the transition between working modes, both planned and unplanned, It can transition to island mode depending on systemic and environmental factors. When all these situations are taken into account, the load groups connected to the microgrid can transitions to the island connection mode from the grid connection mode. In the opposite case there is a case. However, some challenges can be encountered during the transition between operating modes. This is the basic challenges;

- Frequency fluctuations leading to disorder in power angles in distributed energy sources affecting microgrid stability [3,4,16]
- Large deviations in the inverter output of the distributed energy source interface due to the inverter switch in operation mode [3,4,16]
- During the transition between different modes, current and voltage deviations of distributed energy sources may occur due to static transfer switching due to inverters.

In research on the provision of smooth transitions, the main focal point is the smooth transitions to unplanned island mode. Therefore, in the case of transition to unplanned island mode, it is not an easy operation to set the working point of the distributed energy sources according to the unlikely situations or to perform a sudden formation. Therefore, the system determination will be compromised by occurring large distortions and deviations in the voltage and frequency amplifiers of the microgrid. However, as a result of the research in the literature, the distributed energy sources are generally connected to the network Active / Reactive Power (PQ) checked and Distributed energy sources are also observed when the island mode is operating voltage / frequency (V/F) control [17].

However, in the literature, it is understood that the existing methods for microgrid management are grateful from the weak performance structure or the use of extra components. [5]. A decrease in the voltage does not occur together with the cutting of the grid connection. However, the power will not be produced for the current signal will be produced and collapse in the network will be able to occur. The current must be compensated for the current microgrid after the grid connection is disconnected during planned or unplanned transitions.. Not only that, these transitions are generally performed with static transfer switching. Therefore, the realization of phase and frequency matches is serious. In the network follow-up strategy, if the error occurs during the phase sequence and angle match, crashes will occur in the grid. It is critical for mains continuity in frequency values.

If all of this information will make general evaluation in the business;

- Active / Reactive Power (PQ) fluctuations,
- Voltage / Frequency (V/F) fluctuations,
- Current harmonics as a result of the disconnection of the sudden grid connection,
- Frequency fluctuations due to the power angle disruption to compromise microgrids stability,
- Voltage fluctuations against sudden connection breaks at inverter outputs,

Such as specific problems faced. Therefore, in order to eliminate all these errors and disorders, the necessary studies should be carried out for the transition without any problems considering all possible situations.

III. RECOMMENDED SEAMLESS TRANSITION PLAN

The production resources of the microgrid are component with many different features. Microgrids contains many basic differences in terms of supply type and energy production techniques. However, the system can be designed to feed the load specified in different bar connections, including the AC bar, DC bar or hybrid AC/DC bar. However, the microgrids system is intended to provide energy without any interruption of the installation and purpose of use. Therefore, the system must be able to work in both the grid connection and island mode to perform this purpose.

In the general framework, critical loads with certain priority and normal loads are required to provide uninterrupted power. In this context, the transitions in a synchronous manner must be provided between the operating modes. However, as it is known, it will be faced with many challenges during the synchronous operation of the component with such different operating characteristics and features. At the beginning of these, the voltage and frequency deviations during transition from grid connection mode to the island mode or from island connection mode to grid connection mode, Current harmonics against distortion occurring, It is facing a lot of problems such as phase shifts.

To overcome all these difficulties and grid safety, transmission power loss, power quality improvement, in place and efficient operation of the logic of consuming power quality of microgrid. and regenerating energy resources are used in maximum efficiency and reaching many targeted purpose, such as increasing the acquisition of environmentally friendly energy, is prompted to ensure non-stop energy.

As the recommended study, it has been preferred a controller design for the smooth realization of the transitions between the grid connection study and the island mode for microgrids. In this context, it is known that it consists of many distributed production units such as wind power plant, solar power plant, micro turbine, bio mass, geothermal energy, electric vehicles and battery energy storage systems. In addition, the different load groups are provided. As shown in Figure 2 When this complex structure has the grid connection and island mode is also considered in operating situations, a number of different structures have been raised.

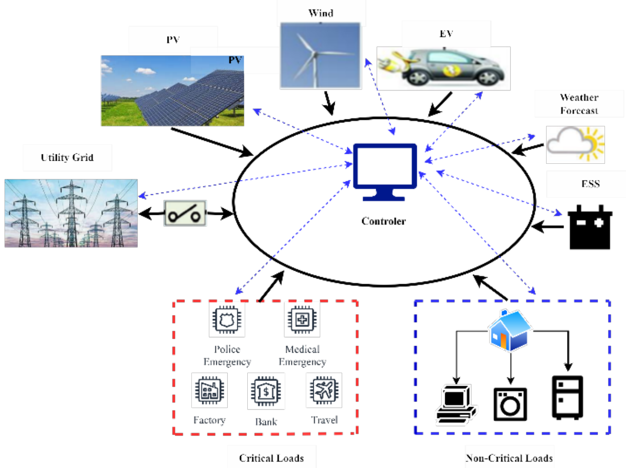

Fig 3. Microgrid control architecture.

Therefore, managing this complex structure will be encountered in different challenges for each distributed generation resources in the management of the distributed generation resources. However, control methods are required to solve the problems encountered for each distributed production. At this stage, it is aimed to maintain our study with some distributed production resources, which we determine with the aim of increasing the efficiency of the study and maintain the work with sound steps. As can be seen in Figure 3, it can say that it is in the reduction phase from general to private. It is planned to design a controller for the provision of smooth transitions with the main mains, by a micrograds design consisting of Solar (PV), Battery Energy Storage System (BESS), load groups and the main grid.

A. Recommended PV-BESS Architecture

Define abbreviations and acronyms the first time they are used in the text, even after they have been defined in the abstract. Abbreviations such as IEEE, SI, MKS, CGS, sc, dc, and rms do not have to be defined. Do not use abbreviations in the title or heads unless they are unavoidable.

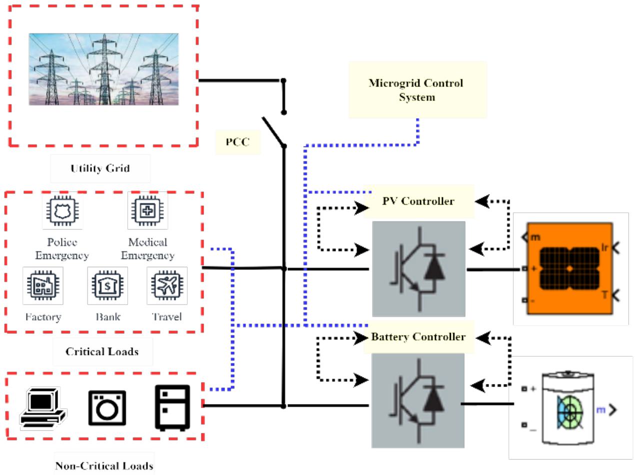

Fig 2 Distributed Energy Sources (DES), Point of common Connected (PCC), Power Electronics Control Unit Block Diagram.

As the Microgrid we suggest is seen in Figure 4, consists from 4 different component impending PV, BESS, load groups and the main mains.

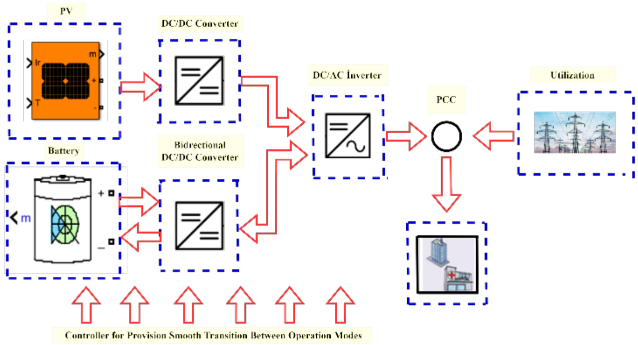

Fig 4. Simplified block diagram for proposed work

In the literature, many Control methods are used in the PV-BESS microgrid. In the proposed study in [17], the main Control unit of the inverter control strategy has benefited from the microgrid Master-Slave Control structure and the microgrids has provided smoothly between the mains. In this structure, the main control unit is connected to grid while voltage/frequency (V/f) control, While in island mode, the active power / reactive power control strategy has adopted. In [18], the grid connected PV-BESS has implemented the learning quantification (LQ) based PV pre-feed (PVFF) method to control the synchronous system in the microgrid system. The advantage of this method has provided rapid follow -up even in changing climatic conditions. [19] In a single-phase grid connected PV-BESS system, it provides grid security during temporary cases such as PCC synchronization, when faced with sudden grid throwing. In addition, while provides maximum power extraction with Perturb & Observe (P&O) the technique, it provides the battery charging discharge status with double-way DC/DC Boost Converter. In addition, the voltage welding converter (VSC) used in the system provides the balanced power distribution between the main grid and BESS that the critical loads require. [20] In the proposed study, a Windows Factor (WF) -based algorithm was used for the integration with the microgrid and battery of the grid. In addition, the PV maximum Power Point Tracking (MPPT) was preferred in the incremental conductivity technique. However, algorithm has improved seamless transitions and dynamic performance of the system. In the study in [21], a multifunctional PV-Bess grid synchronization is presented. There is also a smooth transition between both operating modes. With PVFF helps maximum power inference. In addition, the proposed operation is successful in suppressing the harmonics of non-linear loads in the microgrid. In addition, in case of climate change, 3-phase microgrids improved the dynamic response.

PV, which is the distributed production unit in the proposed microgrid design, will be achieved maximum power with (MPPT). Then, a proper DC voltage is obtained via DC/DC Converter. The battery blocks, replacing in the microgrid system will use both the energy to which it will be fed from the micro grid, as well as to feed the load groups in the microgrids. The battery will be integrated into the system with the help of the bidirectional DC/DC Converter. Because it needs to support the microgrid and charge. These two distributed production output will be combined in a single DC bar and transfer to DC/AC inverter. Inverter output should be combined in the Point Common Connected (PCC). The PCC point is working as a junction point of the inverter at the output of both the PV-BESS block, the inverter in the main grid exit and the inverters in the load groups.

IV. CONCLUSION

As it is known in microgrid systems, the main purpose is to provide reliable, high quality and uninterrupted energy. In addition, it is both grid connected and operating in island mode. Therefore, will be encountered many problems during the synchronization of this complex system, which includes many components independent of each other. One of these problems for grid systems is provided that the smooth transitions between working modes. The provision of smooth transitions between the operating modes is a critical importance in terms of uninterrupted energy. In this context, it is planned to a new controller design for smooth transition between the operation modes of the microgrid consisting of grid connected PV, BESS and load groups. As a result, it is thought that the proposed study will contribute to literature in terms of grid security, power quality, uninterrupted and continuous energy. The conclusion section should emphasize the main contribution of the article to literature.

REFERENCES

[1] G. G. Talapur, H. M. Suryawanshi, L. Xu, and A. B. Shitole, “A reliable microgrid with seamless transition between grid connected and islanded mode for Residential Community With Enhanced Power Quality,” IEEE Transactions on Industry Applications, vol. 54, no. 5, pp. 5246–5255, 2018.

[2] I. J. Balaguer, Q. Lei, S. Yang, U. Supatti, and F. Z. Peng, “Control for grid-connected and intentional islanding operations of distributed power generation,” IEEE Transactions on Industrial Electronics, vol. 58, no. 1, pp. 147–157, 2011.

[3] S. D'silva, M. Shadmand, S. Bayhan, and H. Abu-Rub, “Towards grid of microgrids: Seamless transition between grid-connected and islanded modes of operation,” IEEE Open Journal of the Industrial Electronics Society, vol. 1, pp. 66–81, 2020.

[4] M. Ganjian-Aboukheili, M. Shahabi, Q. Shafiee, and J. M. Guerrero, “Seamless transition of microgrids operation from grid-connected to Islanded Mode,” IEEE Transactions on Smart Grid, vol. 11, no. 3, pp. 2106–2114, 2020.

[5] M. N. Arafat, A. Elrayyah, and Y. Sozer, “An effective smooth transition control strategy using droop-based synchronization for parallel inverters,” IEEE Transactions on Industry Applications, vol. 51, no. 3, pp. 2443–2454, 2015.

[6] R. Tirumala, N. Mohan, and C. Henze, “Seamless transfer of grid-connected PWM inverters between utility-interactive and stand-alone modes,” APEC. Seventeenth Annual IEEE Applied Power Electronics Conference and Exposition (Cat. No.02CH37335).

[7] B. E. Sedhom, M. M. El-Saadawi, A. Y. Hatata, and E. H. E. Abd-Raboh, “H-Infinity versus model predictive control methods for seamless transition between islanded- and grid-connected modes of microgrids,” IET Renewable Power Generation, vol. 14, no. 5, pp. 856–870, 2019.

[8] A. Micallef, M. Apap, C. Spiteri-Staines, and J. M. Guerrero, “Single-phase microgrid with seamless transition capabilities between modes of operation,” IEEE Transactions on Smart Grid, vol. 6, no. 6, pp. 2736–2745, 2015.

[9] Y. Deng, Y. Tao, G. Chen, G. Li, and X. He, “Enhanced Power Flow Control for grid connected droop-controlled inverters with improved stability,” IEEE Transactions on Industrial Electronics, vol. 64, no. 7, pp. 5919–5929, 2017.

[10] M. N. Arafat, A. Elrayyah, and Y. Sozer, “An effective smooth transition control strategy using droop-based synchronization for parallel inverters,” IEEE Transactions on Industry Applications, vol. 51, no. 3, pp. 2443–2454, 2015.

[11] Y. Jia, D. Liu, J. Liu, “A Novel Seamless Transfer Method for a Microgrid Based on Droop Characteristic Adjustment”, IEEE 7th International Power Electronics and Motion Control Conference - ECCE Asia June 2-5, 2012, Harbin, China

[12] A. Karaki, M. Begovic, H. Abu-Rub, S. Bayhan, and I. Poonahela, “On frequency control techniques for microgrids,” 2018 International Conference on Smart Energy Systems and Technologies (SEST), 2018.

[13] I. Ahmed, S. Longting, and C. Xin, “A novel control scheme for microgrid inverters seamless transferring between grid-connected and Islanding mode,” 2017 China International Electrical and Energy Conference (CIEEC), 2017.

[14] D. N. Gaonkar, G. N. Pillai, and R. N. Patel, “Seamless transfer of microturbine generation system operation between grid-connected and Islanding modes,” Electric Power Components and Systems, vol. 37, no. 2, pp. 174–188, 2009.

[15] Y. Zhang, P. Yang, Z. Xu, and J. Chen, “Smooth mode transition strategies of PV-Bess Microgrids,” 2017 2nd International Conference on Power and Renewable Energy (ICPRE), 2017.

[16] X. Hou, Y. Sun, J. Lu, X. Zhang, L. H. Koh, M. Su, and J. M. Guerrero, “Distributed hierarchical control of AC microgrid operating in grid-connected, islanded and their transition modes,” IEEE Access, vol. 6, pp. 77388–77401, 2018.

[17] Q. Xiang, Z. Liao, and T. Li, “A novel control strategy of the seamless transitions between grid-connected and Islanding Operation Modes for the multiple complementary power microgrid,” International Journal of Electronics, vol. 108, no. 8, pp. 1381–1400, 2021

[18] S. Kumar and B. Singh, “Seamless operation and control of single-phase hybrid PV-bes-utility synchronized system,” IEEE Transactions on Industry Applications, vol. 55, no. 2, pp. 1072–1082, 2019.

[19] O. P. Jaga and S. G. Choudhuri, “Seamless transition between grid-connected and islanded Operation Modes for hybrid PV-Bess Combination used in single-phase, Critical Load Applications,” 2021 International Conference on Sustainable Energy and Future Electric Transportation (SEFET), 2021.

[20] S. Kumar and B. Singh, “Windowing Factor Based Control Algorithm for grid integrated SPV system,” 2016 IEEE 1st International Conference on Power Electronics, Intelligent Control and Energy Systems (ICPEICES), 2016.

[21] S. Kumar and B. Singh, “Seamless transition of three phase microgrid with load compensation capabilities,” 2017 IEEE Industry Applications Society Annual Meeting, 2017