Integration of DG Units to Hybrid Microgrid with Power Balancing Control Using CHB Multilevel Inverter under Various Loads

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Abstract*- In This Paper proposes a Hybrid H-bridge (CHB) multilevel grid to reduce the processes of multiple dc–ac–dc or ac–dc–ac conversions in an individual ac or dc grid. The H-bridge (CHB) multilevel grid consists of both ac and dc networks connected together by multi-bidirectional CHB multilevel converters. AC sources and loads are connected to the ac network whereas dc sources and loads are tied to the dc network. Energy storage systems can be connected to dc or ac links. The CHB multilevel inverters increase the output voltage level and enhance power quality. The HPS employs fuel cell (FC) and photovoltaic sources as the main and super-capacitors as the complementary power sources. Fast transient response, high performance, high power density, and low FC fuel consumption are the main advantages of the proposed HPS system. The proposed control strategy consists of a power management unit for the HPS system and a voltage controller for the CHB multilevel inverter. Each distributed generation unit employs a multi proportional resonant controller to regulate the buses voltages even when the loads are unbalanced and/or nonlinear. The proposed H-bridge (CHB) multilevel grid can operate in a grid-tied or autonomous mode. The coordination control algorithms are proposed for smooth power transfer between ac and dc links and for stable system operation under various generation and load conditions. This H-bridge (CHB) multilevel grid system operates under normal conditions which include normal room temperature in the case of solar energy and normal PV ,FC, MTG, BES and SC speed at plain area in the case of PV ,FC, MTG, BES and SC energy. The Power Balancing Control simulation results are presented to illustrate the operating principle, feasibility and reliability of H-bridge (CHB) multilevel grid proposed system.

***Index Terms* - Cascaded H-bridge (CHB) multilevel inverter,fuel cell (FC), hybrid power source (HPS), multiproportional resonant (multi-PR), photovoltaic (PV), Fuel cell (FC) ,Micro turbine generator (MTG), Battery (BES) and, super capacitor (SC).**

I. INTRODUCTION

NOW A DAYS , photo voltaic , Fuel Cell, Micro Turbine Generation , Super Capacitor and Battery (PV, FC, MTG, BES AND SC) energy appears quite attractive for electricity generation because of its noiseless, pollution-free, scale flexibility, and little maintenance. Because of the PV, FC, MTG, BES AND SC power generation dependence on sun irradiation level, ambient temperature, and unpredictable shadows, a PV, MTG, BES AND SC-based power system should be supplemented by other alternative energy sources to ensure a reliable power supply. Fuel cells (FCs) are emerging as a promising supplementary power sources due to their merits of cleanness, high efficiency, and high reliability. Because of long startup period and slow dynamic response of the FC stack intermittent nature of the PV, and quick load changes necessitate the use of super capacitor (SC) as a storage system with high power density [8]. Therefore, parallel hybrid FC/PV/SC/MTG/BES power source and H-bridge (CHB) multilevel response weak points of FCs [1], mismatch power between the load and the FC must be managed by an energy storage system. Batteries are usually taken as storage mechanisms for smoothing output power, improving startup transitions and dynamic H-bridge (CHB) multilevel characteristics, and enhancing the peak power capacity [2], [3]. Combining such energy sources introduces a`132123PV, MTG, BES AND SC/FC/battery hybrid power system. In comparison with single –sourced systems ,the hybrid power systems have the potential to provide high quality ,more reliable ,and efficient power. In these systems with a storage element, the bidirectional power flow capability is a key feature at the storage port. Further input power sources should have the ability of supplying the load individually and simultaneously.

In the present work DC-DC converters are used for the proper coordination with utility grid which will be helpful for uninterrupted and high quality power to AC and DC loads under variable solar radiation and fuel stack levels when grid operates in islanded mode that is autonomous mode. Even when the grid is operating in grid tied mode under unbalanced loads this type of control is possible as a hybrid power system can be classified into AC coupled systems[4],[5] and ac-coupled systems[6]–[12]. However, the main shortcomings of these traditional integrating methods are complex system topology, high count of devices ,high power losses, expensive cost, and large size. In recent years, several power conversion stages used in traditional hybrid systems are replaced by multi-input converters (H-BRIDGE (CHB) MULTILEVELs), which combine different power sources in a single power structure. These converters have received more attention in the literature because of providing simple circuit topology, centralized control, bidirectional power flow for the storage element, high reliability, and low manufacturing cost and size. In general, the systematic approach of generating H-BRIDGE (CHB) MULTILEVEL is introduced in[13],in which the concept of the pulsating voltage source cells and the pulsating current source cells is proposed for deriving H-BRIDGE (CHB)

MULTILEVELs. One of the samples of these H-BRIDGE (CHB) MULTILEVELs is utilized in[14] to hybridize PV ,FC, MTG, BES AND SC power sources in a unified structure .Besides ,a systematic method to synthesize H-BRIDGE (CHB) MULTILEVELs is proposed in[15].This paper deals with two types of H-BRIDGE (CHB) MULTILEVELs :in the first type ,only one power source is allowed to transfer energy to the load at a time, and in the second type, all the input sources can deliver power to the load either individually or simultaneously .As another basic research in H-BRIDGE (CHB) MULTILEVELs ,in [16] assumptions, restrictions ,and conditions used in analyzing H-BRIDGE (CHB) MULTILEVELs are described, and then it lists some basic rules that allow determining feasible and un- feasible input cells that realize H-BRIDGE (CHB) MULTILEVELs from their single-input versions .Two multiple-input converters based on flux additivity in a multi PV, FC,,MTG, BES and SC in transformer are reported in [17]and[18]. Because there was no possibility of bidirectional operating of the converter in [17], and complexity of driving circuits and output power limitation in[18], they are not suitable for hybrid systems. In [19], a Four port bidirectional converter with Four active full bridges, two series resonant tanks, and a Four- PV, FC,,MTG, BES and SC in high-frequency transformer are proposed. In comparison with Four-port circuits with only inductors and Diode Bridge at the load side, it gives higher boost gain and reduced switching losses due to soft-switching operation.

H. Tao et al. [20] present a family of multiport converters based on combination of dc link and magnetic coupling by utilizing half-bridge boost converters. The system features minimum number of conversion steps, low cost, and compact packaging. In [21], the input–output feedback control linearization for a DC–AC bidirectional H-BRIDGE (CHB) MULTILEVEL composing a high frequency isolating link transformer, two half-bridge boost converters at the input ports and a bidirectional cycloconverter at the output port is proposed. In [12]-[14], FourH-BRIDGE (CHB) MULTILEVELs are proposed based on structure of the dc–dc boost converter. The dc–dc boost converter in [12] is useful for combining several energy sources whose power capacity or voltage levels are different. The multi input dc–dc converter proposed in [13] has the capability of operating in different converter topologies (buck, boost, and buck–boost) in addition to its bidirectional operation and positive output voltage without any additional transformer. A Four input dc–dc boost converter proposed by authors in [14] can combine a PV, MTG, BES and SC, PV, MTG, BES AND SC, an FC, and a battery in a simple unified structure. A comprehensive power management algorithm is realized in order to achieve maximum power point tracking (MPPT) of the PV, MTG, BES AND SC source and set the FC in its optimal power operation range. A Four port isolated full bridge topology is proposed in [3] for hybrid FC/battery system, which its aim is feeding a small autonomous load. This topology gains the advantage of bidirectional power flow due to the active full bridges in each port. Based on the model of the transformer reported in [3], the Four transformer coupled half bridge converters proposed in [25] are analyzed. Thereby, phase-shift control method is used to manage the power flow among the Four ports in addition to soft switching for all switches over a wide input range.

Wai et al. presents two kinds of H-BRIDGE (CHB) MULTILEVELs in [2] and [16]. a high step-up ratio bidirectional H-BRIDGE (CHB) MULTILEVEL with high efficiency is proposed. The converter operates in standalone state, united power supply state, and charge and discharge states. A two input power converter for a hybrid FC/battery power system is proposed in [2] with zero voltage switching characteristic. Although the circuit efficiency is greatly developed, the converter does not provide bidirectional functionality and is not able to boost the input voltage to a higher level. Moreover, the summation of duty ratios should be greater than 1 and the two input voltages should be in the same level in the dual power supply operation state. Qian et al. presents a hybrid power system consist of a PV ,MTG, BES AND SC and a battery for satellite applications, and a four port hybrid power system supplied by a PV ,MTG, BES AND SC, a PV ,MTG, BES and SC, and a battery ,a power control strategy is designed to manage the charge balance of the battery in order to regulate the output voltage. In these systems, the PV ,MTG, BES AND SC sources are exploited in MPPT conditions. Moreover, control strategies of the both systems are designed based on small signal modeling of the converters. Proper decoupling method is productively introduced to separately design compensators for cross coupled control loops.

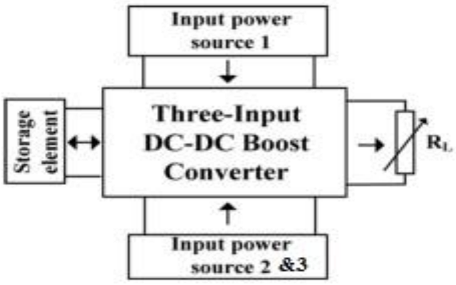

Fig.1 Proposed system overview.

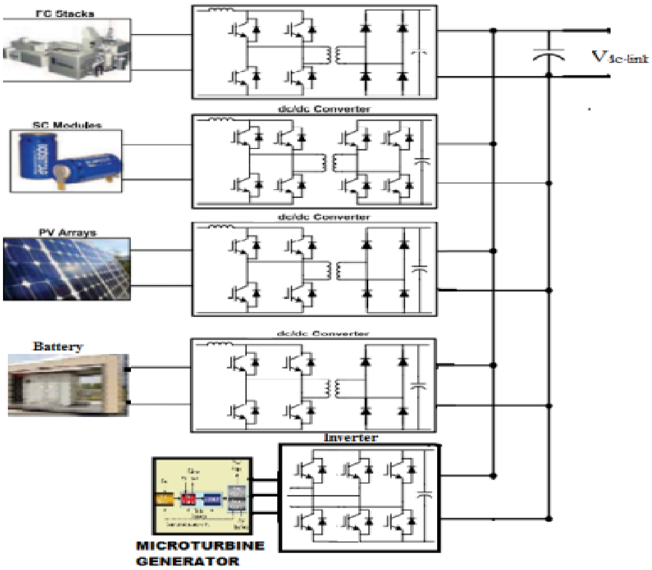

Fig.2 Configuration of Hybride power source for various DERs application.

In this paper, a new Four input dc–dc boost converter is proposed for hybrid power system applications. As shown in Fig. 1, the proposed converter interfaces two unidirectional ports for input power sources, a bidirectional port for a storage element, and a port for output load in a unified structure. The converter is current source type at the both input power ports and is able to step up the input voltages.. Utilizing the duty ratios of PV, FC, MTG, BES AND SC the DC-DC converters provide controlling the power flow among the input sources and the load. Powers from the input power sources can be delivered to the load individually or simultaneously.

II. OPERATION PRINCIPLES OF THE PROPOSED CONTROL STRATEGY

The proposed control strategy comprises 1) a power management for the HPS system, and 2) a voltage control for the CHB multilevel inverter. To manage the power and regulate the dc-link voltage of the HPS unit, two independent controllers are designed. Furthermore, a voltage control loop is proposed to provide a set of balanced sinusoidal voltages at the terminals of CHB multilevel inverter in the presence of nonlinear and unbalanced loads.

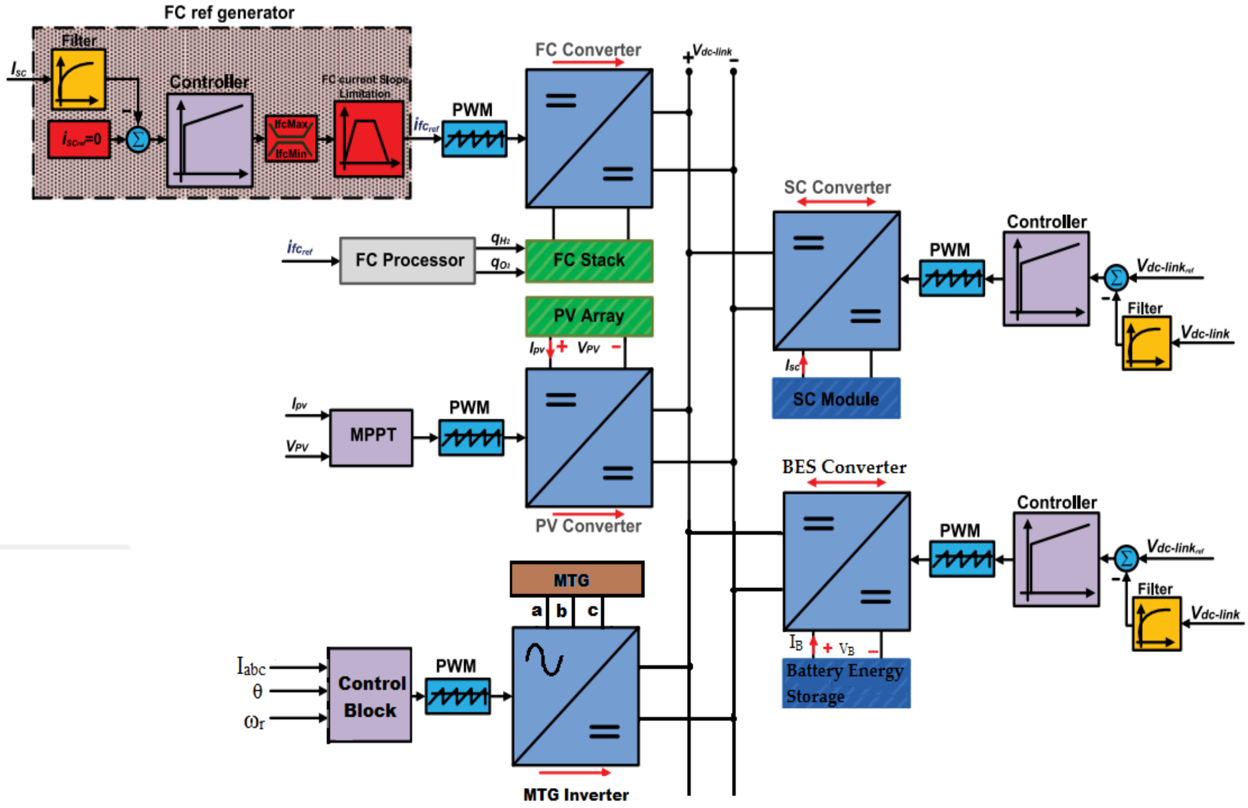

Fig. 3 Proposed control strategy of hybrid FC/PV ,MTG, BES AND SC/SC power source.

A. Control Strategy of the HPS

The proposed control strategy of the hybrid FC/PV ,MTG, BES AND SC/SC powersource is shown in Fig. 3. The HPS uses the FC and PV ,MTG, BES AND SC units as the main power sources and the SC as the complementary power source. The PV ,MTG, BES AND SC unit enables the FC to obtain an appropriate operating point at which the hydrogen consumption is minimized. The

SC modules support the FC and PV, MTG, BES AND SC to achieve good transient response and meet the grid power demand. The utilization of Four separate full-bridge converters in parallel provides the power management capability and increases the overall performance and flexibility of the HPS. The HPS controller is designed such that the SC converter regulates the dc-link voltage, and the FC and PV, MTG, BES AND SC converters fulfill the dc-link power demand.

The unidirectional power flow of the FC and PV ,MTG, BES AND SC converters results in decoupled dynaH-bridge (CHB) multilevels for FC, PV ,MTG, BES AND SC, and SC systems. Therefore, the control design for each converter is carried out individually. Parameters of the SC and FC controllers are determined by the appropriate selections of bandwidth and phase margin using MATLAB Control Toolbox. According to the proposed control strategy, the dc current of the SC module must accurately follow its reference to zero. A PI controller determines the duty cycle of the FC converter. The reference signal generated by the controller is limited not to exceed the FC capability in injecting the current. The corresponding limitation for the current demand is calculated according to the typical range of utilization factor, which ensures the desired operation of FC stack. Furthermore, the FC current slope is limited to avoid the fuel starvation phenomena and to guarantee the safe operation of the FC stack. For control design purposes, the dc/dc converters are modeled using the state-space averaging technique. Based on the average model of the full-bridge converter, the FC control-to-input current transfer function is obtained as [20]:

$$\frac{\widehat{I_L}}{d}=\frac{\frac{2I_L}{(1-D)}\left(1+\frac{R_{FC}C_{FC}}{2}S\right)}{1+\frac{n^2L_{FC}}{R_{FC}(1-D)^2}S+\frac{n^2L_{FC}C_{FC}}{(1-D)^2}S^2}(1)$$

whereI_L is the inductor current, D is the nominal duty cycle, $n$is the transformer PV ,MTG, BES and SCing ratio, and L_{FC}, C_{FC}, and R_{FC} are, respectively, the inductor, capacitor, and equivalent output resistor of the FC converter. The bode diagrams of the closedloop transfer functions are shown in Fig. 4. As it is observed, the closed-loop systems show good robust stability margins. To attenuate the current ripple of the downstream inverter and to accommodate the slow dynamic H-bridge (CHB) multilevels of the FC stack, parameters of the controller are designed such that the current-loop bandwidth is more than 628.3 rad/s [21]. Therefore, as seen from Fig. 4(a), the current-loop bandwidth of the FC converter is set to 4360 rad/s to obtain a phase margin of 88.4◦. The FC processor plays a vital role in regulating hydrogen flow according to the output power from the FC stack. The detailed mathematical model of the FC processor is described in [22].

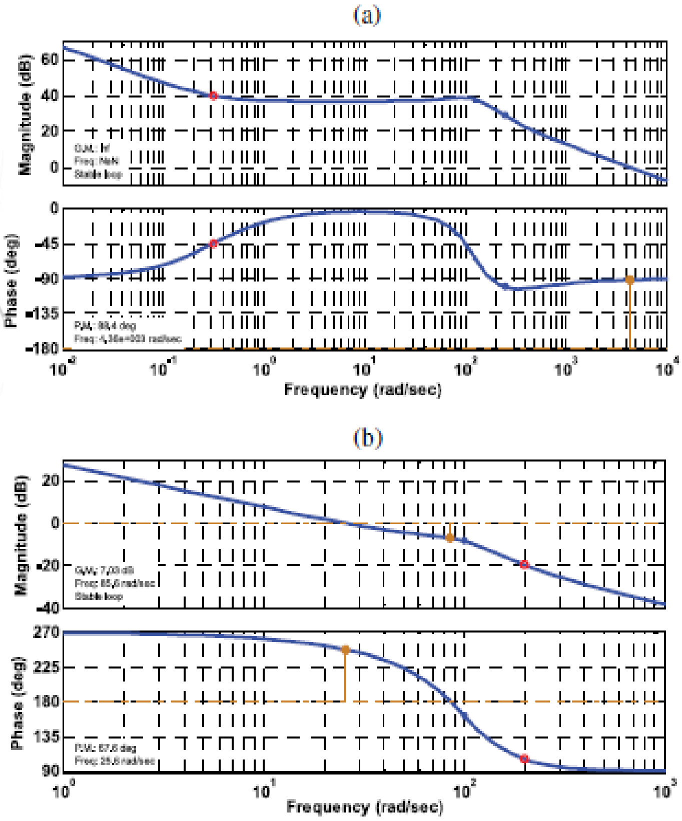

Fig. 4 Bode diagrams of closed-loop transfer functions. (a) FC current-loop response. (b) SC voltage-loop response.

The SC voltage control loop regulates the dc-link voltage using a PI controller. When the SC is charging (discharging), the duty cycle of the SC converter will decrease (increase) to maintain the dc-link voltage regulation. Based on the average model of the full-bridge converter, the SC control-to-output voltage transfer function is obtained as [20].

$$\frac{\widehat{V_c}}{d} = \frac{\frac{V_c}{(1-D)}\left(1-\frac{n^2 L_{SC}}{R_{SC}(1-D)^2}S\right)}{1+\frac{n^2 L_{SC}}{R_{SC}(1-D)^2}S+\frac{n^2 L_{SC} C_{SC}}{(1-D)^2}S^2} \quad (2)$$

Where V_c is the output voltage of capacitor. The frequency response of the compensated SC system is shown in Fig. 4(b). The parameters of the designed controllers are listed in Table I.

TABLE I PARAMETERS OF CONTROLLERS

Controller	Parameters value
FC Converter	k_p=0.031, k_I=0.01
SC Converter	k_p=6e^{-5}, k_I=0.012
Current controller	k_c=0.9
Lead compensator (C(s))	k_1=1, k_2=67, k_3=11700
G$_1$(s)	K_4=5.8, k_5=5170, k_6=5.4e6
G$_5$(s)	K_7=7.9, k_8=2860, k_9=4.5e6
G$_7$(s)	k_{10}=8.3, k_{11}=3420, k_{12}=1e7

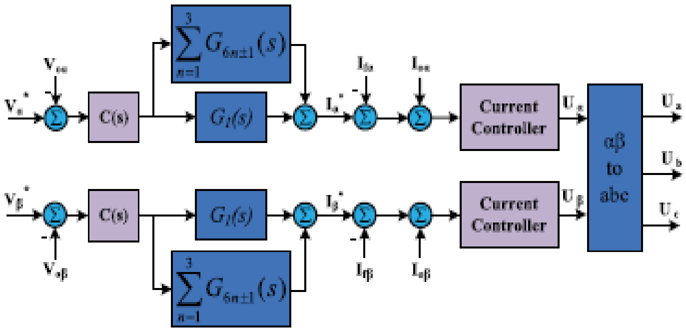

Fig. 5. Block diagram of the proposed multi-PR controller.

B. Control Strategy of the Inverter

The circuit diagram representation of the CHB-based DG subsystem is given in Fig. 1(b). The dynaH-bridge (CHB) multilevel model of a Fourwire inverter in the stationary reference frame ($\alpha\beta$-frame) is given in [16]. The ac-side controller should robustly regulate the load voltages in the presence of load uncertainties and the external disturbances. It should be noted that since the reference signals are sinusoidal in the $\alpha\beta$-frame, the use of a PR controller is more advantageous as compared to a PI controller [16], [23]. Fig. 5 shows the block diagram of the proposed voltage controller in the $\alpha\beta$-frame. The magnitude and frequency of the reference voltage (V^*_αandV^*_β) are determined by the droop controller [16]. To protect the inverter against over current and to increase the internal stability of the voltage control loop, an inner current loop is also incorporated. The current controller is a simple gain, k_c, whose value is calculated such that the damping factor of the dominant poles of the inner loop system becomes 0.7. To eliminate the impact of load dynamic H-bridge (CHB) multilevels, the output currents, i.e., $I_{o\alpha}$ and $I_{o\beta}$, are feed forward to the output of the voltage control loop. The resultant signals are then applied to the current controllers to generate the control signals U_α and U_β . Finally, the control signals in $\alpha\beta$-frame are transformed to the *abc*-frame and then applied to the modulation unit.

The phase-shifted pulse width modulation (PWM) reference required is used as the modulation strategy since it provides an even power distribution among the units [24]. Moreover, the phase-shifted PWMstrategy balances the dc capacitors voltages and mitigates the input current harmonics of the CHB multilevel inverter.

According to the internal model principle, a reference (disturbance) can be asymptotically tracked (rejected) if the controller contains the Laplace transform of the reference signal in its transfer function. The output currents ($I_{o\alpha}$ and $I_{o\beta}$), which can be considered as disturbances in the control system, contain fundamental and higher order harmonics when the load is nonlinear. Notice that since the loads are not connected to the H-bridge (CHB) multilevelgrid buses via Y/Δ transformers, zero-sequence nor third-order harmonic currents exist in the inverter side of the DG units.To achieve zero steady-state error in the presence of harmoniccurrents, a multi-PR controller is proposed as follows:

$$K(s) = C(s)[G_1(s) + G_5(s) + G_7(s)] \qquad (3)$$

Where C, G_1, G_5, G_7 are

$$C(s) = k_1 \frac{s+k_2}{s+k_3}$$

$$G_1(s) = k_4 \frac{s^2 + k_5 s + k_6}{s^2 + \omega_c s + \omega_0^2}$$

$$G_5(s) = k_4 \frac{s^2 + k_8 s + k_9}{s^2 + 5\omega_c s + (5\omega_0)^2}$$

$$G_7(s) = k_4 \frac{s^2 + k_{11} s + k_{12}}{s^2 + 7\omega_c s + (7\omega_0)^2} \quad (4)$$

G_5 (s) and G_7 (s) are harmonic compensators, and C(s) is a lead compensator which is employed to guarantee the robust stability of the closed-loop voltage control system. According to the bandwidth of the voltage control system (400 Hz), only the fifth- and seventh-order harmonics can be compensated. In (4), the coefficients k_i, i = 1, . . .12, are the design parameters of the multi-PR controller. To obtain the coefficients k_ is, the following performance characteristics are to be met.

1) The closed-loop system achieves good stability margins.
2) The bandwidth of the open-loop system should be less than 10% of the switching frequency.
3) The reference should be tracked within two cycles with zero steady-state error
4) The disturbance (harmonic currents) should be rejected.

Considering the aforementioned performance indices and using MATLAB SISO tools, the coefficients of the controller are designed and listed in Table I.

The frequency response of the open-loop controlled system considering is shown in Fig. 6. It is clear that the desired phase margin, gain margin, and bandwidth for the system are achieved. The phase margin is almost 30◦, gain margin is infinite, and the bandwidth of the system is close to 400 Hz. In addition, the gain of the system at 50 Hz and the other harmonic frequencies is high which results in significant disturbance rejection

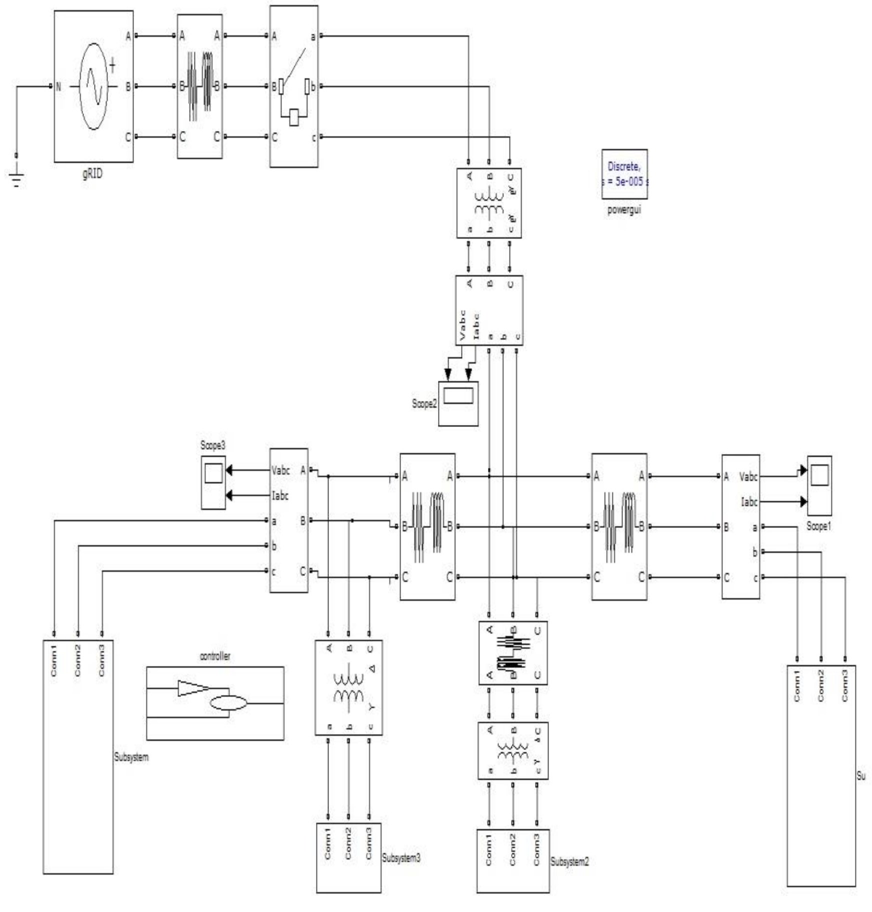

Fig.5 Main Block Diagram of Hybrid CHB Micro Grid.

III. SIMULATION RESULTS

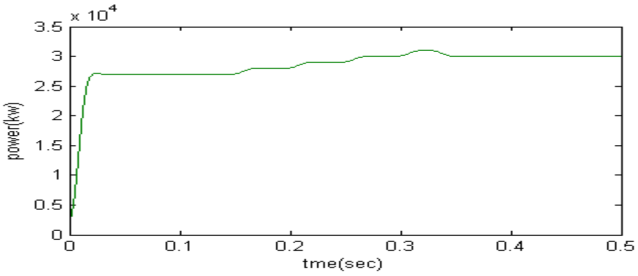

Fig. 6. Super capacitor DC bus voltage transient response inGrid mode.

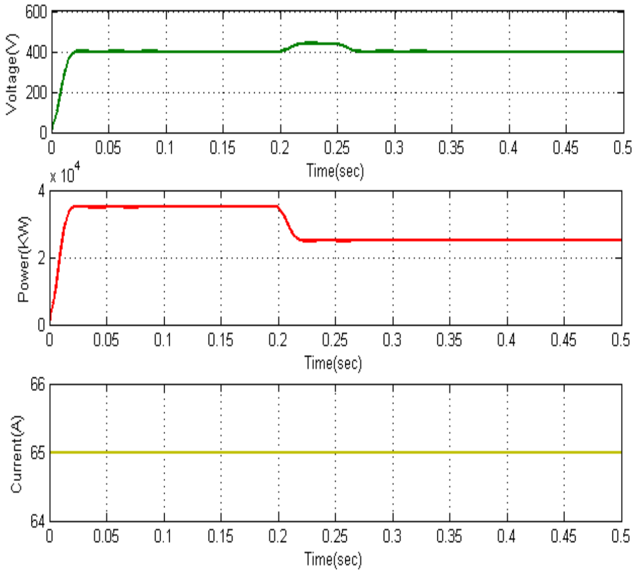

Fig. 7. DC bus voltage, PV output power, and battery current

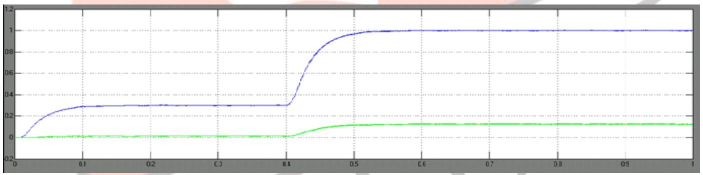

Fig.8.Fuell cell Active and reactive Power

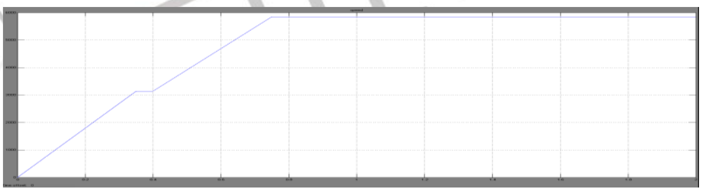

Fig 9 Speed variation of PMSM

Fig.10: Active power variation during motoring /generating mode at the grid

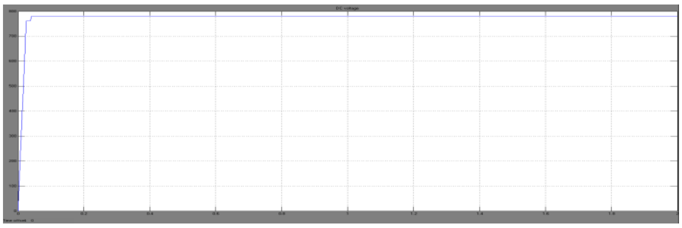

Fig 11.micro grid DC link voltage.

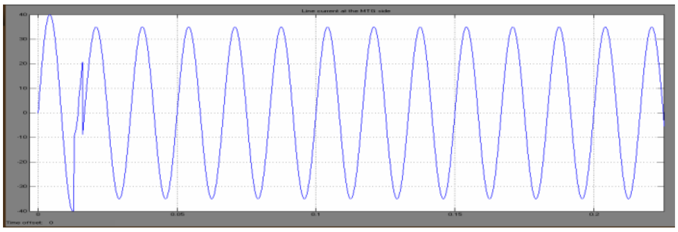

Fig.12.Line current at the MTG side of the interface.

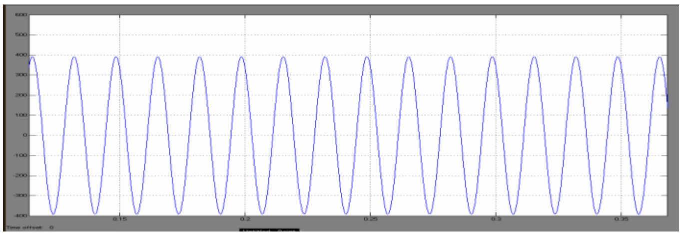

Fig.13.Voltage across the load terminals.

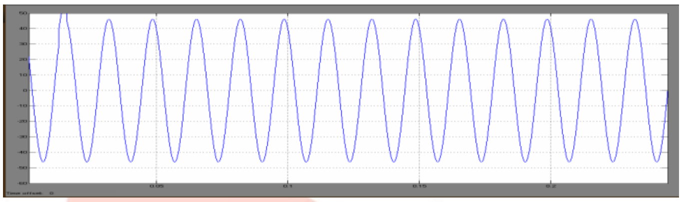

Fig.14 Current across the load terminals

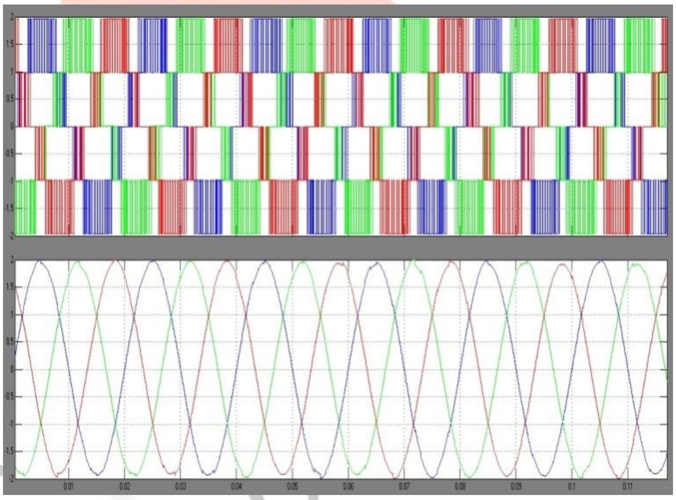

Fig.15 Hybrid CHB Multilevel converter Voltage and current

IV. CONCLUSION

This paper presents an effective control strategy for an islanded H-bridge (CHB) multilevelgrid including the HPS and CHB multilevel inverter under unbalanced and nonlinear load conditions. Theproposed strategy includes power management of the hybridFC/PV, MTG, BES AND SC power source and a voltage control strategy for theCHB multilevel inverter. The main features of the proposed HPS include high performance, high power density, and fast transient response. Furthermore, a multi-PR controller is presented to regulate the voltage of the CHB multilevel inverter in the presence of unbalanced and nonlinear loads. The performance of the proposed control strategy is investigated using MATLAB software. The results show that the proposed strategy:

- Regulates the voltage of the H-bridge (CHB) multilevelgrid under unbalanced and nonlinear load conditions,
- Reduces THD and improves power quality by using CHB multilevel inverters,
- Enhances the dynamic H-bridge (CHB) multilevel response of the H-bridge (CHB) multilevel grid under fast transient conditions,
- Accurately balances the dc-link voltage of multilevel inverter modules and
- Effectively manages the powers among the power sources in the HPS system.

REFERENCES

[1] H.Zhou,T. Bhattacharya,D.Tran,T. S. T. Siew, and A. M. Khambadkone, “Composite energy storage system involving battery and ultracapacitor withdynaH-bridge (CHB) multilevelenergymanagementinH-bridge (CHB) multilevelgrid applications,” *IEEE Trans. Power Electron.*, vol. 26, no. 3, pp. 923–930, Mar. 2011.

[2] W. S. Liu, J. F. Chen, T. J. Liang, and R. L. Lin, “Multicascoded sources for a high-efficiency fuel-cell hybrid power system in high-voltage application,” *IEEE Trans. Power Electron.*, vol. 26, no. 3, pp. 931–942, Mar.2011.

[3] A. Ghazanfari, M. Hamzeh, and H. Mokhtari, “A control method for integrating hybrid power source into an islanded H-bridge (CHB) multilevelgrid through CHB multilevel inverter,” in *Proc. IEEE Power Electron., Drive Syst. Technol. Conf.*, Feb. 2013, pp. 495–500.

[4] *IEEE Recommended Practice for Electric Power Distribution for Industrial Plants*.ANSI/IEEE Standard 141, 1993.

[5] *IEEE Recommended Practices and Requirements for Harmonic Control in Electrical Power System*. IEEE Standard 519, 1992.

[6] X. Yu, A. M. Khambadkone, H. Wang, and S. T. S. Terence, “Control of parallel-connected power converters for low-voltage H-bridge (CHB) multilevelgrid–part i: A hybrid control architecture,” *IEEE Trans. Power Electron.*, vol. 25, no. 12, pp. 2962–2970, Dec. 2010.

[7] J. Pereda and J. Dixon, “23-level inverter for electric vehicles using a single battery pack and series active filters,” *IEEE Trans. Veh. Technol.*, vol. 61, no. 3, pp. 1043–1051, Mar. 2012.

[8] A. Ghazanfari, M. Hamzeh, H. Mokhtari, and H. Karimi, “Active power management of multihybrid fuel cell/supercapacitor power conversion system in a medium voltage H-bridge (CHB) multilevelgrid,” *IEEE Trans. Smart Grid*, vol. 3, no. 4, pp. 1903–1910, Dec. 2012.

[9] L. N. Khanh, J. Seo, Y. Kim, and D.Won, “Power-management strategies for a grid-connected PV ,MTG, BES AND SC-FC hybrid system,” *IEEE Trans. Power Del.*, vol. 25, no. 3, pp. 1874–1882, Jul. 2010.

[10] F. Nejabatkhah, S. Danyali, S. H. Hosseini, M. Sabahi, and S. M. Niapour,“Modeling and control of a new Four-input DC–DC boost converterfor hybrid PV ,MTG, BES AND SC/FC/battery power system,” *IEEE Trans. Power Electron.*,vol. 27, no. 5, pp. 2309–2324, May 2012.

[11] S. K. Kim, J. H. Jeon, C. H. Cho, J. B. Ahn, and S. H. Kwon, “DynaH-bridge (CHB) multilevel modeling and control of a grid-connected hybrid generation system with versatile power transfer,” *IEEE Trans. Ind. Electron.*, vol. 55, no. 4, pp. 1677–1688, Apr. 2008.

[12] M. I. Marei, T. K. Abdel-Galil, E. F. El-Saadany, and M. M. A. Salama, “Hilbert transform based control algorithm of the DG interface for Voltageflicker mitigation,” *IEEE Trans. Power Del.*, vol. 20, no. 2, pp. 1129–1133,Apr. 2005.

[13] M. Cirrincione, M. Pucci, and G. Vitale, “A single-phase DG generation unit with shunt active power filter capability by adaptive neural filtering,”*IEEE Trans. Ind. Electron.*, vol. 55, no. 5, pp. 2093–2110, May 2008.

[14] Y. A.-R. I. Mohamed and E. F. El-Saadany, “A control scheme of gridconnected PWM source inverters for fast load voltage regulation and effective mitigation of unbalanced voltage disturbances,” *IEEE Trans. Ind. Electron.*, vol. 55, no. 5, pp. 2072–2084, May 2008.

[15] C. J. Gajanayake, D. M. Vilathgamuwa, P. C. Loh, R. Teodorescu, and F. Blaabjerg, “Z-source-inverter-based flexible distributed generation Systemsolution for grid power quality improvement,” *IEEE Trans. Energ.Convers.*, vol. 24, no. 3, pp. 695–704, Sep. 2009.

[16] M. Hamzeh, H. Karimi, and H. Mokhtari, “A new control strategy for a multi-bus MV H-bridge (CHB) multilevelgrid under unbalanced conditions,” *IEEE Trans. Power Syst.*, vol. 27, no. 4, pp. 2225–2232, Nov. 2012.

[17] D. De and V. Ramanarayanan, “Decentralized parallel operation of inverters sharing unbalanced and non-linear loads,” *IEEE Trans. Power Electron.*, vol. 25, no. 12, pp. 3015–3025, Aug. 2010.

[18] J. He, Y. W. Li, and M. S. Munir, “A flexible harmonic control approach through voltage-controlled DG grid interfacing converters,” *IEEE Trans. Ind. Electron.*, vol. 59, no. 1, pp. 444–455, Jan. 2012.

[19] C. H. Ng,M. A. Parker, L. Ran, P. J. Tavner, J. R. Bumby, and E Spooner, “A multilevel modular converter for a large, light weight PV ,MTG, BES and SC turbine generator,” *IEEE Trans. Power Electron.*, vol. 23, no. 3, pp. 1062–1074, May 2008.

[20] R. W. Erickson and D. Maksimovic, *Fundamental of Power Electronics*. 2nd ed., New York, NY, USA: Wiley, 2001.

[21] A. Ghazanfari, M. Hamzeh, and H. Mokhtari, “Power management strategy for amulti-hybrid fuel cell/energy storage power generation systems,”in *Proc. IEEE Power Electron., Drive Syst. Technol. Conf.*, Feb. 2012,pp. 348–353.

[22] M. Y. El-Sharkh, A. Rahman, M. Y. Alam, P. C. Byrne, A. A. Sakla, and T. Thomas, “A dynaH-bridge (CHB) multilevel model for a stand-alone PEM fuel cell power plant for residential applications,” *J. Power Sources*, vol. 138, pp. 199– 204, Aug. 2004.

[23] A. Timbus, M. Liserre, R. Teodorescu, P. Rodriguez, and F. Blaabjerg, “Evaluation of current controllers for distributed power generation systems,”*IEEE Trans. Power Electron.*, vol. 24, no. 3, pp. 654–664, Mar.2009.

[24] J. Chavarria, D. Biel, F. Guinjoan, C. Meza, and J. J. Negroni, nergybalance control of PV ,MTG, BES AND SC cascaded multilevel grid-connected inverters under level-shifted and phase-shifted PWM modulations,” *IEEE Trans. Ind.Electron.*, vol. 60, no. 1, pp. 98–111, Jan. 2013.

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