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Switching Strategies of Single Stage Battery based Microgrid

Abstract. Renewable sources creates new opportunity when it is integrated with the microgrid increasing the energy efficiency of the system. This paper focuses on the adaptive control strategies which utilizes different energy management system for single stage PV based battery management system connected with the microgrid which operates on maximum power. The proposed system is carried in MATLAB/Simulink 2017B and its performance measures is demonstrated for different scenarios.

*Streszczenie. Źródła odnawialne stwarzają nowe możliwości, gdy są zintegrowane z mikrosiecią zwiększając efektywność energetyczną systemu. Niniejszy artykuł koncentruje się na adaptacyjnych strategiach sterowania, które wykorzystują różne systemy zarządzania energią dla jednostopniowego systemu zarządzania baterią PV, połączonego z mikrosiecią, która działa z maksymalną mocą. Proponowany system jest realizowany w MATLAB/Simulink 2017B, a jego mierniki wydajności są demonstrowane dla różnych scenariuszy. (**Strategie przełączania mikrosieci opartej na baterii jednoetapowej**)*

Keywords: Microgrid, Maximum Power Point Tracking, Battery, Voltage source converter.
Słowa kluczowe: mikrosieć, zarządzanie energią, baterias.

Introduction

The performance of the renewable system created major concern among the researchers to improve its functionality based on the available resources [1]. Due to fast depletion of the non-renewable resources [2], there needs a solution to move on with alternative sources of energy such as Wind Energy Systems (WES) [3], Fuel cell-based storage systems [4], Biomass Plants [5, 6], Solar Photovoltaic (SPV) systems [7-10] and Hybrid Power Plants [11]. The primary concern is to integrate microgrid [12] with these alternative distributed sources. These distributed sources are connected with the microgrid to supply power due to increasing demand which is a major concern in developing nations. Generally, microgrids are connected either in Standalone mode or Grid connected mode during operational condition [13]. Whenever distributed sources of energy are integrated with microgrid system, one has to ensure its reliability [3, 6] and adaptability [5] with the system until normal operation is carried out. Usage of power electronic devices across Point of Common Coupling (PCC) with the grid creates non-linear load. The quality of power delivered to the microgrid should be checked before it is connected. This can be attained by using different control strategies which are efficient for smooth functioning of the grid [14].

Replacement of passive components with power electronic switches creates non-linearity in the system. This affects the quality of the power to be non-linear while delivering to the grid. Usually, the harmonic currents are generated using non-linear loads such as printers, Switched Mode Power Supply (SMPS) used in computers, electronic ballasts, refrigerators, Televisions and other switching devices. As per the latest regulation of IEEE standard 519-2014 for Total Harmonic Distortion (THD) [15-17], when the operating bus voltage is around 69kV and below; the maximum individual harmonic component should be around 3% whereas the maximum THD should be around 5%. When the bus voltage is around 115kV and 161kV, then the maximum individual harmonic component should be around 1.5% whereas the maximum THD should be around 2.5%. When the operating bus voltage is above 161kV, then the maximum individual harmonic component should be around 1% whereas the maximum THD should be around 1.5%. These standards should be met in order to solve power quality problems while connecting with the grid.
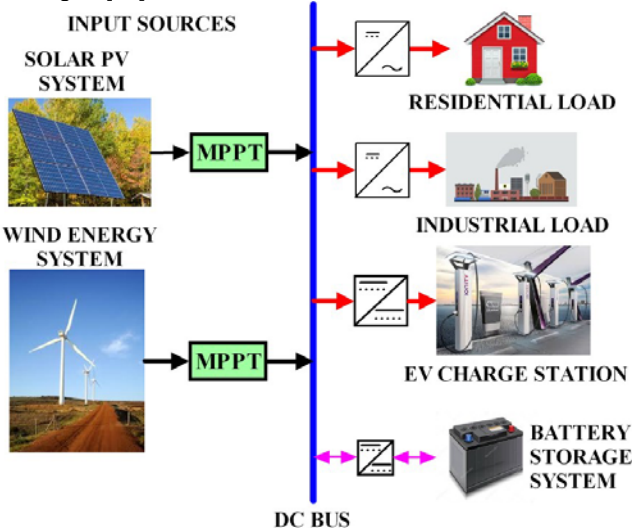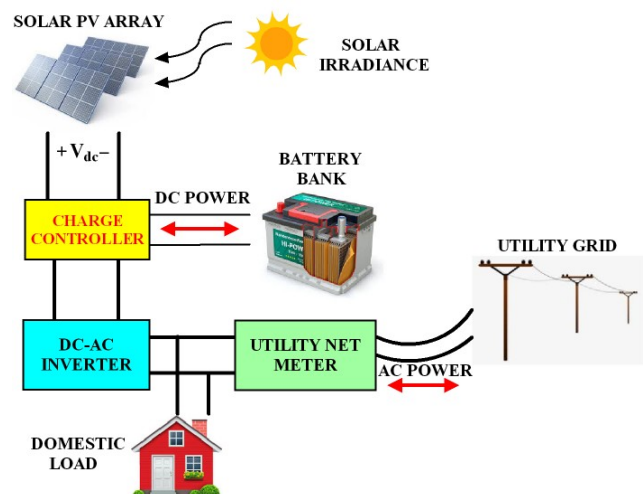

Fig. 2. Battery Storage System based microgrid

Fig. 1. Grid Integrated System

Another problem while integrating the renewable sources with the grid is output fluctuation. This is generally experienced in Wind Generation Systems (WGS) and Solar Photovoltaic System. Voltage fluctuation in WGS causes voltage swell and Sag during the switching operation of WGS. In SPV systems, the fluctuations are due to hotspots,

irradiance and shading effect. Introduction of Battery storage system would reduce the problem of output fluctuations while connecting with the grid [18-20]. So, requirement of an adaptive control strategies using Battery Storage system would compensate the energy utilization to the grid [21]. These control strategies would help in maintaining stability of the grid. The performance of the grid is measured based on the two distinct modes of operation. The microgrid is generally operated either in Grid connected mode or Islanded connected mode [22]. When the microgrid is operated in grid connected mode, then it acts as a current controller which injects power based on the power generated to the main [23-25]. When the system has multiple distributed generators (DG) units are available in grid connected mode then droop control strategy is best suitable [26-28].

When the microgrid is operated in islanded connected mode, then it acts as a voltage controller where the voltage and frequency regulation of the system dominate by the microgrid during grid outage. Above Fig.1 provides the basic details of input sources connected with grid integrated system and Fig. 2 highlights the battery storage system based microgrid.

Performance and Control Strategies of Grid System
The performance analysis is carried based on the system behaviour under grid connected mode and islanded connected mode for different scenarios such as input variations, load variations, stability conditions, voltage ride through capability issues which are analysed by implementing it in MATLAB/ Simulink.

Grid connected mode
When the microgrid is operating in grid-connected mode, it acts as a current controller and feeds energy into the grid based on the energy generated. If the system has multiple DG's available in online mode, it is best to adopt a voltage drop strategy. When the grid is available, an adaptive control of the grid and the battery will supply power to the load through the photovoltaic array. Voltage source converter uses photovoltaic cells to power the load, maintain network quality on the network side, and charge

the battery.Maximum Power Point Tracking (MPPT) [29, 30] algorithm is used to monitor the changes in DC bus voltage across battery. When the photovoltaic output reaches below the threshold value, the remaining energy used to power the load will be obtained from the grid. when the overall power generation exceeds the load, the photovoltaic field starts to supply power to the grid and batteries.

Islanded connected mode
When the microgrid operates in islanded mode, it acts as a voltage controller. In the event of a grid interruption, the system voltage and frequency regulation will control the microgrid. In the islanded mode, the load is only borne by the photovoltaic field and the battery. The Point of Common Coupling (PCC) voltage and its frequency are maintained using voltage source converter. The battery is charging because the load is the same and the power generation has exceeded the load. Due to the corresponding change in the intermediate circuit voltage, the photovoltaic field operates in MPPT mode. Without changing the solar radiation, if the load is reduced to half of its value. If the power generation exceeds the load condition, then the intermediate circuit voltage will increase with time. However, the converter will start regulating constant current. As a result, the battery starts to absorb the excess energy, and the intermediate circuit voltage returns to its original value.

Simulation Results of Grid System
The proposed system uses control scheme which has the ability to operate the battery even during absence or presence of the grid. In this mode of operation, battery storage devices are used in order to maintain DC-link voltage constant. In case of battery storage devices are absent, then load follower can beused to operate under single stage PV based system.This paper focuses only the single stage battery based system. Incase if single stage PV based system is used, then MPPT algorithm is to be carried out using Perturb and Observe method (P&O) or any other optimization tools need to be used. In this case the battery voltage (V_{bat}) is ascertained and correlate with the measured DC link voltaage (V_{DC}).
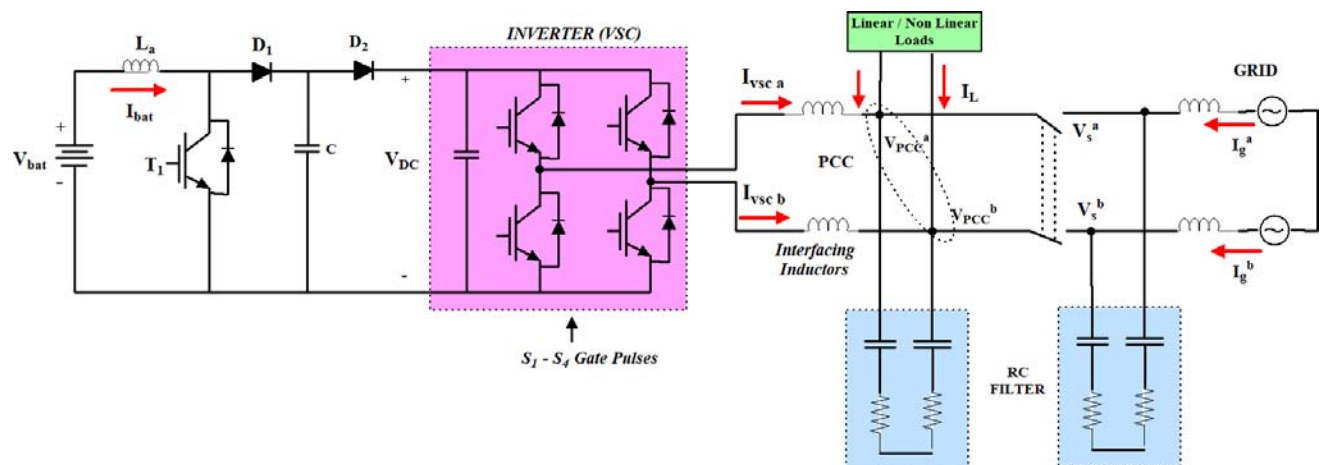

Fig. 3. Schematic approach of the system

The proposed system uses boost converter which is integrated with the voltage source converter (VSC) [31]. Pulse Width Modulation (PWM) technique [32] is used for control pulsesfor the boost converter. Proportional-Integral-Derivative (PID) controller [33] is used to obtain the current reference for the battery. The power quality issues across

the grid side are controlled through VSC in grid connected mode. It also helps in battery charging during this mode. Point of common coupling voltage and frequency issues are controlled in Standalone mode. The availability of the grid is first checked by using passive method which is indicated in eq. (1)-(2)

(1) $$V_{max} > V_{grid} > V_{min}$$

(2) $$f_{max} > f_{grid} > f_{min}$$

During the availability of the grid, the grid voltage is sensed based on the templates generated by active and reactive power. Fig.3 indicates the schematic approach of the system and Fig. 4 provides the simulated diagram of the system. The proposed system uses Lease Mean Square (LMS) adaptive control algorithm in order to reduce power quality issues in the grid side. Voltage source converter are divided into two major subparts which as unit template

estimation (u_t) and terminal voltage estimation (V_t). Unit template estimation is calculated using template voltage (V_t) and grid voltage (v_g) which is indicated in eq. (3)–(4).

(3) $$V_t = \sqrt{v_g{}^2 + v_g{}'^2}$$

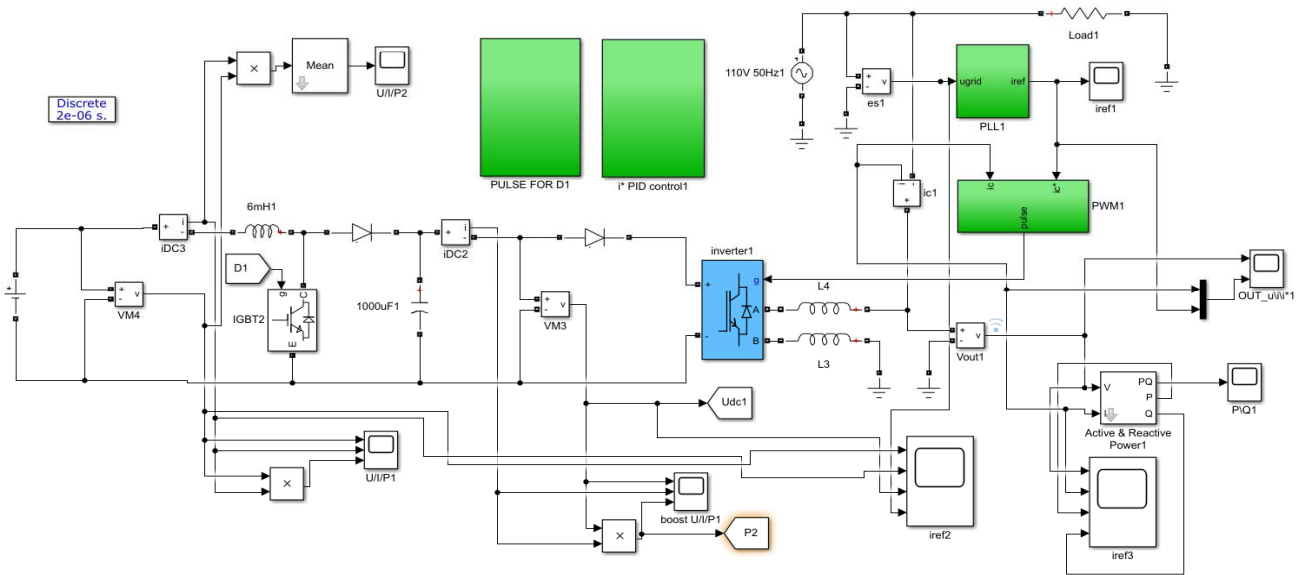(4) $$u_t = \frac{v_g}{V_t}$$
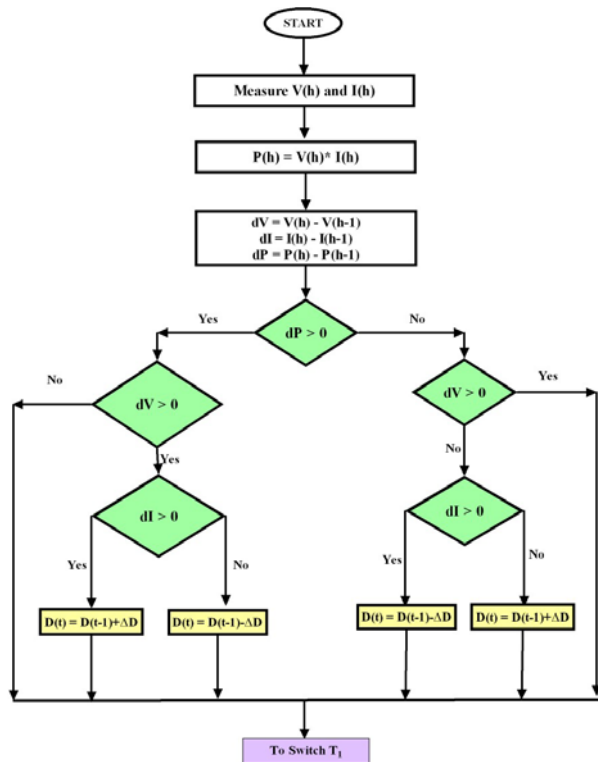

Fig. 4. Simulated diagram of the proposed system

Fig. 5. Flowchart of MPPT algorithm

The flowchart of the MPPT algorithm is shown in Fig.5 which provides the switching operation of T_1. The gating pulses for the switches S1-S4 for voltage source converter are generated by comparing the reference VSC current with actual VSC current.

Fig.6 indicates the simulated Phase-Locked Loop (PLL) circuitry done using MATLAB software and Fig.7 shows the simulated PID controller for tuning the system. Table 1 provides the information about the simulated specifications carried for the proposed system.
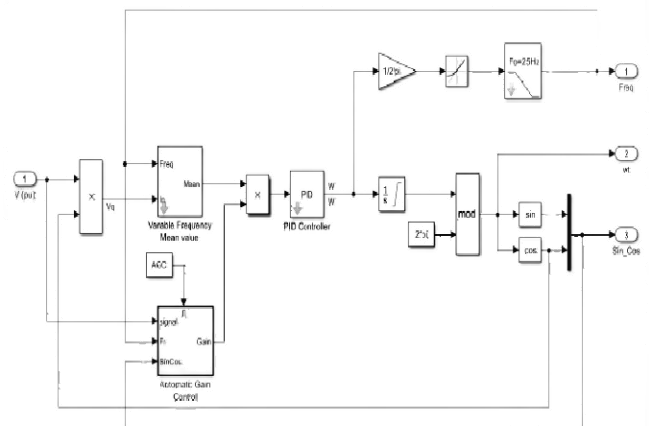

Fig. 6. PLL circuitry of the simulated system

Table 1. System Specifications

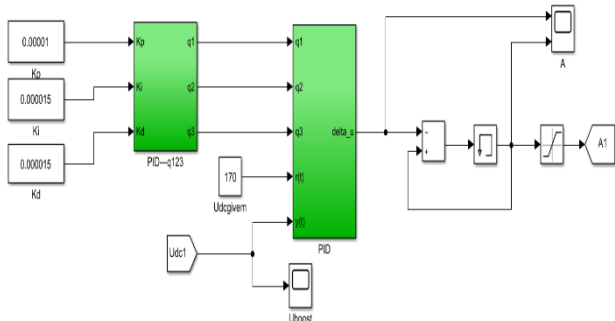| System specification	Values
DC link-voltage	230 V
DC link-capacitor	3500 µF
Filter Inductance	5.46 mH
Filter Capacitance	4.7 µF
Inverter Output Frequency	50 Hz
Ripple filter resistance (Rf)	5
Ripple filter capacitor (Cf)	10 µF

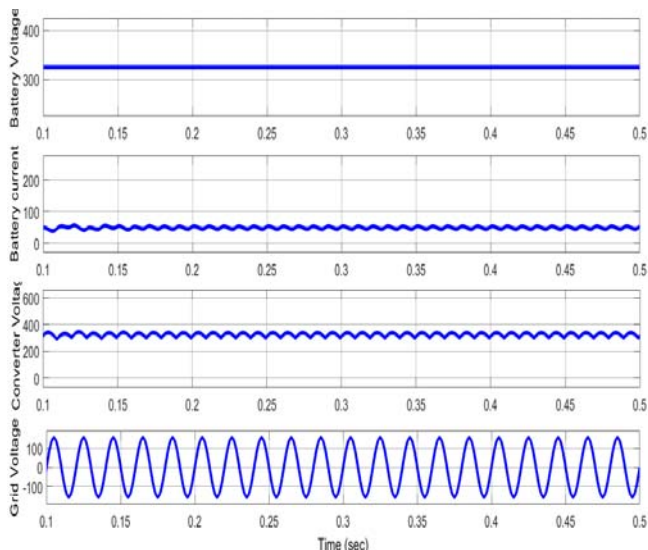Fig. 7. PID controller values of simulated system

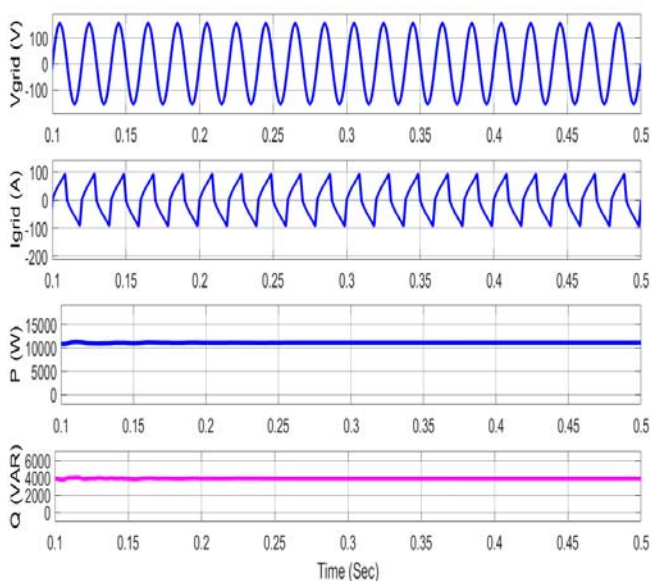Fig. 8. Simulated voltage and current response of Battery, Converter and Grid

Fig. 9. Simulated results of grid voltage and current with active and reactive power components

The test results in Fig. 8 confirm the transmission of active energy from the battery side to the grid side. The test results include grid power (Pg), load power (PL) and photovoltaic solar energy. (Ppv), power supply VSC (Pvsc). The reactive power of the load is provided by the VSC, and the reactive power of the network is regarded as zero, so the system maintains a power factor of 1. As shown in Fig. 9, in the system under non-linear load, the THD of the line current is 5.2%, while the THD of the VSC current and the THD of the load current are 15.8% and 23.4%, respectively. Thus, the simulation results comply with power quality standard of IEEE 519.

An improved photovoltaic system with a single-phase grid based on the least squares method was implemented, and tests were conducted for various changes in solar radiation and load. The convergence speed of the proposed algorithm is higher than that of the standard LMS algorithm.

Conclusion

In the grid-connected mode and the islanded mode, the single-stage control of the micro-grid based on photovoltaic cells is introduced. The proposed control scheme makes it possible to control the photovoltaic field in the MPPT independently of the presence or absence of the network without using a special boost converter for the photovoltaic field. The analysis is only done in simulation from MATLAB/Simulink and the performance of the system looks to be satisfactory when connected with the grid.

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