PAPER • OPEN ACCESS

Voltage and Active Power Management Control of PV Source Distributed Generations under Unbalanced Voltage of Non-islanded Microgrid

To cite this article: Wan Azman Wan Abdullah and Abu Zaharin Ahmad 2022 *J. Phys.: Conf. Ser.* **2319** 012003

Voltage and Active Power Management Control of PV Source Distributed Generations under Unbalanced Voltage of Non-islanded Microgrid

Wan Azman Wan Abdullah[1], Abu Zaharin Ahmad[2]

[1]*Faculty of Engineering Technology, University College TATI, Kemaman, Terengganu, Malaysia, Email:*wazman@uctati.edu.my

[2]*Faculty of Electrical & Electronics Engineering Technology, University Malaysia Pahang, Pekan, Pahang, Malaysia, Email:*zaharin@ump.edu.my

Abstract. Key solution for future electrical power generation depends on alternative energy such as Solar Energy and renewable energy. Solar energy can be harvested by using a fast growing technique like Photovoltaic Plants (PV) in order to fulfill the demand of electrical energy. Proportional Integral Derivative Controller (PID controller) is added together with power electronic components such as boost converter combined with suitable controller of different maximum power point tracking techniques (MPPT) combined to optimized the PV system. In this paper, sudden irradiance and cell temperature variations are the variable input tested on grid PV systems modeled in MATLAB SIMULINK software. Incremental Conductance PID Controller with the trial and error method is used randomly in order to have good and efficient of transmission of energy and avoiding the unbalance voltage at the same time enhancing the protection system from bad disturbances. The stability of the system is checked to counter various irradiance and temperature in order to have a balance voltage and optimum energy. The new controller then been compared with previous literature in order to ensure the designed controller operating following the state of boundary and limitation of the operation.

Keywords: Renewable Energy, Energy storage, Microgrid, PV Power source.

1. Introduction

The increasing incidence of distributed generation (DG) and active distributed networks, changing regularities, and needs to improve the power system reliability and clean power support is providing development of a new power system perception commonly referred to as the smart grid. In this regard, the microgrid can be considered as one of the most promising concepts. Microgrids have a long history. In fact, Thomas Edison's first power plant constructed in 1882 – the Manhattan Pearl Street Station – was essentially a microgrid since a centralized grid had not yet been established. By 1886, Edison's firm had installed fifty-eight direct current (DC) microgrids and started from that revolution of electricity services. Microgrid is an integrated energy system that consists of multiple distributed energy resources and multiple electrical loads. It can operate as a single, autonomous grid either in parallel with the mainstream grid or separated from the grid of the origin.

Normally microgrids were categorized as smaller versions of the electrical grid. Same as the national distribution grid, microgrids also consist of power generation, distribution, and control. The microgrid can increase the efficiency of energy distribution by providing a closer proximity between power generation and power consumption.

The use of renewable energy introduces the need for energy storage to overcome the intermittent constraint created by nature. An interruption such as a blackout can happen due to this issue. To avoid the problem, the strategy of energy management needs to be established in order to control this problem.

The best example can be shown is Sendai Microgrid at Tohoku Fukushi University. The electrical grid collapsed during a devastating earthquake and tsunami in 2011. The Sendai microgrid supplies the electricity using the distributed generator and batteries to a variety of facilities. Microgrids can fulfill the need of application in industrial, commercial, military and institutional. The microgrid indeed can help many people that cannot access the electricity. These rural and remote areas normally get electricity by diesel generator or small scale electricity generating equipment.

On an economic perspective, microgrids can be used to reduce energy cost, generate revenue and reduce the environmental issues created by conventional power generation but still can provide electricity at off-grid areas with regular access to electricity as well as provide electricity to critical applications like hospitals. Figure 1 shows the capacity of microgrids in the world market from the years 2010 to 2016 [1]. It shows that over 3.5GW of new microgrid capacity is projected to come online worldwide, representing a total market value of $ 3 billion.

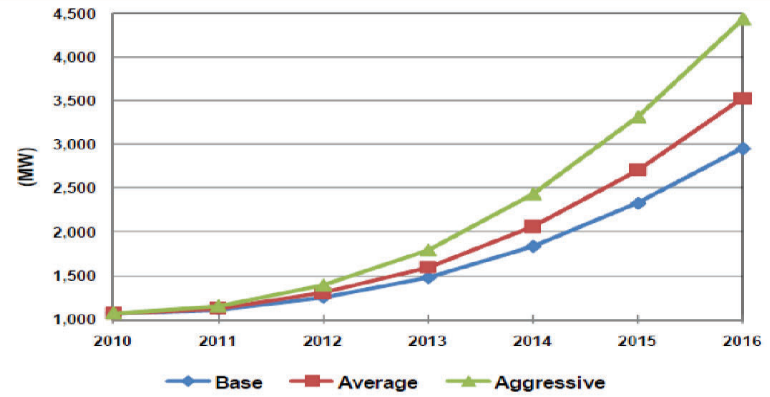

Figure 1: Capacity of microgrid in world market from years 2010-2016

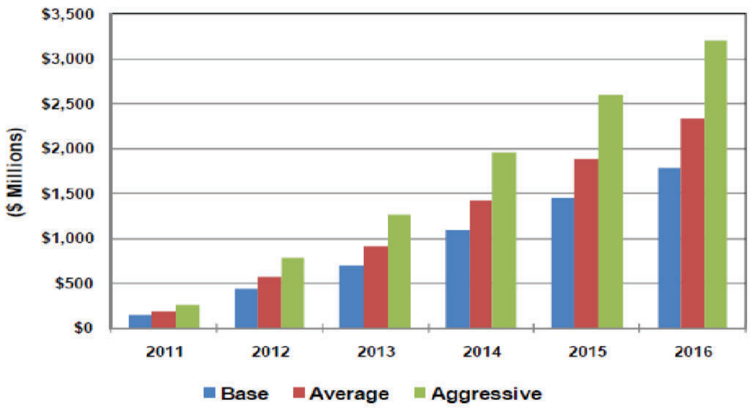

Figure 2: Annual Microgrid Revenue, Base, Average, and Aggressive Scenarios, World Markets: 2011-2016

Nowadays, the direction of electricity distribution has encouraged the use of distributed generation (DG) in most of the countries. The current electricity grid infrastructures consist of large power plants located at certain areas with complex grid networks from generation to distribution. However, with a new trend of electricity distribution, the development of DGs, which is situated closely to the electricity consumers, has increased the reliability of energy distribution. The integration and emergence of DGs into the grid, especially renewable energy sources, has brought the solution for electricity with the increasing load demand. Not only that the utilization of renewable energy as a source can minimize the effect of green-house to the environment, it also shows the cost of operation can be optimally controlled. The key to power reliability in the distribution stage or microgrid is to ensure the energy management control of DGs can enhance power supply to the load and meet the objective required for certain events or situations. Therefore, a proper control for DGs system in grid is essential in maintaining the operational within the desired distribution system. Most of the DGs are connected to the grid using power electronics interfacing circuits (converter), which is converting DC or AC voltage to the AC grid voltage.

Thus, it is important that the control strategy is applied to keep the voltage stable under any disturbances and fault events. The grid-connected converters are highly sensitive to any grid disturbances, hence minimizing the effects of voltage disturbances is vital in DGs systems that eventually improve the power quality of the distribution voltage. Furthermore, the grid voltage has various disturbances such as swell, sag, frequency distortion with voltage harmonics due to the nature of weak grid and load increasing. These contribute to the unbalanced voltage in distribution voltage. Therefore, the grid-connected DGs system is required to investigate for robustness analysis in unbalanced voltage affected to the grid.

2. Methodology

In Figure 3, the architecture of the suggested microgrid is presented together with the PV power sources and whole system of the distributed generators (DGs). The controller is used as a focused control of voltage management and the irradiance change was not affected due to effectiveness of the controlled system accordingly. The Non-islanded microgrids, makes the system related to each other in term of controlling mode due to grid-connected mode that seems suitable with the microgrid. However, the advantage of this system is it can connect to the main source easily if anything happens to the microgrid. This creative work helped the system to achieve the target and ensure all the voltage supply reach the demand and suited with PV solar power with supported by the control system consist of power electronic device combined with PI and MPPT controller. The demand profile for every working day is constant and must be fulfilled by optimizing the production rate of the PV power source.

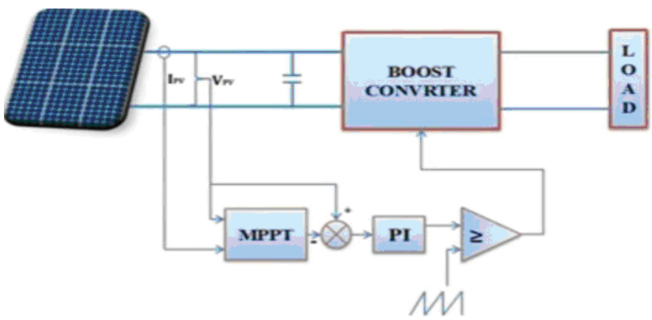

Figure 3: The block diagram of non-islanded system

The controller which consist of maximum point power tracking (MPPT) and the PI controller made the system easily achieved the optimum energy and produced sufficient generated supply from the irradiance changed then supported to all the network system being controlled. The condition of the PV will be monitored and recalculated regarding the performance of the main grid source and load demand in order to maintain the overall voltage capability to the system link. The irradiance is being checked by the controller system step by step in detail so that the execution of the power and energy can be made smoothly.

In this paper, to produce a comprehensive PV solar system, we have to put three elements that may result in a good output of the system. The first element is the design of the PV solar array itself, then to design the PV solar converter and finally to design the controller of the PV system.

To design a PV solar array, the number of series and parallel modules must be considered in order to get the required output power and voltage output. To produce high power capacity in the PV system, a series and parallel combination of a PV module and 1 SOLTECH (1STH-215-P) module have been used in this paper. The PV solar arrays have the configuration as presented in the Table 1 below:

Table 1: Configuration of PV array

STC power rating Pmp (W)	215
PTC power rating Pmpp (W)	189.4
PTC/STC Power Ratio	88.1%
Open circuit voltage Voc (V)	36.3
Short Circuit Current Isc (A)	7.84
Voltage at Max Power Vmp (V)	29.0
Current at Max Power Imp (A)	7.35

To produce 100 kW power capacities, 47 series and 10 parallel modules will be required.

Rated Power (P) = power rating * series * parallel (1)

Rated power (PV array) = P = 47*10*215 = 101050 = 100 kW

Output voltage = Vmp * Number of parallel module (2)

Output voltage (PV array) = 29*10 =290V

Design specification of the PV solar system as below:
Input voltage = Vin = 250-350V
Output voltage = Vo = 500V
Rated power = 100 KW
Switching frequency = 5khz
Voltage ripple = 1%
Current ripple = 5%

Next, we design the PV solar converter. For this purpose the component of power electronics is very useful and beneficial to have a good PV Solar converter. In this paper, a boost converter is used instead of a buck converter or buck-boost converter. The advantages of boost converter compared to the mentioned converters above is quite obvious. With a boost converter we can set up the output voltage without a transformer and it can replace the function of the transformer generally. And of course the main reason of using boost converter is that it respon with high-efficiency due to single switch operation. The single switch operation can minimize the loss of energy via the system.

The design for this boost converter is according to the design below:

Output current = P/ V_o (3)

Output current = I_o = P/V_o = 200A

$$\textbf{Current ripple} = 0.05 \times I_o * V_o Vin \quad (4)$$

Current ripple = $0.05*I_o*V_o/Vin$ = 20A

$$\textbf{Voltage ripple} = 0.01 * V_o \quad (5)$$

Voltage ripple = $0.01*V_o$= 5V

Inductance = L =1.25Mh

Capacitor = C= 4000microF

Finally we design the controller, the crucial part of this paper. This controller is used to make sure the system is stable and follow the required output needed. In this paper the controller is using the hybrid system using MPPT and PI controller. This controller is combined to make sure of its optimal impact to the system where a single controller fails to give the right result. The optimization technique is vary and wide choice but for a better result the Proportional Integral Controller (PI controller) have been chosen as a main controller and monitoring system. This will use the trial and error method to get the optimum value and output.

The P&0 algorithms can be portrayed in the Figure 4 below:

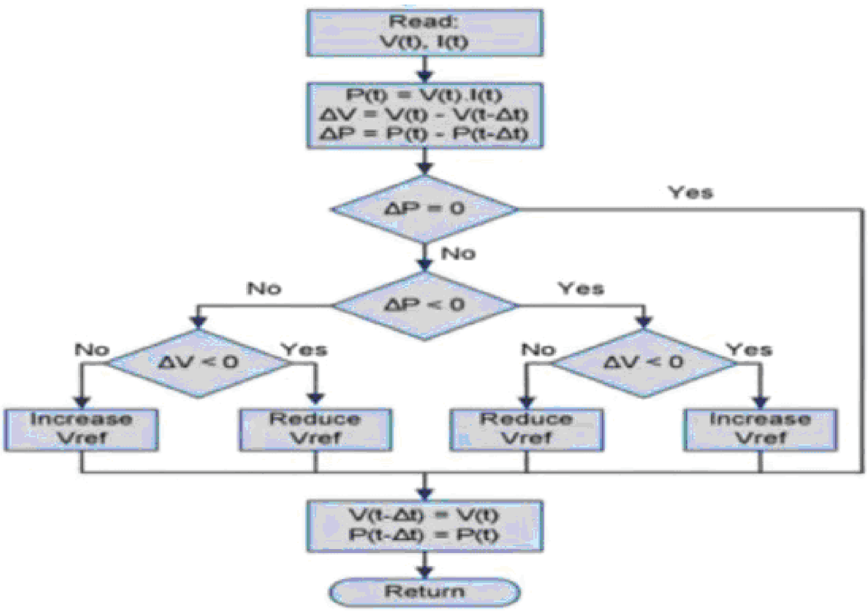

Figure 4: P&O Algorithm of Controller

3. Results and discussion

In this section, the simulation's result of the controlled PV solar panel with the variations of the irradiance value versus the voltage control are showed in the graph accordingly. Making determination of the overall size of the system including the loads was made to ensure that the controller are reliable to the system and costing is sufficiently counted. The irradiance of the solar is set to several values to be analyzed and starting from the lowest value that is zero and increasingly to maximum value that is afford by the controller. The controller played the role to optimize the load produced according to the load demand set by the client or the designer of the system.

There are two segment for the results of simulations countered from the system tested. Initial segment is the result under variable irradiance pattern and constant PV cells temperature. The next segment is under test of variable irradiance pattern and variable PV cells temperature. From these two segments it yielded the best method of controlling the system and the comparison have been done in term of performance and production.

In Figure 5 below the irradiance we can see is varied but the temperature is remained constant. The input is checked into the PV system and produced the simple and strong optimization process harmonically and can be tuned step by step.

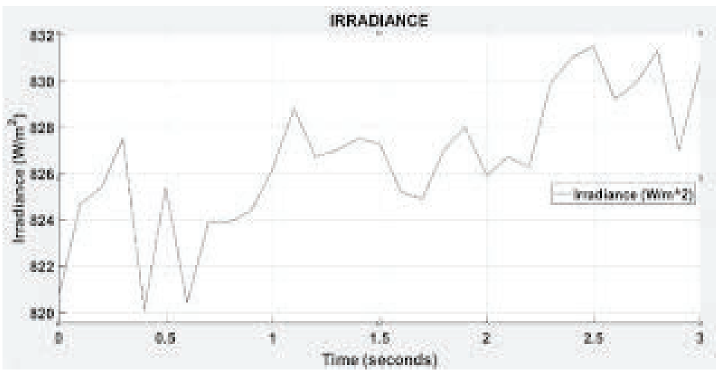

Figure 5: Variable irradiance of PV system

The irradiance is the radiance flux received by a surface per unit area. The more the radiance flux received will affect the load and the system itself. Using MATLAB the irradiance is being varied to see the effectiveness of the controller to ensure the system is constantly optimal load.

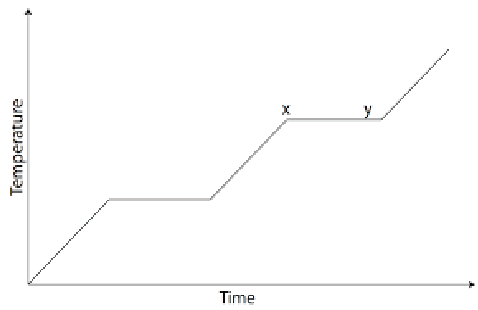

Figure 6: Constant temperature for PV system

In figure 6, The temperature is made constant at the point of x till y due to the limitation of the controller to process both at a time. The most important thing is to see the controller react well to the effect of the irradiance first and secondly react to the temperature effect.

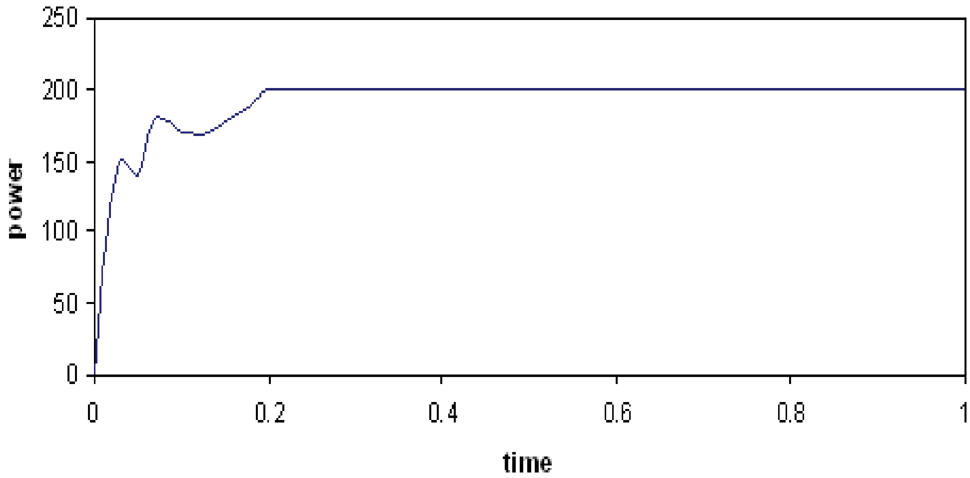

Figure 7: Power for constant temperature

From Figure 7, the output power is remaining at the desired output and the unbalanced voltage from the variable irradiance is controlled in a good shape with the usage of a PI controller.

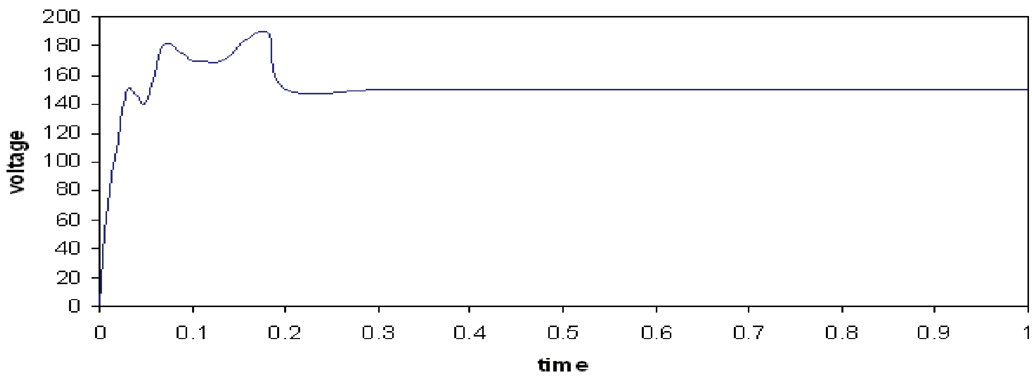

Figure 8: Voltage for varied irradiance

Figure 8 shows the output voltage after being optimized using the controller. We can see a slight overshoot initially but then get it constant and stable to the desired output finally.

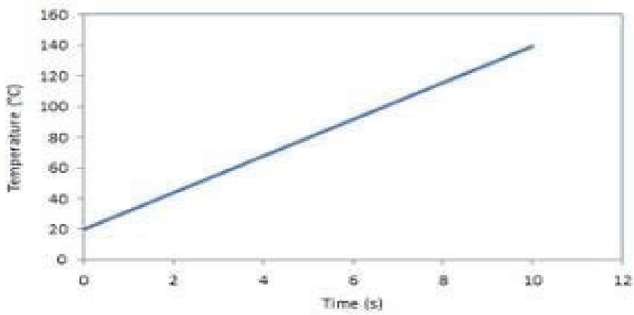

Figure 9: Variable temperature for PV system

From Figure 9, the output power and voltage is controlled well although the temperature is altered. The controller works very well to keep the voltage and power balance and keep the unbalance away from the system.

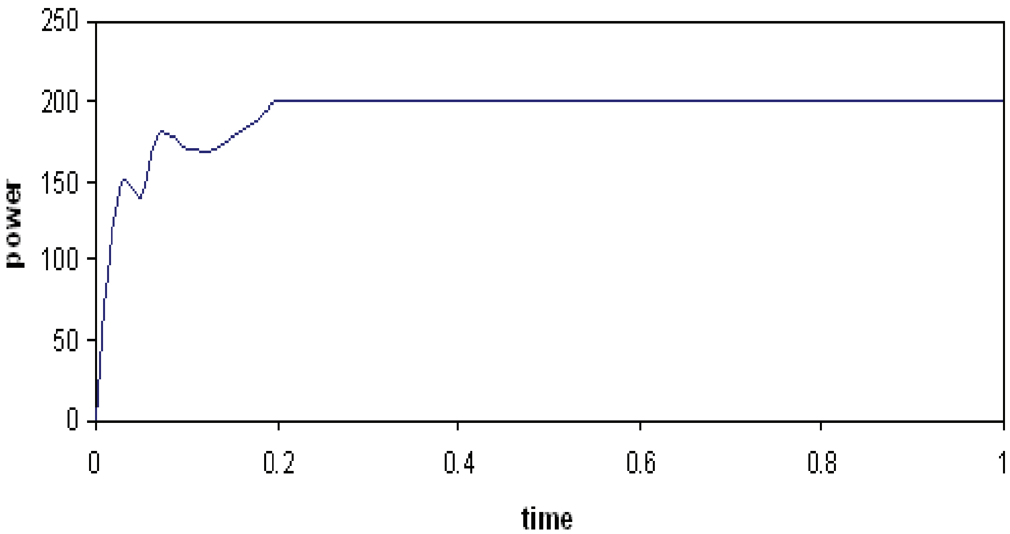

Figure 10: Output power for varied temperature

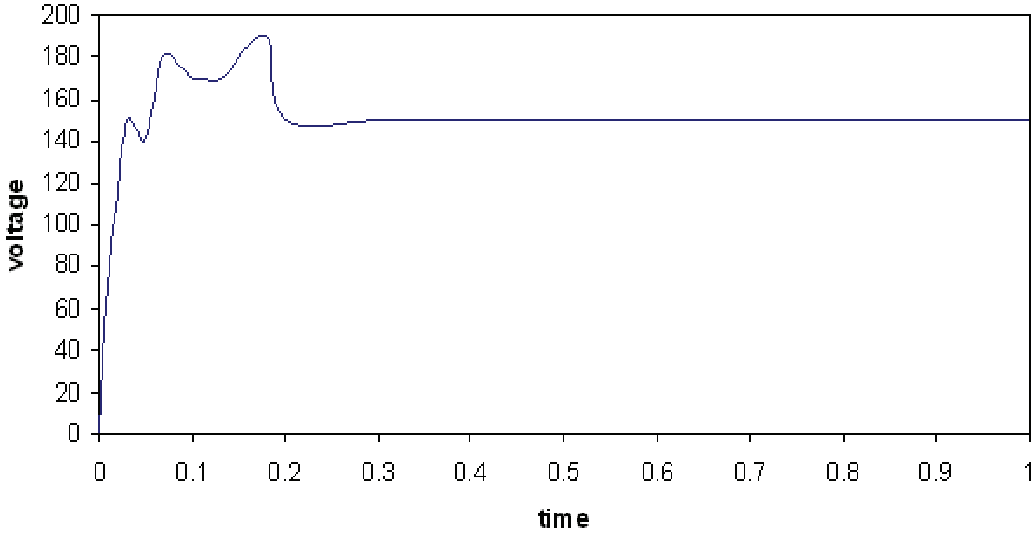

Figure 11: Output voltage for varied temperature

From figure 10 and figure 11 we can see that the result is achieving the objectives and satisfies the need. The power and voltage resulted from the optimization of the controller are fluctuated in the initial rise but quickly come to the settlement in the next second and proved the reliability of the system regardless in constant temperature or constant irradiance eventually.

4. Conclusion

This paper proposed a solid and step by step process of analyzing the algorithm and creating the optimize controller for a PV system gaining the critical point to be optimized and suit with the demand and the counted voltage needed in the loaded environment. The change of the irradiance is being monitored closely and processed in the controller following the designed algorithm which result the good environment for the system of overall check and monitor.

With the benefit of controller, such unwanted case including the drop of energy can be avoided and the power smoothly being delivered to the load. All the test is conducted in steady state software such Matlab/Simulink isolated environment.

References

[1] D. Cornforth. The role of Microgrids in the Smart Grid. Journal of Electronic Science and Technology. 9 (2011) 9-16.
[2] Omar Mohammed Benaissa, Samir Hadjeri, Sid Ahmed Zidi," Modeling and Simulation of Grid Connected PV Generation System Using Matlab/Simulink, "International Journal of Power Electronics and Drive Systems (IJPEDS), Vol. 8, No. 1, March 2017, pp. 392-401.
[3] Knut Makowsk, "The daily temperature amplitude and surface solar radiation," University of Zurich, Doctoral degree book, chapter 3.
[4] Fei Ding, Peng Li, Bibin Huang, Fei Gao, Chengdi Ding and Chengshan Wang, "Modeling and Simulation of Grid-connected Hybrid Photovoltaic/Battery Distributed Generation System", in Proc. Electricity Distribution China International Conference CICED, PP.I- 10 , 201
[5] AI Bratcu, LMunteanu, S.Bacha, D.Picault and B. Raison "Cascaded DC-DC Converter Photovoltaic Systems: Power Optimization Issues" in Proc. Industrial Electronics, IEEE Trans on, vol58, pp 403·411,2011
[6] P. Tsao "Simulation of PV systems with power optimizers and distributed power electronics", 35th IEEE Photovoltaic Specialists Conference (PVSC) IEEE Conference on, pp.389 - 393, June 2010.

[7] P.Tsao, S.Sarhan and LJorio, "Distributed max power point tracking for photovoltaic arrays", 34th Photovoltaic Specialists Conference (PVSC) IEEE Conference 2009, pp.2293-2298, June 2009
[8] Yang Du and Dylan Dah-Chuan Lu, "Analysis of a Battery·integrated Boost Converter for Module-Based Series Connected Photovoltaic System", IEEE Conf. 2010 International Conference on Power Electronics, pp.694 - 698, June 2010.
[9] X. Lin, R. Xinbo, M. Chengxiong, Z. Buhan, L. Yi. An Improved Optimal Sizing Method for Wind-Solar-Battery Hybrid Power System. Sustainable Energy, IEEETransactions on. 4 (2013) 774-85.
[10] R. Yu, J. Kleissl, S. Martinez. Storage Size Determination for Grid-Connected Photovoltaic Systems. Sustainable Energy, IEEE Transactions on. 4 (2013) 68-81.
[11] Y. Ye, L. Hui, A. Aichhorn, Z. Jianping, M. Greenleaf.Sizing Strategy of Distributed Battery Storage System With High Penetration of Photovoltaic for Voltage Regulation and Peak Load Shaving. Smart Grid, IEEE Transactions on. 5(2014) 982-91.
[12] A. Poullikkas. A comparative overview of large-scale battery systems for electricity storage. Renewable and Sustainable Energy Reviews. 27 (2013) 778-88.
[13] PVPS 2011 'The Role of Energy Storage for Mini-grid stabilization", lEA PVPS Task II, July 2011 .
[14] M. A. Hossain, H. R. Pota, A. M. O. Haruni, M. J. Hossain, Dc-link voltage reg475 ulation of inverters to enhance microgrid stability during network contingencies, Elect. Power Syst. Res. 147 (Jun. 2017) 233–244.
[15] M. A. Hossain, H. R. Pota, W. Issa, M. J. Hossain, Overview of ac microgrid controls with inverter-interfaced generations, Energies 10 (9) (2017) 1300.
[16] F. Petrakopoulou, On the economics of stand-alone renewable hybrid power 480 plants in remote regions, Energy Convers Manage 118 (Jun. 2016) 63–74.
[17] M. H. Moradi, M. Eskandari, S. M. Hosseinian, Cooperative control strategy of energy storage systems and micro sources for stabilizing microgrids in different operation modes, Int Journal of Elec. Power & Energy Syst. 78 (Jun. 2016) 390–400.
[18] L. Meng, A. Luna, E. R. Diaz, B. Sun, T. Dragicevic, M. Savaghebi, J. C. Vasquez, J. M. Guerrero, M. Graells, F. Andrade, Flexible system integration and advanced hierarchical control architectures in the microgrid research laboratory of Aalborg university, IEEE Trans. Ind. Appl. 52 (2) (Mar. 2016) 1736–1749.
[19] I. Ali, S. M. S. Hussain, Communication design for energy management automation in microgrid, IEEE Trans. Smart Grid PP (99) (May 2017) 1–1.
[20] C. Yang, J. Yao, W. Lou, S. Xie, On demand response management performance optimization for microgrids under imperfect communication constraints, IEEE 560 Inter. Things Journal PP (99) (May 2017) 1–1.
[21] B. Bhattarai, K. Kouzelis, I. Mendaza, B. Bak-Jensen, J. Pillai, K. Myers, 565 Smart grid constraint violation management for balancing and regulating purposes, IEEE Trans. Ind. Inf. PP (99) (Mar. 2017) 1–1.