Control and Management of Hybrid AC-DC Microgrid Performance with PR based droop Controller

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Abstract

In recent years, many countries are attempting to generate extensive power through the sustainable sources. The hybrid power plants are integrated to the microgrid system due to their significances.However, the coexistence in these systems of power electronics equipment, energy storage systems and very often, conventional electric power plants poses new challenges over their stability, reliability and resiliency. In this work, two power stations such as hydro and photovoltaic (PV) plants are incorporated to AC/DC microgrid with proper energy storage device (battery). Further, proportional resonant (PR) controller-based SV PWM method is suggested and primary droop control is applied to the overall microgrid to regulate state variables and to control the shared contribution of each energy sources in the microgrid. The simulation results disclose that the suggested PR based SV PWM technique contributes better enhancement in the hybrid microgrid system with battery.

Keywords:Microgrid, Battery, Hydro plant, PV plant, PR-SV PWM.

1.0Introduction

ONE of the main challenges in the expansion of a power system is the issue of eliminating transmission and distribution system constraints and bottlenecks. With the increased peak customer demand, the distribution system suffers severe power quality and continuity of supply issues [1]. There is general consensus that the future power grid will need to be smart, fault tolerant, self-healing, dynamically controllable, and energy efficient [2]. In fact, AC systems have well known dynamic models, with established protection, frequency and voltage regulation standards, while DC microgrids are more suited when there is a need to optimize and cost-effectively integrate Distributed Energy Resources (DER) [3].Construction of these hybrid systems poses some new challenges over the development of effective control methods and operational standards. The use of hierarchical control, well known for its application in conventional AC power grids [4, 5] has been of increased interest in hybrid, AC and DC microgrids. A description of hierarchical control method is given in [6].

Droop control applied as basis for primary level control in microgrids is addressed in [7]; this stage in the global microgrid control scheme is used to trigger a direct response of distributed generation units to measured local deviation of system variables caused by load variations or external disturbances. With the increasing need to provide flexible and effectively shared contributions of DER located in DC as well as AC sub-grids, interest has been raised for in-depth studies and simulations of the expected behaviour of these hybrid systems under different operating conditions, and to provide ways to validate control methods at different stages.

A hybrid energy system consisting of two or more type of energy sources, has ability to reduce the BES requirement and increases reliability. Wind and solar energies are natural allies for hybridization. Both have been known to be complementary to each other in daily as well as yearly pattern of the behaviour. Acknowledging advantages of this combination, many authors have presented autonomous wind solar hybrid systems [8-10]. The most favourite machine for small wind power application, is permanent magnet synchronous generator [11-13]. It is possible to achieve gearless configuration with PMSG, however, it requires 100% rated converter in addition to costlier machine [14]. Some authors have also used wind solar hybrid system with a squirrel cage induction generator (SCIG) [6], Though SCIG has commercial edge regarding machine cost, however, the scheme doesn't have speed regulation required to achieve MPPT. Moreover, if the speed regulation is done, it requires full power rated converter.

In this work, two power stations such as hydro and photovoltaic (PV) plants are incorporated to AC/DC microgrid with proper energy storage device (battery). Further, proportional resonant (PR) controller-based SV PWM method is suggested and primary droop control is applied to the overall microgrid to regulate state variables and to control the shared contribution of each energy sources in the microgrid. The simulation results disclose that the suggested PR based SV PWM technique contributes better enhancement in the hybrid microgrid system with battery.

2.0Modelling of hybrid system

As seen in Figure 1, the typical system under study in this paper features a micro-hydro power plant, which provides the main reference frame for the AC side of the microgrid, giving substantial inertia to the system; while the interlinking converter, basically made of a three-phase IGBT power converter with filtering components, has fast dynamics and the internal control system includes power flow and current controllers. The DC side of the system features a solar power plant which mainly consists of sets solar panels with suitably controlled MPPT boost converters [8], and a battery storage system is used to ensure the availability of energy in case oflow production or load peaks.

This system provides two main connection points, the first for AC load is also the point of common coupling (PCC) where power generated from AC sources is shared, and where connection can be made with the utility grid through a suitable breaker [9]. The second connection point is the main DC bus required for interconnection between the solar power plant, the battery storage system and the AC-DC interlinking unit. An important feature of the DC bus is the high value capacitor which ensures DC voltage smoothing. This bus is also the main point where loads are connected to the DC microgrid.

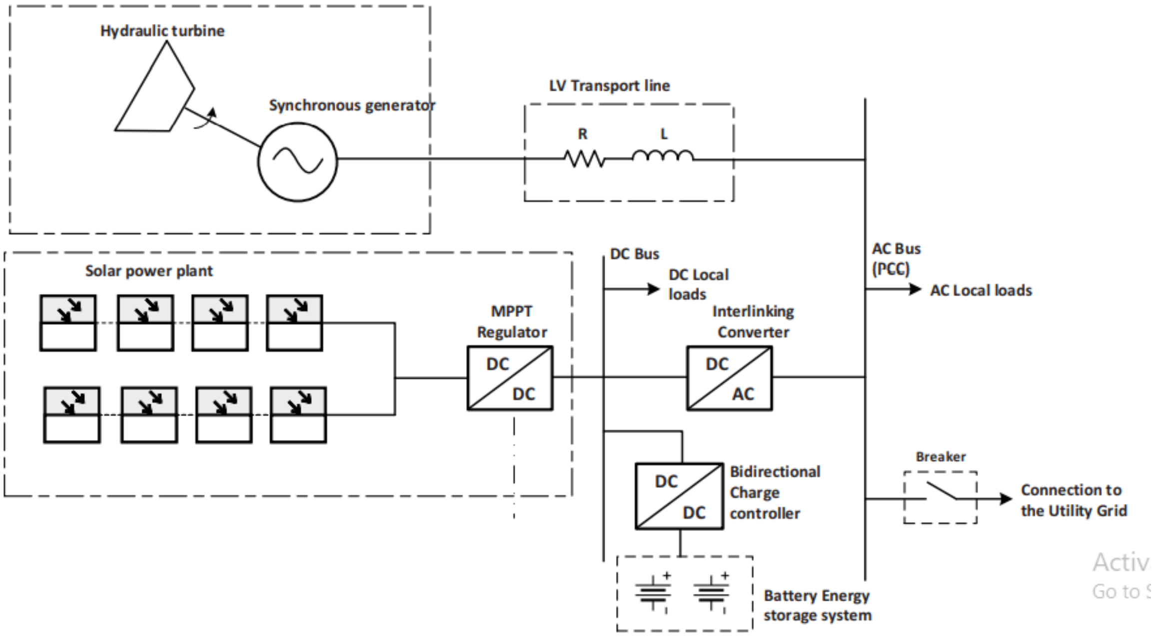


Fig.1 Hybrid AC/DC microgrid system with battery.

3.0Modelling of the energy storage system

The BESS is made of a set of battery cells, connected in appropriate manner in order to provide desired nominal values of voltage, storage capacity and output current. Charge and Discharge operations in BESS are done using a bidirectional converter as in Figure 2.

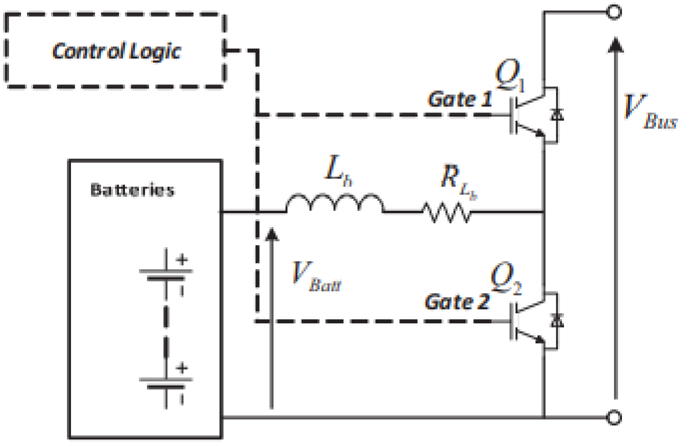


Fig.2 Configuration of BESS

The simplified model used for the Li-Ion batteries considered in this study reflects the dependence of the open circuit voltage, on the state of charge, a polarization voltage in charge/discharge mode, a polarization resistance, and an exponential factor [13]. During the discharge:

$$V_{OC} = E_0 - \underbrace{K\frac{Q}{Q-it}\cdot it}_{Polarization\ voltage} + \underbrace{A\exp(-B\cdot it)}_{Exponential\ term} - \underbrace{K\frac{Q}{Q-it}}_{Polarization\ res.}\cdot i^*$$

In charge mode, the polarization resistance changes to represent rapid increase in internal voltage and is now given by:

$$R_p^{(Charge)} = K\frac{Q}{it - 0.1\cdot Q}$$

4.0SV PWM method

A different approach to SPWM is based on the space vector representation of voltages in the d, q plane. The d, q components are found by Park transform, where the total power, as well as the impedance, remains unchanged.

Fig: space vector shows 8 space vectors in according to 8 switching positions of inverter, V* is the phase-to-centre voltage which is obtained by proper selection of adjacent vectors V1 and V2 and represented in Figure 3.

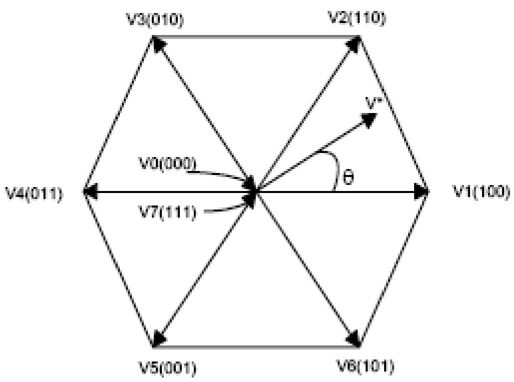


Fig.3 Inverter output voltage space vector

The reference space vector V* is given below, where T1, T2 are the intervals of application of vector V1 and V2 respectively, and zero vectors V0 and V7 are selected for T0.

V* Tz = V1 *T1 + V2 *T2 + V0 *(T0/2) + V7 *(T0/2)

Fig. 3 below shows that the inverter switching state for the period T1 for vector V1 and for vector V2, resulting switching patterns of each phase of inverter are shown in Figure 4 pulse pattern of space vector PWM.

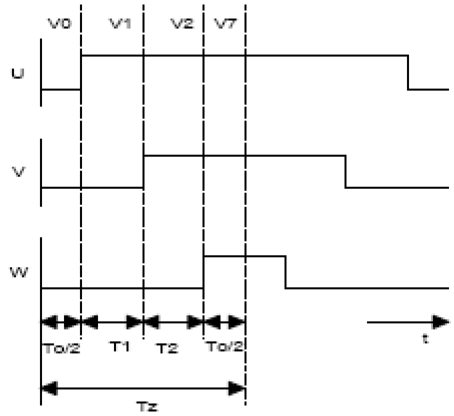


Fig.4 Pulse pattern of Space vector PWM

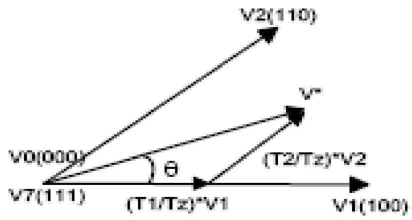


Fig.5 Determination of Switching times

The Pulse Width modulation technique permits to obtain three phase system voltages, which can be applied to the controlled output. Space Vector Modulation (SVM) principle differs from other PWM processes in the fact that all three drive signals for the inverter will be created simultaneously. The implementation of SVM process in digital systems necessitates less operation time and also less program memory and demonstrated in figure 5.

5.0PR controller

The ideal resonant controller, which is given by, can be mathematically derived by transforming an ideal synchronous frame PI controller to the stationary frame and achieves infinite gain at the AC frequency of ω0 as shown to force the steady-state voltage error to zero, and no phase shift and gain at other frequencies. For Kp, it is tuned in the same way as for a PI controller. Unfortunately, the ideal PR controller acts like a network with an infinite quality factor, which is hard to implement the PR controller in reality. Firstly, the infinite gain introduced by PR controller leads to an infinite quality factor which cannot be achieved in either analogy or digital system. Secondly, the gain of PR controller is much reduced at other frequencies and it is no adequate to eliminate harmonic influence caused by grid voltage. Therefore, an approximating ideal (non-ideal) PR controller.

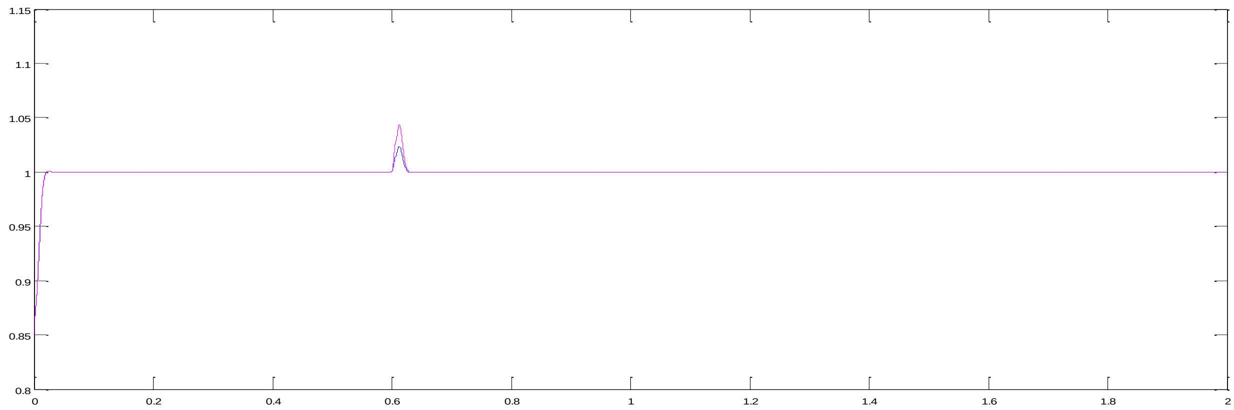
$$G_s(s) = K_p + \frac{2K_i s}{s^2 + \omega_0^2}$$

$$G_s(s) = K_p + \frac{2K_i \omega_{cut} s}{s^2 + 2\omega_{cut} s + \omega_0^2}$$

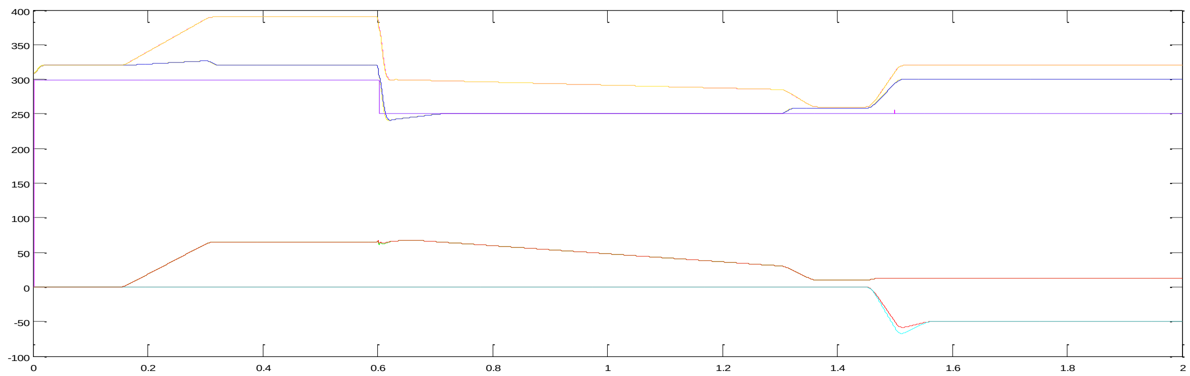
where Kp, Ki are gain constants; ω_0 (= 2π×60rad/s) is grid frequency and ω_{cut} is cut off frequency.

In addition, a wider bandwidth is observed around the resonant frequency, which minimizes the sensitivity of the controller to slight grid frequency variations. At other harmonic frequencies, the response of the non-ideal PR controller is comparable to that of the ideal PR controller. From equation, it can be seen that there are three parameters in the PR controller including Kp, Ki and ωcut. For simplicity of analysis, we assume two of these parameters to be constant, and then the effect of changes in the third parameter can be easily observed.

6.0Simulation Results

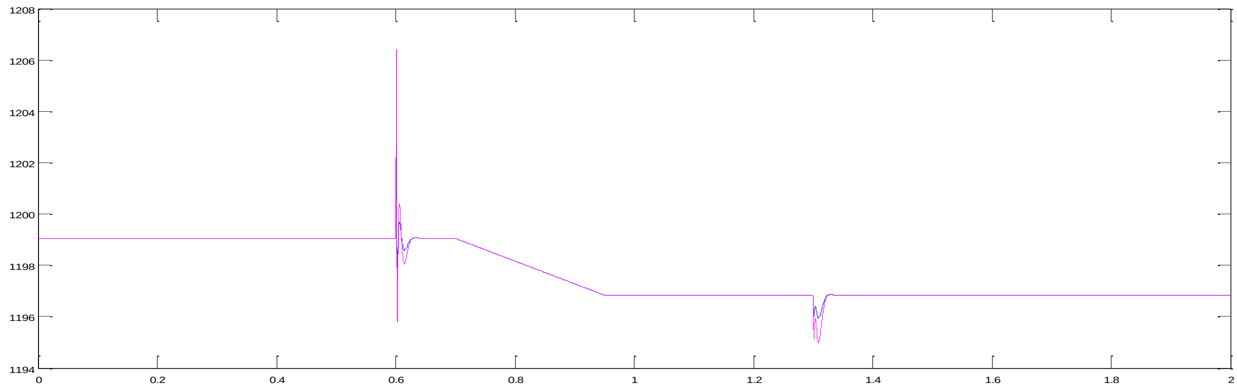


(a) Frequency

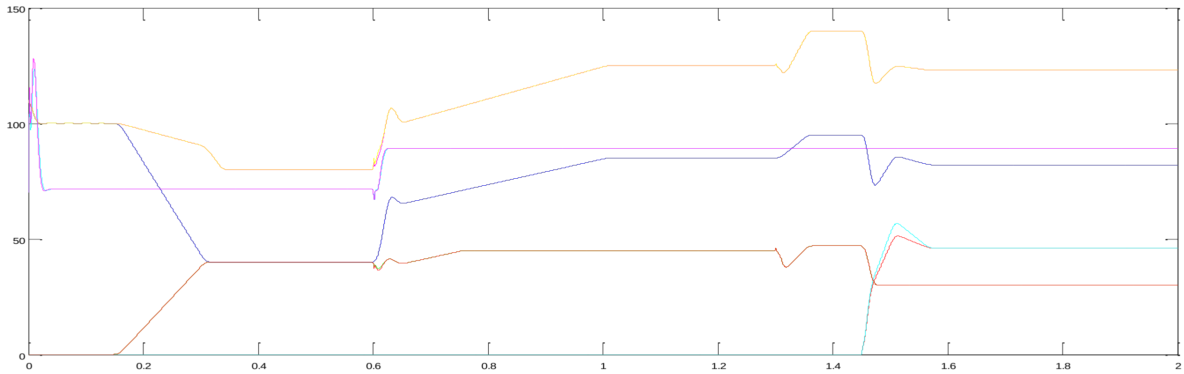


(b) Active Power

Fig.6 Active power and frequency in the AC microgrid

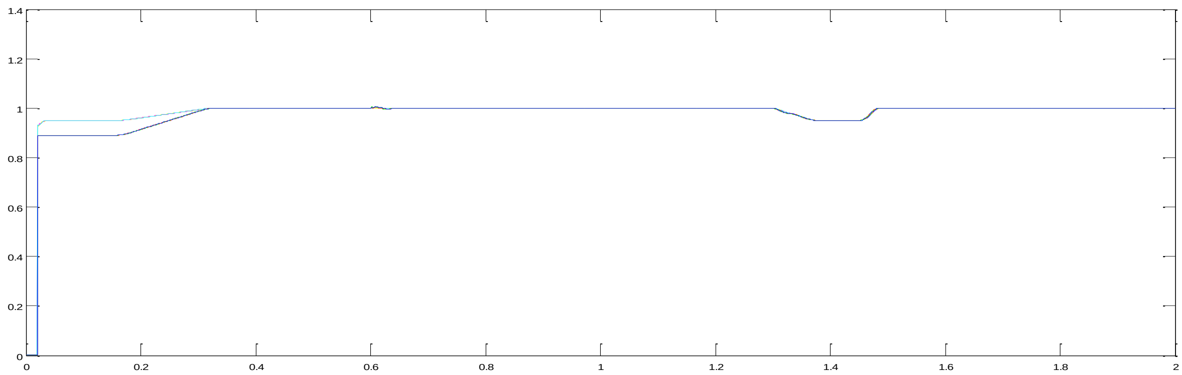


(a) RMS voltage at PCC

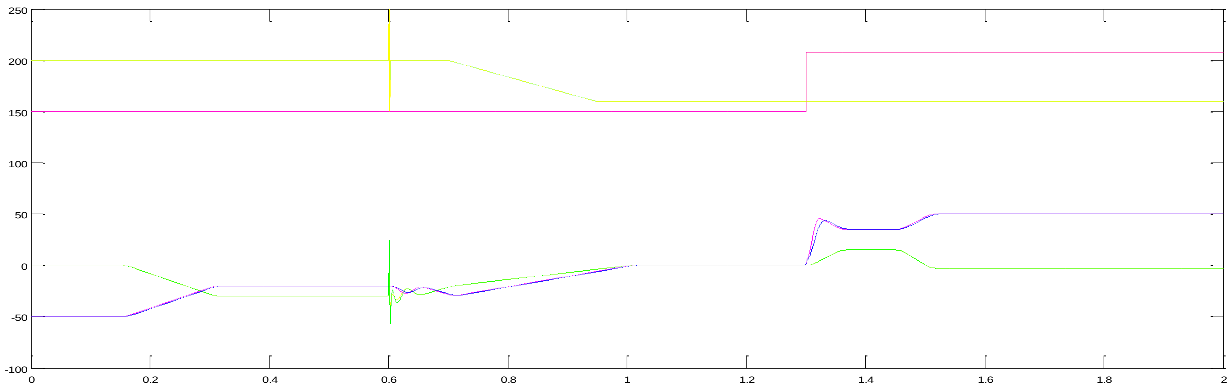


(b) Reactive power

Fig.7 Reactive power in the AC microgrid and RMS voltage at PCC



(a) DC link voltage



(b) Powers

Fig.8 Power flow in the DC microgrid and DC bus voltage

7.0Conclusion

In this paper, clearly described the performance of the primary loop control with suggested methods in hybrid AC/DC microgrid system. With PR based SV PWM method, the dynamic model of the hybrid microgrid system has been predicted at various operation circumstances. The simulation outcomes disclose that the suggested primary droop control with PR based SV PWM can be productively identified the disturbance at operational circumstances.Another point of this paper was the simplified d-q model of the whole AC microgrid along with models of the DC components of the system and of the interlinking converter, which allowed to eliminate fast and sub-transient dynamics not of use in this study.

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