| e-ISSN: 2278 – 8875, p-ISSN: 2320 – 3765| www.ijareeie.com | Impact Factor: 7.122|

|| Volume 9, Issue 7, July 2020 ||

Grid Power Balance of Cascaded H-Bridge Multilevel Converters Using Auxiliary converter for Photovoltaic Plants

Dr. C. Bhargava[1], M. Arvind Kumar[2]

Professor& Head of Dept. of EEE,Sreenidhi Institute of Science and Technology, Hyderabad, Telangana, India[1]

PG Research Scholar, Dept. of EEE, Sreenidhi Institute of Science and Technology, Hyderabad, Telangana, India[2]

ABSTRACT*:* Power generated by large scale photovoltaic power plants with Multilevel cascaded H-bridge converters are the most encouraging candidates by their marvellous characteristics like low switching losses and the efficiency of the conversion is very high with their modular structure; this type of characteristics are most suitable for the next generations photovoltaic power plants. It will allow direct connection between converter and medium distribution network without any intermediate very large power transformer. However, irradiance level and temperatures on the panels will affects the generation of the power in three phase. Imbalance of power will creates unexpected problems on the grid connected distribution networks. To deal with power imbalance problems zero sequence voltages are injected on converter output voltage in controller by summation of both voltages the currents on grid side are redistributed. But still when the irradiance and temperature on the solar panel connected in each phase are in different areas creates more imbalance between three phases then zero sequence injection will fail to redistribute the currents among the 3-phases. This paper proposes that an auxiliary back to back converter added to normal topology, then this auxiliary the BTB converter will connected between the multilevel converter and distribution network will convert unbalance power to the balance power. Results are obtained are tabulated by simulation this type of topology with 6.6KV, 10MW 3-phase 7level cascaded H-bridge and 2-level back to back auxiliary converter in MATLAB are taken and verified under severe imbalance.

KEYWORDS*:* zero sequence injection, Multilevel cascaded H-bridge inverter, Auxiliary back to back converter, Isolated DC-DC converters, Fundamental frequency zero-sequence injection (FFZSI).

I.INTRODUCTION

Due to tremendous growth of power demand, the world is seeing the different ways of generating the power in that process centralized large-scale photovoltaic plants are increasing exponentially worldwide than the small scale photovoltaic (PV) power plants due its operation is very close to the conventional one and it is very economical to produce the power [1]-[3]. In studies of evaluation in CHB for PV plants explains that multilevel CHB converter Levelized Cost Of Energy (LCOE) is reduced is compared with state-of-the-art 2-level converters [12]. In all available topologies in the inverter Cascaded high power multilevel H-bridge inverters using in to large scale centralized photovoltaic plants because of their marvellous characteristics like lower switching losses, higher conversion power efficiency and power rating [6], [7] is high than compare to 2-level inverters with these reasons the researchers in this area around the world exploring their characteristics to achieve the more generation of power form it. Additionally to several merits cascaded h-bridge multilevel inverter can direct connected to medium distribution network without any isolation with high and bulky line frequency transformer, because galvanic isolation provide by transformer in the isolated dc-dc converter [6]. In this topology, more number of dc links presented and operated independently connected with the isolated dc-dc converter, so there will be raises of main problems which is caused by the nature, generally large scale PV plants occupies very large area then their will stochastically changes in climate there will be a non-uniform solar irradiance levels and the temperature on PV modules which are presented in different phases. Thus power imbalance is created between the 3 phase CHB and grid is not acceptable. However, if CHB is not able to meet the grid codes [20] CHB converters is disconnected from the grid, thus there will be totally wasted of power. The problem is mainly divided into two categories: 1) the inter-phase (clustered) power imbalance, occurs between the 3 phases when the power in the each phases is generated unequally; and 2) inter-bridge (individual) power imbalance, this is when the power in each H-bridges which are connected to one leg in any of 3-phase generates different amount of power [15], [16]. The main objective of this paper is to simulate and verify proposed method that which is connect the auxiliary back-to-back converter is more superior to deal with the clustered power imbalance problem of 7-level cascaded H-bridge converters which are connected to large-scale PV power plants. This is compared with the conventional solution FFZSI is the voltage v^o that will added with CHB references sine wave. This will gives us redistributed of currents among the three phases on the basis of instantaneous power theory [17]. Even through it is a simple implementation this type of injection is clearly explains physically it not a best option to use it will be very less economical with increasing with no. of CHB and also if severity increases this method will completely fails [5]. The proposed auxiliary back-to-back method offer best utilization of voltages on dc-side, and able to rebalance the current on the grid side and total amount of power is available at PV side is able to transfer the grid side by adding the currents from the auxiliary back to back converter and 7-level multilevel inverter. The method proposed in this paper are able to generate three-phase currents which are ready to add unbalance on converter currents under very severe imbalance in the power in three phases.

II.SYSTEM CONFIGURATION

Fig.1 shows the schematic figure of grid connected 10MW 6.6KV centralized large scale photovoltaic system connected by cascaded H-bridge inverter through isolated DC-DC converter integration with auxiliary back to back voltage source converter, used for implementing/simulating the proposed scheme in MATLAB/simulink environment using simpower system block sets. The schematic design and equations involved for development criteria of the entire system components such as solar photovoltaic generation, Isolated DC-DC boost converter, v_{dc} voltage at dc-link capacitor and the interfacing inductor for ripple filter are described below [10]-[11]. In initially the PV power is converted into the AC using high frequency inverter which is 10 times the nominal frequency and it is stepped up and converted with rectifier to maintain the voltages and dc-link where single H-bridges is connected. The MPPT and Voltage orient controllers [20 21] to transfer the maximum power form the PV strings [10] v_{dc} regulated respectively.

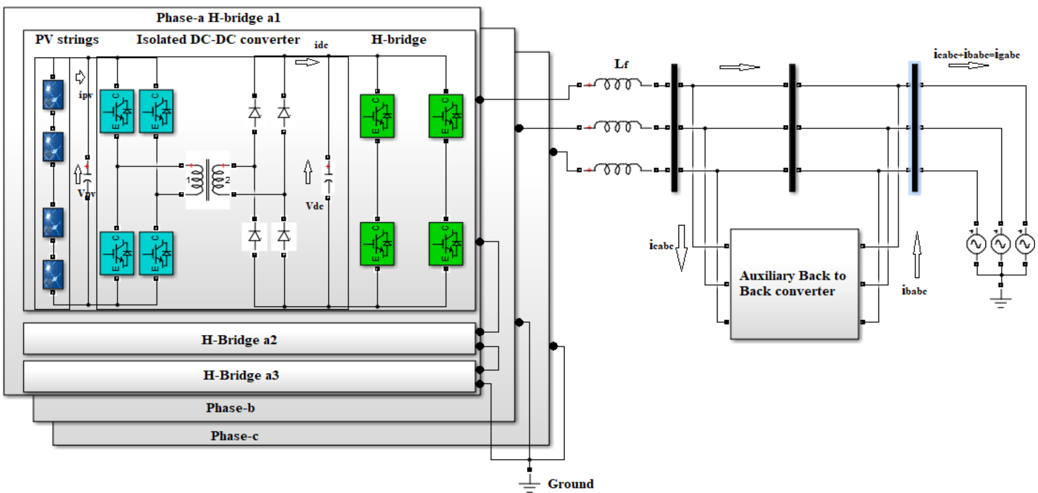


Fig.1 Grid connected Three-phase seven-level cascaded H-bridge inverter with parallel connected Auxiliary back to back converter.

A. Design of the large scale Photovoltaic generation:

The large scale centralized photovoltaic power generating system is designed for a 10MW peak power capacity. In each H-bridge is connected with the 1.11MW so that their will 9 H-bridges 3 in each phase. So that accordingly to design considerations 33 modules in series 311 modules in parallel, one solar module consists of 36 cells in series. Each cell has an open circuit voltage (V_{oc}) 0.6139 V and short circuit current (I_{sc}) of 3.9A with maximum power of (P_{max}) 65watts

B. Design of Isolated DC-DC Converter:

The Isolated DC-DC boost converter is shown in [4] Fig.1. The voltage from PV string is first inverted and stepped up and again rectified, by using each isolated dc-dc converter obtained the voltage at dc link v_{dc} will be 2200V. Where N_1, N_2 are the no of turn in transformer, D is duty ratio for the inverter which is used to maintain for the maximum power, v_d is the output voltage across the inverter in isolated dc-dc converter The design parameters v_{dc} of the isolated dc-dc converter are given as**.**

$$v_{dcn} = \frac{v_d*2*N_2*D}{N_1} \qquad ..1$$

C. Selection of DC link Capacitor:

The output capacitor c_{dc} for this Isolated DC-DC converter shown in Fig.1 is given as.

$$c_{dcn}\frac{dv_{dcn}}{dt} = i_{dcin} - i_{dcn} \quad ..2$$

Where, $c_{dcn}$is capacitor in dc link, n is the no of h-bridge, i_{dcin} is current that leaves form the isolated dc-dc converter and i_{dcn}.

D. Selection of interfacing Inductor:

Design of filtering inductor L_f is defined as,

$$L_f = \frac{2*\pi*f*P_{nom}}{V_g^2} \quad ..3$$

Where, P_{nom} is nominal power of photovoltaic, V_g(rms) is the grid voltage.

III REVIEW OF FUNDAMENTAL FREQUENCY ZERO SEQUENCE INJECTION

$$v^0 = \sqrt{2}V^0\cos(\omega t + \theta) \quad ..4$$

$$V^0 = \frac{\sqrt{6}\Delta}{3(\lambda a + \lambda b + \lambda c)}V_g \quad ..5$$

In Eq.4 the rms value v^0 of the FFZSI is added to the converter output voltage to rebalance the currents which are unequally generated by the CHB and the θ is the phase angle, ω=2*π*frequency, λ_a, λ_b, λ_c are the power imbalance ration is defined by the power generated in each phase to the one third of the total three phase nominal power. The rms v^0 is expected to be increases with increases in power imbalance [5],[6]. In other hand any other voltage sources converter voltage are determined by dc link voltages v_{dc} if the v^o is increases and it is added to CHB voltages will turns converter into over-modulated region. With this over-moduation of converter output voltage the current will also goes to saturation state which will increase in total harmonic distortion which is not acceptable.

IV.AUXILIARY BACK TO BACK CONVERTERS

The auxiliary back to back converters show in Fig.2 are used in this topology so that the output currents form the 7level cascaded H-bridge inverter are unequal which is highly not acceptable by the grid, this back to back converter consist of the rectifier and inverter which is connected back to back the common dc link, [9] initially when the balanced currents are generated in the each phase then this back to back converter are isolated from the grid when the only imbalance is created by the pv modules then initially 7 level h-bridge converters transfers power form PV side [8] to grid but the current i_{cabc} in the 3 phases are unequal at this time the back to back converters will come in to active part with h-bridge inverters so that output currents i_{babc} from the back to back converter will be in the way that when it added to left part of the currents i_{labc}as shown in the eq.4 grid currents will in balanced and the equal.

$$i_{gabc} = i_{labc} + i_{babc} \quad ..6$$

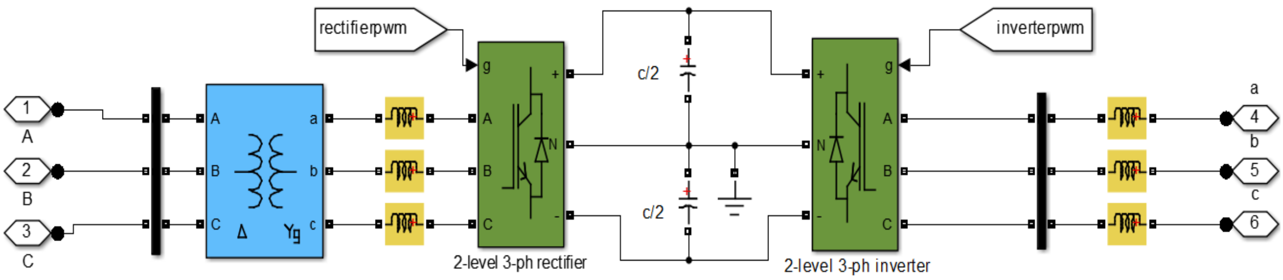


Fig 2: Back to Back voltage source converter

Fig.2 contains the 2 three level diode-clamped igbt converter connected back to back with intermediate dc-link is which is one act as the rectifier and another inverter auxiliary dc-link voltage v_{adc}divide in three different levels by connecting the bulk capacitors in series, C_1= C_2=C/2between them consider as the neutral point. The output voltages from the inverter V_{an}, V_{bn}, V_{cn} has a three states: V_{an} = V_{dc} /2, 0, –V_{dc} /2 [22].

The output voltage at inverter in the btb converter is given V_{an} = (V_{dc} /2), then switches in upper side S_{11} and S_{21} need to be turned 'ON'. For V_{an}=(–Vdc /2) then the switches in lower side S' 11 and S' 21 need to be turned 'ON'; and for the V_{an}=0 either pair (S21, S' 11) needed to be turned 'ON.

| e-ISSN: 2278 – 8875, p-ISSN: 2320 – 3765| www.ijareeie.com | Impact Factor: 7.122|

|| Volume 9, Issue 7, July 2020 ||

V.CONTORL IMPLEMNTANTION

In fig-3 illustrates the implementation of that voltage orient control of cascaded H-bridge converter and auxiliary back to back converter the topology consist of 7-level H-bridge inverter, 3-level three phase diode clamped igbt bridge rectifier and inverter which is connected parallel to grid, and last isolated dc-dc converter. The maximum power point tracking (mmpt) is implemented on the isolated dc dc inverter, the voltage V_{pv} will maximum voltage at maximum power form the PV string. This voltage is stepped up through a transformer and rectified to keep readily available across the dc-link. A decoupled current control figb obtains voltage across the dc link and compared with the constant to set the direct axis reference current to generate the reference sine wave for pwm.

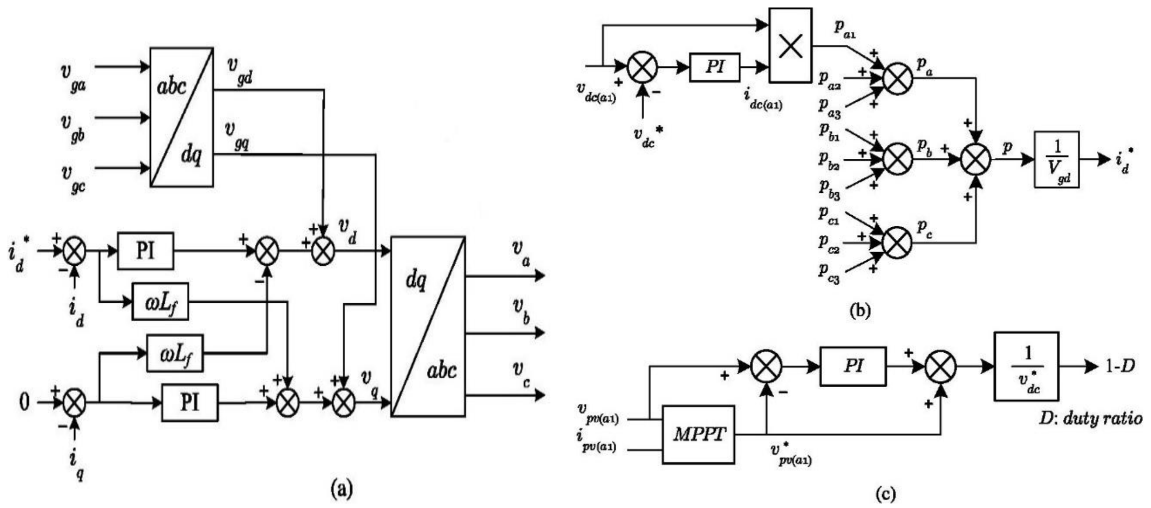


Fig.3 Control implementation. (a) VOC of the CHB converter; (b) obtaining the current references; (c) MPPT regulation of the dc–dc converter

Control of Proposed System:

In Fig.4 illustrates that it generate the references voltage from the power generation ratios in each phase to the rectifier and inverter in the auxiliary back to back converter, P_a, P_b, P_c are the total individual power which are generated in each phase divide by nominal power of each phase. The ratios are subtracted from the total power, among them maximum value is chosen for the reference voltage and it is given to the decoupled current controller to get direct axis reference current to generate a sine wave signal for the rectifier and the current generated form the inverter in BTB converter will calculated form the actual power generated from the each phase in CHB by taking the sum of power in all phases then the one third of the summation must be the final grid currents. By comparing the power in all phase with one third of the summation power will leaves the information of the amount of power should generated form back to back converter. The dc link in auxiliary back to back converter is maintain V_{bdc} in fig is equal to 13200V then the capacitor and filtering inductors values will be $c_1=c_2=c/2=20$mf and 10mH respectively. The references is generated to meet the currents on the grid side must be balance. As from the Eq.6 is the grid connected currents is equal to the sum of the currents back to back voltage source converter and the remaining amount of currents after the back to back converter is consumed.

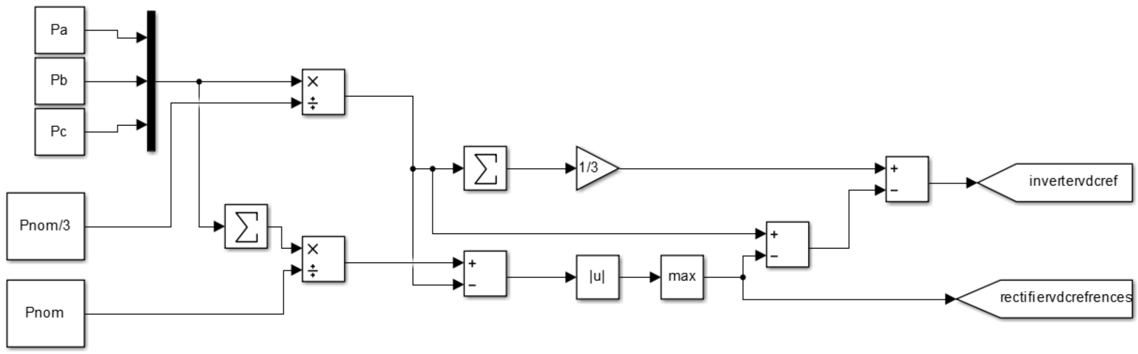


Fig.4 control scheme of proposed systems for generating the voltage references for direct axis current

| e-ISSN: 2278 – 8875, p-ISSN: 2320 – 3765| www.ijareeie.com | Impact Factor: 7.122|

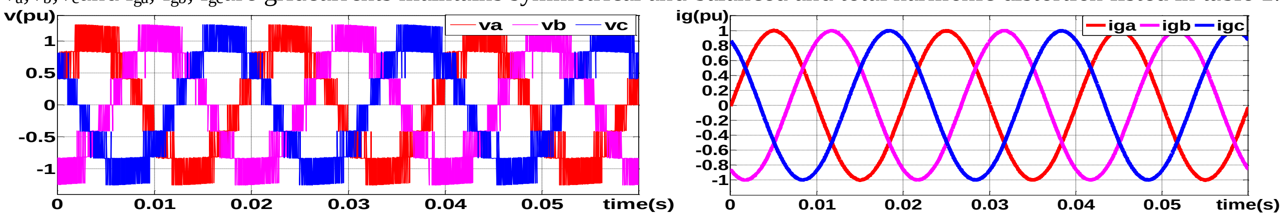
|| Volume 9, Issue 7, July 2020 ||

VI.SIMULATION AND ITS RESULTS

A 6.6KV 10MW three-phase seven-level CHB of power converter was simulated to find out the feasibility of the proposed method using MATLAB/SIMULINK. This is studied in three cases results obtained and tabulated in Table I and Table II shows the imbalance ratio is equal to negative sequence divide by positive sequence[19] and THD.

Case A (a=1, b=1, c=1)

Irradiance on the PV modules are 1000 W/m^2 in Fig.5 shows case A, 3- phase, 7-level CHB inverter voltages v_a,v_b,$v_c$and i_{ga}, i_{gb}, $i_{gc}$are gridcurrents maintains symmetrical and balanced and total harmonic distortion listed in table 1.

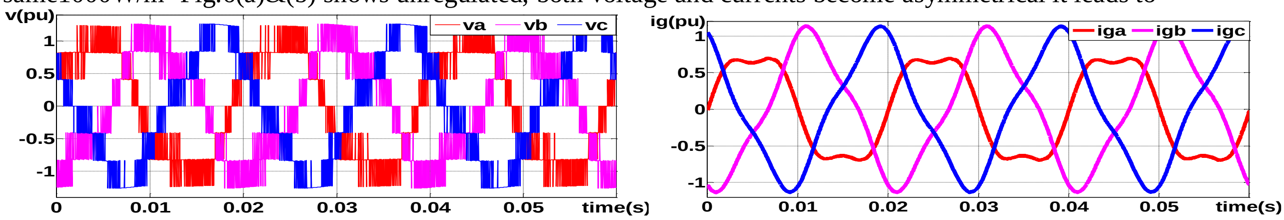


5(a) 5(b)

Fig.5. (a)Balaced 3-ph 7-level H-bridge inverter voltagesv_a, v_b, v_c; (b)Balanced grid currentsi_{ga},i_{gb},i_{gc}

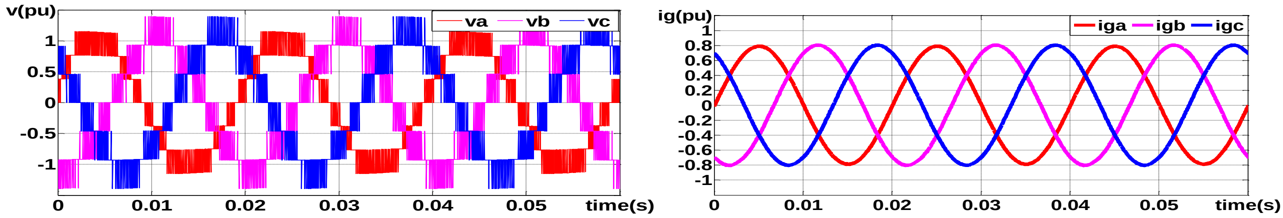
Case B (a=0.80, b=1, c=1)

In phase a falls from 1000W/m^2 to 800W/m^2 with loss of 20% in peak power, in b and c phasesare maintain same1000W/m^2 Fig.6(a)&(b) shows unregulated, both voltage and currents become asymmetrical it leads to



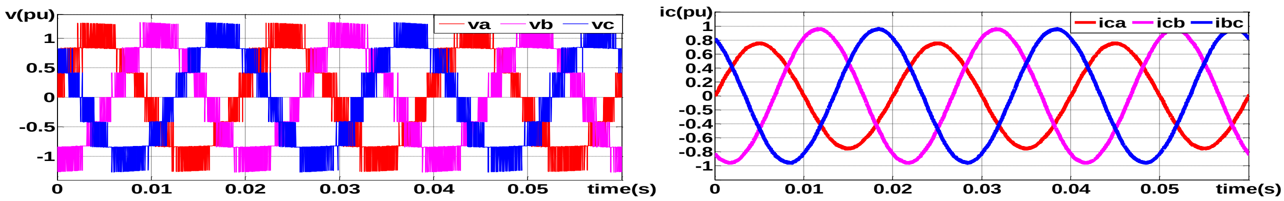
6(a) 6(b)

Fig.6 Unregulated with case B, a) 3-ph 7-level CHB converter voltages v_a, v_b, v_c and b) grid currents i_{ga},i_{gb},i_g

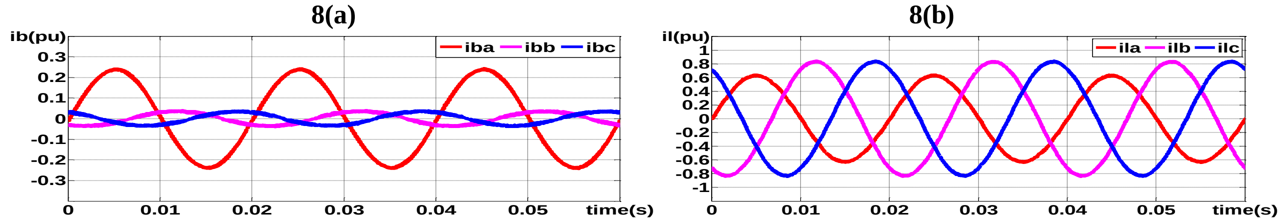


7(a) 7(b)

Fig.7 Regulated with FFZSI case B, a) 7-level CHB converter voltages v_a, v_b, v_c and b) grid currents i_{ga},i_{gb},i_g



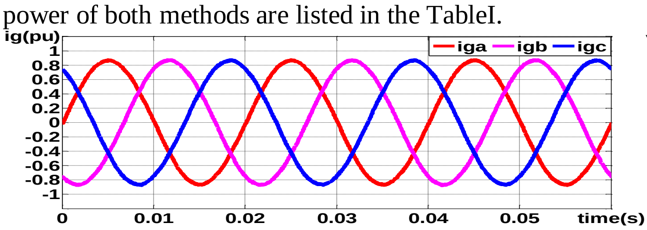
8(a) 8(b)



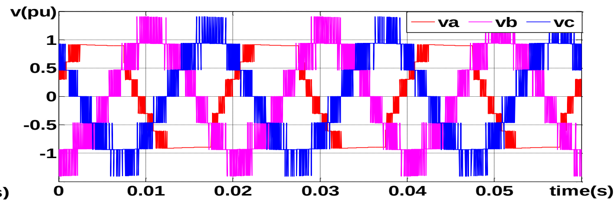
8(c) 8(d)

Fig.8 (a)&(b) 3-ph 7-level CHB converter voltages v_a, v_b, v_c and currents i_{ca}, i_{cb}, i_{cc} ;8(c) BTB converter currents i_{aa}, i_{bb}, i_{bc} ;8(d) Remaining currents i_{la}, i_{lb}, i_{lc} after the BTB consumed.

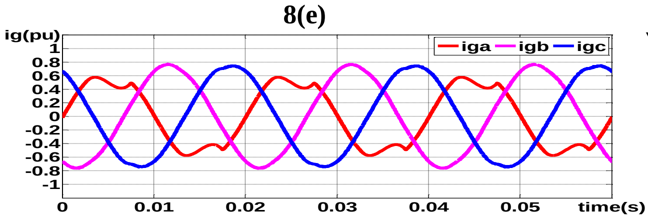
disconnection of CHB form the grid.Fig.7(a) CHB voltages and 7(b) grid currentsregulated with FFZSI by reducing the 20% of the peak power in phase b & c. Fig8(a)&(b) 3-ph 7level CHB voltages v_{abc} and currents i_{cabc} Fig 8(c) is the currents i_{aabc} from BTB converter Fig.8(d) are the currents i_{labc} left after the consumed by the BTB converter and the finally the 8(e) is the final current which is connected to the grid $i_{gabc}$is the summation of the i_{labc} and i_{aabc} THD and power of both methods are listed in the TableI.



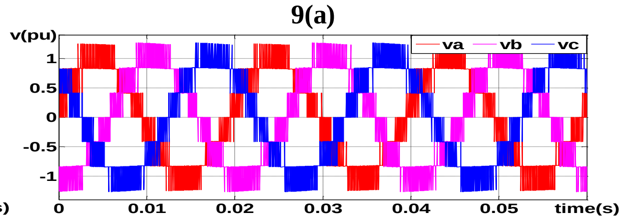
8(e)



9(a)



9(b)

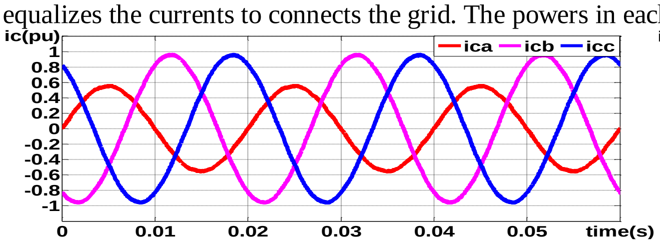


10(a)

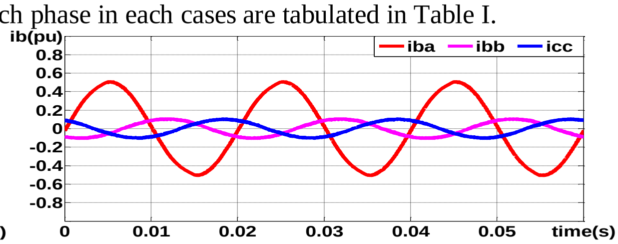
Fig. 8(e) Final grid currents i_{ga}, i_{gb}, i_{gc} in case B; Fig.9 FFZSI regulated with case c 9(a)and9(b) 3-ph 7-level CHB voltages v_a, v_b, v_c and grid currents i_{ga},i_{gb},i_{gc}; Fig.10(a) 3-ph 7-level CHB converter voltages v_a, v_b, v_c.

Case C (a=0.6, b=1, c=1)

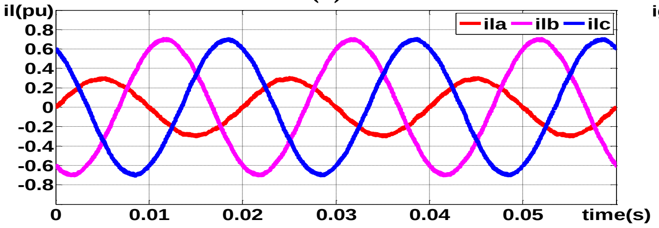
In this the irradiance levels on the PV modules of phase a, drops to 600 W/m^2 with loss of40% of peak power in phase a in b&c phases remains 1000W/m^2 same in Fig 9(a) and 9(b) shows CHB voltages v_a, v_b, v_c and grid currentsi_{ga}, i_{gb}, i_{gc} in per unit system respectively with FFZSI which is unable to rebalance the grid currents in severe imbalance. In Fig.10 results with the connection of the parallel Auxiliary BTB converter 10(a) and 10(b) are 3ph 7-level CHB voltage and current in per unit shows that total PV generation in all phases individually with converted by 3ph 7-level CHB inverter, but the current in the phase a is less then phase b and c at output of the CHB auxiliary back to back voltage sources converter both outputs connected to grid parallel. In Fig.10(c) 3ph per unit currents i_{aa}, i_{bb}, i_{bc} from auxiliary BTB converter which will connected to grid therefore, i_{labc} which is shown in the Fig. 10(d) currents after the BTB converter consumed both $i_{labc}$and i_{babc} are connected to bus to form final grid currents i_{gabc} in fig.10(e), which satisfies Eq.6 by verifying the total generated powers by PV systems in each phase seems that in phase a is 42.3% less than the b and c phases same is reflected on the output of CHB converter, BTB voltage source converter act like a load to equalizes the currents to connects the grid. The powers in each phase in each cases are tabulated in Table I.



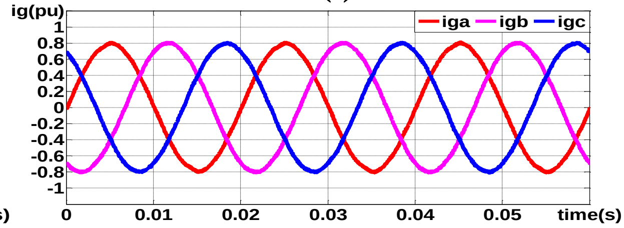
10(b)



10(c)



10(d)



10(e)

Fig.10 Results with Parallel connection of BTB voltage source converter 10(b) 3-ph 7level CHB currents; 10(C) BTB converter currents; 10(d) Remaining currents i_{la}, i_{lb}, i_{lc}after the BTB consumed;10(e) Final grid currents i_{ga}, i_{gb}, i_{gc} in case C.

Table I Power in different phases in all cases

		Total power in Phase A	Total power in Phase B	Total power Phase C
Case A	**PV GENERATION**	**3.505×10^6**	**3.505×10^6**	**3.505×10^6**
	7-LEVEL CHB	**3.49×10^6**	**3.497×10^6**	**3.496×10^6**
Case B	**PV GENERATION**	**2.756×10^6**	**3.505×10^6**	**3.505×10^6**
	7-LEVEL CHB	**2.75×10^6**	**3.497×10^6**	**3.496×10^6**
	FFZSI	**2.722×10^6**	**2.720×10^6**	**2.721×10^6**
	BTB CONVERTER	**3.175×10^6**	**3.179×10^6**	**3.174×10^6**
Case C	**PV GENERATION**	**2.017×10^6**	**3.505×10^6**	**3.505×10^6**
	7-LEVEL CHB	**2.014×10^6**	**3.497×10^6**	**3.496×10^6**
	FFZSI	**2.014×10^6**	**3.496×10^6**	**3.497×10^6**
	BTB CONVERTER	**2.932×10^6**	**2.945×10^6**	**2.935×10^6**

Table II Total harmonic distortion and Imbalance

Methods	Ratio of Imbalance currents in (%)	THD $i_{ga(\%)}$	THD $i_{gb(\%)}$	THD $i_{gc(\%)}$
Normal conditions in case A	**0%**	**0.60%**	**0.59%**	**0.57%**
Imbalance conditions in case B	**NA**	**11.38%**	**9.78%**	**9.67%**
FFZSI in case B	**0.03%**	**0.68%**	**0.68%**	**0.69%**
BTB converter in case B	**0.01%**	**1.13%**	**1.19%**	**1.17%**
FFZSI in case C	**NA**	**15.76%**	**6.94%**	**6.89%**
BTB converter in case C	**0.02%**	**1.24%**	**1.34%**	**1.32%**

VII.CONCLUSION

In this section results obtained by simulating the 3-phase 7-level cascaded H-bridge inverter with auxiliary back to back converter simulation results are seen and verify with conventional zero sequence injection that is fundamental frequency zero sequence injection (FFZSI) is achieved when the imbalance is low up to 20% of the peak power but it is failed to transfer the total power generated by the PV strings. By creating the more than 20% imbalances the grid currents and converter voltages goes to saturation in very severe conditions. All the powers in different stages are shown in Table I. But by adding the auxiliary back to back converter to the main h-bridge inverter it converts acts as load when the imbalance is created, by adding the output currents i_{babc} at the end of back to back converter with the remaining currents i_{labc} will equal to final grid currents i_{gabc}.The THD are also show in the Table II.Simulation results have been provided here to validate the feasibility and superiority of the proposed method.

REFERENCES

[1] Z. Moradi-Shahrbabak, A. Tabesh, and G. R. Yousefi, "Economical design of utility-scale photovoltaic power plants with optimum availability," IEEE Trans. Ind. Electron., vol. 61, no. 7, pp. 3399–3406, Jul. 2014.
[2] M. Morjaria, D. Anichkov, V. Chadliev, and S. Soni, "A grid-friendly plant: The role of utility-scale photovoltaic plants in grid stability and reliability," IEEE Power Energy Mag., vol. 12, no. 3, pp. 87–95, May/Jun. 2014.
[3] P. Denholm, R. Margolis, T. Mai, G. Brinkman, E. Drury, M. Hand, and M. Mowers, "Bright future: Solar power as a major contributor to the U.S. grid," IEEE Power Energy Mag., vol. 11, no. 2, pp. 22–32, Mar./Apr. 2013
[4] Yifan Yu, GeorgiosKonstantinou, BranislavHredzak, and Vassilios G. Agelidis, "Power Balance of Cascaded H-Bridge Multilevel Converters for Large-Scale Photovoltaic Integration" IEEE Transactions on Power Electronics, vol. 31, no. 1, january 2016.

| e-ISSN: 2278 – 8875, p-ISSN: 2320 – 3765| www.ijareeie.com | Impact Factor: 7.122|

|| Volume 9, Issue 7, July 2020 ||

[5] T.Kerekes, E.Koutroulis,D. S´era, D. R. Teodorescu, and M. Katsanevakis,"An optimization method for designing large PV plants," *IEEE J. Photovoltaics*,vol. 3, no. 2, pp. 814–822, Apr. 2013.

[6] J.Carrasco, L. Franquelo, J.Bialasiewicz, E. Galvan,R.Guisado, M. Prats ,J. Leon, and N. Alfonso, "Power-electronic systems for the grid integration of renewable energy sources: A survey," *IEEE Trans. Ind. Electron.*, vol. 53, no. 4, pp. 1002–1016, Jun. 2006.

[7] SMA Sunny Central 800CPXT/850CPXT/900CPXT. (2013). [Online]. Available: http://files.sma.de/dl /18859/SC800CP-900CPDEN131915W.pdf

[8] ABB central inverters PVS800 100 to 1000 kW. (2013). [Online]. Available: http://www05.abb.com /global/scot/scot232.nsf/veritydisplay/2d8c5c00c2efeee4c1257ceb002b4289$file/17135_PVS800_central_inverters_flyer_EN_3AU A0000057380 _RevK_lowres.pdf.

[9] S. Kouro, M. Malinowski, K. Gopakumar, J. Pou, L. Franquelo, B. Wu, J. Rodriguez, M. Perez, and J. Leon, "Recent advances and industrial applications of multilevel converters," *IEEE Trans. Ind. Electron.*, vol. 57,no. 8, pp. 2553–2580, Aug. 2010.

[10] M. Cavalcanti, A. Farias, K. Oliveira, and J.Afonso, "Eliminating leakage currents in neutral point clamped converters for photovoltaic systems," *IEEE Trans. Ind. Electron.*, vol. 59, no. 1, pp. 435–443, Jan.2012.

[11] S. Monge, J. Rocabert, P. Rodriguez, S. Alepuz, and J. Bordonau, "Multileveldiode-clamped converter for photovoltaic generators with independent voltage control of each solar array," *IEEE Trans. Ind. Electron.*, vol. 55, no. 7, pp. 2713–2723, Jul. 2008.

[12] M. R. Islam, Y. Guo, and J. Zhu, "A high-frequency link multilevel cascaded medium-voltage converter for direct grid integration of renewable energy systems," *IEEE Trans. Power Electron.*, vol. 29, no. 8, pp. 4167–4182, Aug. 2014.

[13] J. Sastry, P. Bakas,H.Kim, L.Wang, andA.Marinopoulos, "Evaluation of cascaded H-bridge inverter for utility-scale photovoltaic systems," *Renew.Energy*, vol. 69, pp. 208–218, Sep. 2014.

[14] D. Sun, B. Ge, X. Yan, D. Bi, H. Zhang, Y. Liu, H. Abu-Rub, L. Ben-Brahim, and F. Z. Peng, "Modeling, impedance design, and efficiency analysis of quasi-*Z* Source module in cascaded multilevel photovoltaic power system," *IEEE Trans. Ind. Electron.*, vol. 61, no. 11, pp. 6108–6117, Nov. 2014.

[15] W. Zhao, H. Choi, G. Konstantinou, M. Ciobotaru, and V. Agelidis, "Cascaded H-bridge multilevel converter for large-scale PV grid-integration with isolated DC-DC stage," in *Proc. IEEE Power Electron. Distrib. Gener.Syst. Conf.*, 2012, pp. 849–856.

[16] E. Villanueva, P. Correa, J. Rodriguez, and M. Pacas, "Control of a single-phase cascaded H-bridge multilevel converter for grid-connected photovoltaic systems," *IEEE Trans. Ind. Electron.*, vol. 56, no. 11,pp. 4399–4406, Nov. 2009.

[17] J. Chavarria, D. Biel, F. Guinjoan, C. Meza, and J. Negroni, "Energy balance control of PV cascaded multilevel grid-connected converters under level-shifted and phase-shifted PWMs," *IEEE Trans. Ind. Electron.*,vol. 60, no. 1, pp. 98–111, Jan. 2013.

[18] C. Townsend, T. Summers, and R. Betz, "Control and modulation scheme for a cascaded H-bridge multi-level converter in large scale photovoltaic systems," in *Proc. IEEE Energy Convers. Congr. Expo.*, 2012, pp. 3707–3714.

[19] Y. Yu, G. Konstantinou, B. Hredzak, and V. Agelidis, "On extending the energy balancing limit of multilevel cascaded H-bridge converters for large-scale photovoltaic farms," in *Proc. Australas. Univ. Power Eng.Conf.*, 2013, pp. 1–6.

[20] IEEE *Recommended Practice for Monitoring Electric Power Quality*,IEEE Standard 1159-2009, 2009

[21] B. Xiao, L. Hang, J. Mei, C. Riley, L. Tolbert, and B. Ozpineci, "Modular cascaded H-bridge multilevel PV inverter with distributed MPPT for gridconnectedapplications," *IEEE Trans. Ind. Appl.*, to be published.

[22]Mohamed flitti, Mohammed-karim fellah, Mohamed khatir, Sid-ahmedzidi, Mohammed-fouadbenkhoris,"CONTROL OF BACK-TO-BACK VOLTAGE SOURCE CONVERTER" : https://www.researchgate.net/publication/271964769