Grid Connected Applications of Modular Cascaded H-Bridge Multilevel PV Inverter with Distributed MPPT

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Abstract— This paper shows a particular cascaded H-bridge multilevel photovoltaic (PV) inverter for single-or three-phase lattice related applications. The specific cascaded multilevel topology helps to enhance the capability and flexibility of PV systems. To recognize better utilization of PV modules and increase the sun based essentialness extraction, a scattered most outrageous power point following control scheme is associated with both single-and three-phase multilevel inverters, which grants self-governing control of each dc-interface voltage. For three-phase system related applications, PV mismatches may display disproportionate provided power, inciting unequal network current. To light up this issue, a control scheme with modulation compensation is also proposed. An experimental three-phase seven-level cascaded H-bridge inverter has been manufactured utilizing nine H-bridge modules (three modules for each phase). Each H-bridge module is related with a 185-W sun based board. Amusement also, experimental results are introduced to check the attainability of the proposed approach.

List Terms—Cascaded multilevel inverter, circulated greatest power point (MPP) following (MPPT), particular, modulation remuneration, photovoltaic (PV).

I. Presentation

Because of the shortage of petroleum derivatives and natural issues caused by conventional power generation, sustainable power source, especially sun powered vitality, has turned out to be extremely famous. Sunlight based electric-vitality request has developed reliably by 20%– 25% for every annum in the course of recent years, and the growth is for the most part in grid-associated applications. With the phenomenal market growth in grid-associated photovoltaic (PV) systems, there are expanding premiums in grid-associated PV configurations. Five inverter families can be characterized, which are related to different setups of the PV system:

1) central inverters; 2) string inverters;
3) multistring inverters; 4) ventilating module inverters; and
5) cascaded inverters.

Cascaded inverters contain a couple of converters related in game plan; thus, the high power and also high voltage from the blend of the various modules would bolster this topology in medium and broad lattice related PV systems. There are two sorts of cascaded inverters. A cascaded dc/dc converter relationship of PV modules. Each PV module has its own specific dc/dc converter, and the modules with their related converters are up 'til now related in course of action to make a high dc voltage, which is given to a revamped dc/aerating and cooling inverter.

This approach joins parts of string inverters and aerating and cooling module inverters and offers the advantages of individual module most extraordinary power point (MPP) following (MPPT), yet it is not so much exorbitant but rather more effective than air conditioning module inverters. However, there are two power change arranges in this configuration. Another cascaded inverter, where each PV board is associated with its own dc/air conditioning inverter, and those inverters are then put in arrangement to reach a high-voltage level. This cascaded inverter would keep up the advantages of "one converter for each board," such as better use per PV module, capacity of blending distinctive sources, also, redundancy of the system. Additionally, this dc/aerating and cooling cascaded inverter empties the necessity for the per-string dc transport and the central dc/ventilating inverter, which further enhances the general proficiency.

LITERATURE SURVEY

Papers by J. M. Carrasco et al., bargain the utilization of conveyed vitality resources is progressively being sought after as a supplement and another option to substantial conventional focal power stations. The particular of a power-electronic interface is liable to necessities related to the sustainable power source itself as well as to its consequences for the power-system operation, particularly where the irregular vitality source constitutes a huge piece of the aggregate system limit. In this paper, new patterns in power gadgets for the integration of wind and photovoltaic (PV) power generators are displayed. An audit of the fitting stockpiling system technology utilized for the integration of discontinuous sustainable power sources is likewise presented. Discourses about common and future patterns in sustainable power source systems based on dependability and development of each technology are introduced.

The work displayed by L. M. Tolbert and F. Z. Peng, have portrayed a nitty gritty examination of Multilevel inverter structures to defeat shortcomings in strong state switching device appraisals with the goal Consequently, multilevel inverters are perfect for associating either in arrangement or in parallel an AC grid with sustainable power sources such as photovoltaics or energy components or with

vitality stockpiling devices such as capacitors or batteries. In this paper the cascaded H-bridges multilevel inverter is depicted.

C. D. Townsend, T. J. Summers, and R. E. Betz, have displayed [3] a point by point depiction of Multi-level Cascaded H-bridge (CHB) converters are perfect for actualizing extensive scale photovoltaic systems. The enhanced quality of the voltage waveforms, high effectiveness and capacity to utilize multiple Maximum Power Point Tracking (MPPT) algorithms are quite recently a portion of the preferences. In this paper a three-phase CHB converter supplied with photovoltaic clusters is considered. A control and modulation structure based on Model Predictive Control (MPC) is depicted. The scheme inherently controls the DC interface voltages while likewise giving the capacity to alter any of those voltages to meet MPPT prerequisites. This maintains a strategic distance from the cost and included unpredictability of additional DC/DC converters that are normally required to keep the DC connect voltages uniform. Simulation and experimental results are introduced that affirm the right operation of the proposed approach.

Y. Xu, L. M. Tolbert, J. N. Chiasson, F. Z. Peng, and J. B. Campbell, [4] have dissected the various techniques for most extreme power point following of photovoltaic (PV) clusters are examined. The techniques are taken from the writing going back to the most punctual methods. It is shown that no less than 19 unmistakable methods have been presented in the writing, with numerous minor departure from execution. This paper should fill in as a helpful reference for future work in PV power generation.

II. SUSTAINABLE POWER SOURCES

In this thesis, a breeze PV hybrid power generation system model is studied and reproduced. A hybrid system is more good as individual power generation isn't absolutely dependable. When any of the system is shutdown the other can supply power. A square graph of whole hybrid system is shown underneath.
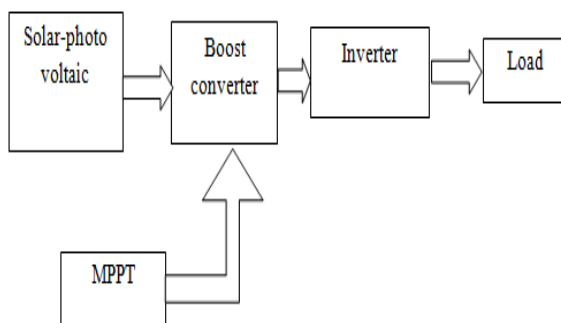

Fig 1: Block diagram of hybrid system

The whole hybrid system contains PV and the breeze systems. The PV system is powered by the sun based vitality which is copiously accessible in nature. PV

modules, most extreme power point following systems make the PV vitality system. The light episode on the PV cells is changed into electrical vitality by photovoltaic vitality harvesting implies. The MPPT system with P&O algorithm is used, which tracks the maximal conceivable power from the photo-voltaic modules. The air conditioner dc converter is used to change over air conditioning voltage to dc. Wind turbine, equip box and generator are joined into the breeze vitality system. The breeze turbine changes over breeze vitality into rotational mechanical vitality and this mechanical vitality open at the turbine shaft is changed over to electrical vitality using a generator.

III. CONFIGURATIONS OF PV SYSTEMS

The deliberate cascaded H-bridge multilevel inverter, which requires a detached dc source for each H-bridge, is one dc/aerating and cooling cascaded inverter topology. The diverse dc associates in the multilevel inverter impact self-governing voltage to control possible. Thus, individual MPPT control in each PV module can be achieved, and the essentialness harvested from PV sheets can be helped. Meanwhile, the deliberate quality and negligible exertion of multilevel converters would position them as a prime contender for the best in class age of profitable, vigorous, and strong network related sun situated power devices. A deliberate cascaded H-bridge multilevel inverter topology for single-or three-phase matrix related PV systems is presented in this paper. The board mismatch issues are steered to show the need of individual MPPT control, and a control scheme with appropriated MPPT control is then proposed. The Passed on MPPT control scheme can be associated with both single and three-phase systems. What's more, for the showed three-phase system related PV system, if each PV module is worked at its own specific MPP, PV mismatches may familiarize unequal power provided with the three-phase multilevel inverter, inciting uneven injected matrix current. To change the three-phase network current, modulation compensation is moreover added to the control system. A three-phase segregated cascaded multilevel inverter model has been gathered. Each H-bridge is related with a 185-W sun powered board. The deliberate arrangement will extend the flexibility of the system and diminish the cost moreover. Simulation and experimental results are given to exhibit the made control scheme.
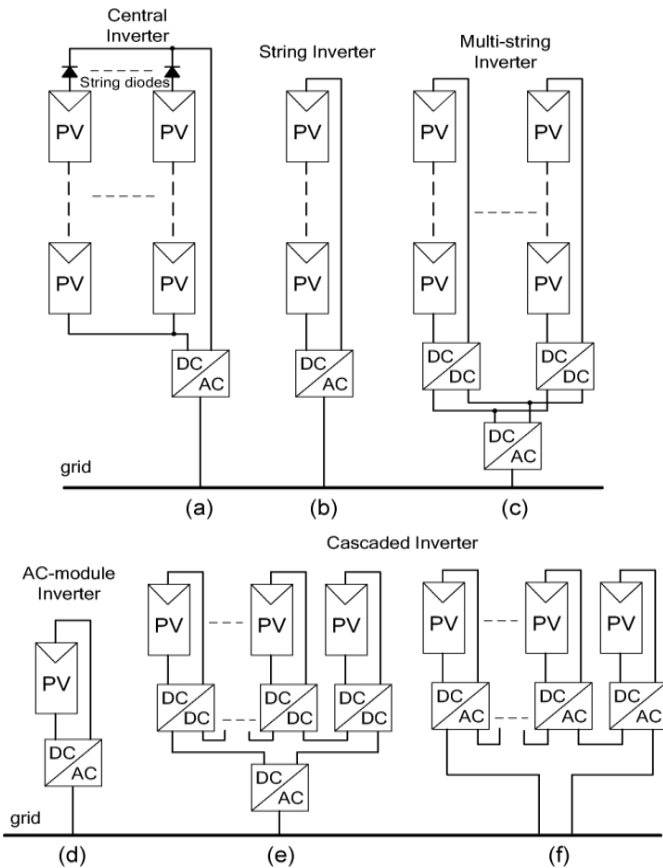
Fig.2. Configurations of PV systems.
(a) Central inverter.   (b) String inverter. (c)Multistring inverter. (d) AC-module inverter.   (e) Cascaded dc/dc converter.(f) Cascaded dc/ac inverter.

CASCADED H-BRIDGES INVERTER

A single-phase structure of a m-level cascaded inverter is sketched out in Fig. 3. Each extraordinary dc source (SDCS) is related with a single-phase full-bridge, or H-bridge, inverter. Each inverter level can generate three different voltage outputs, +Vdc, 0, and – Vdc by interfacing the dc source to the ventilation system output by different blends of the four switches, S1, S2, S3, and S4. To obtain +Vdc, switches S1 and S4 are turned on, whereas – Vdc can be gotten by turning on switches S2 and S3. By turning on S1 and S2 or S3 and S4, the output voltage is 0. The aeration and cooling system outputs of each of the assorted full-bridge inverter levels are related in game plan such that the synthesized voltage waveform is the aggregate of the inverter outputs. The amount of output phase voltage levels m in a course inverter is characterized by m = 2s+1, where s is the amount of separated dc sources. A case phase voltage waveform for a 11-level cascaded H-bridge inverter with 5 SDCSs and 5 full bridges is shown in Fig 3. The phase voltage van = va1 + va2 + va3 + va4 + va5. For a stepped waveform such as the one portrayed in Fig 3 with s steps, the Fourier Transform for this waveform takes after
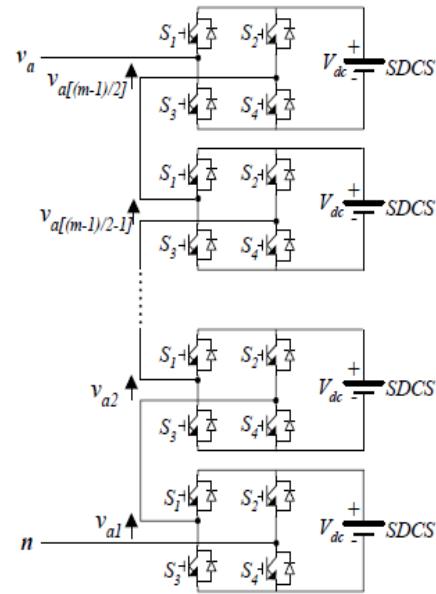

Fig.3. Single-phase structure of a multilevel cascaded H-bridges inverter

IV. PROPOSED METHOD

The measured cascaded H-bridge multilevel inverter, which requires a disengaged dc source for each H-bridge, is one dc/air conditioning cascaded inverter topology. The different dc interfaces in the multilevel inverter influence free voltage to control conceivable. Subsequently, individual MPPT control in each PV module can be achieved, and the vitality harvested from PV boards can be amplified. Meanwhile, the measured quality and minimal effort of multilevel converters would position them as a prime contender for the up and coming generation of effective, robust, and solid grid associated sun oriented power gadgets. A measured cascaded H-bridge multilevel inverter topology for single-or three-phase grid-associated PV systems is exhibited in this paper. The board mismatch issues are routed to show the need of individual MPPT control, and a control scheme with disseminated MPPT control is then proposed. The conveyed MPPT control scheme can be connected to both single and three-phase systems.

Also, for the exhibited three-phase grid-associated PV system, if each PV module is worked at its own particular MPP, PV mismatches may acquaint lopsided power supplied with the three-phase multilevel inverter, prompting uneven infused grid current. To adjust the three-phase grid current, modulation pay is additionally added to the control system. A three-phase particular cascaded multilevel inverter model has been assembled. Each H-bridge is associated with a 185-W sun based board. The measured outline will expand the adaptability of the system and lessen the cost also. Simulation and

experimental results are given to show the created control scheme.

SYSTEM DESCRIPTION

Measured cascaded H-bridge multilevel inverters for single and three-phase grid-associated PV systems. Each phase comprises of n H-bridge converters associated in arrangement, and the dc connection of each H-bridge can be encouraged by a PV board or a short string of PV boards. The cascaded multilevel inverter is associated with the grid through L filters, which are utilized to diminish the switching harmonics in the current. By various blends of the four switches in each H-bridge module, three output voltage levels can be generated: −v dc, 0, or +v dc. A cascaded multilevel inverter with n input sources will give 2n + 1 levels to synthesize the air conditioner output waveform. This (2n + 1)- level voltage waveform empowers the reduction of harmonics in the synthesized current, diminishing the extent of the required output filters. Multilevel inverters likewise have other favourable circumstances such as diminished voltage stresses on the semiconductor switches and having higher effectiveness when contrasted with other converter topologies.
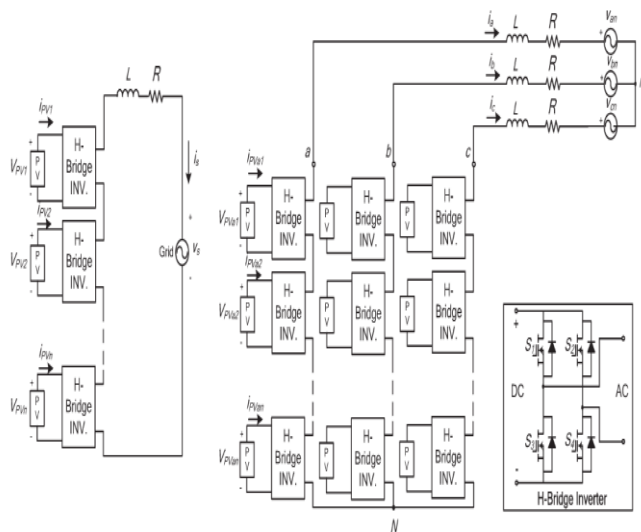

Fig.4. Topology of the modular cascaded H-bridge multilevel inverter for grid-connected PV systems.

PANEL MISMATCHES:

PV mismatch is a basic issue in the PV system. In view of the unequal got irradiance, particular temperatures, and developing of the PV sheets, the MPP of each PV module might be uncommon. If each PV module isn't controlled independently, the viability of the general PV system will be diminished. To show the need of individual MPPT control, a five-level two-H-bridge single-phase inverter is recreated in MATLAB/SIMULINK. Each H-bridge has its own specific 185-W PV board related as a detached dc source. The PV board is modeled by the particular of the business PV board from Astronergy CHSM-5612M. Consider a working condition that each board has an

alternate illumination from the sun; board 1 has irradiance S = 1000 W/m2, and board 2 has S = 600 W/m2. On the off chance that lone board 1 is followed and its MPPT controller decides the normal voltage of the two boards, the power separated from board 1 would be 133 W, and the power from board 2 would be 70 W, as can be seen in Fig.4.2. Without individual MPPT control, the aggregate power harvested from the PV system is 203 W. However, Fig. 4.3 shows the MPPs of the PV boards under the distinctive irradiance. The greatest output power esteems will be 185 and 108.5 W when the S esteems are 1000 and 600 W/m2, separately, which implies that the aggregate power harvested from the PV system would be 293.5 W if individual MPPT can be achieved. This higher esteem is around 1.45 times of the one preceding. Thus, individual MPPT control in each PV module is required to grow the profitability of the PV system. In a three-phase lattice related PV system, a PV mismatch may cause more issues.
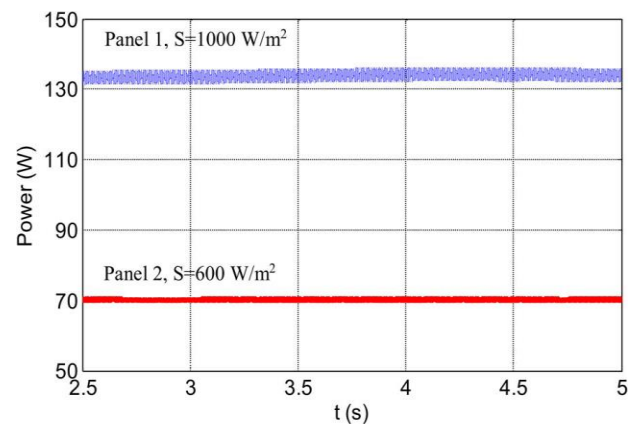

Fig. 5. Power separated from two PV boards.

Beside diminishing the general proficiency, this could even acquaint unequal power supplied with the three-phase grid-associated system. On the off chance that there are PV mismatches between phases, the input power of each phase would be unique. Since the grid voltage is adjusted, this distinction in input power will make uneven current the grid, which isn't permitted by grid norms. For instance, to unbalance the current per phase over 10% isn't took into consideration a few utilities, where the rate awkwardness is computed by taking the most extreme deviation from the normal current and partitioning it by the normal current

To comprehend the PV mismatch issue, a control scheme with individual MPPT control and modulation pay is proposed. The subtle elements of the control scheme will be examined in the following area.
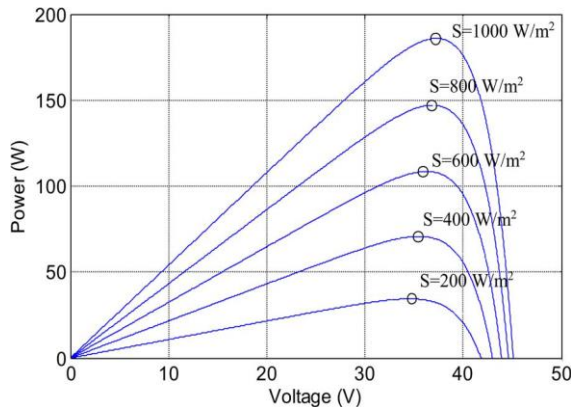
Fig. 6. P–V characteristic under the different irradiance.

CONTROL SCHEME:

A. Dispersed MPPT Control:

Keeping in mind the end goal to dispense with the antagonistic impact of the mismatches and increment the proficiency of the PV system, the PV modules need to work at various voltages to enhance the use per PV module.
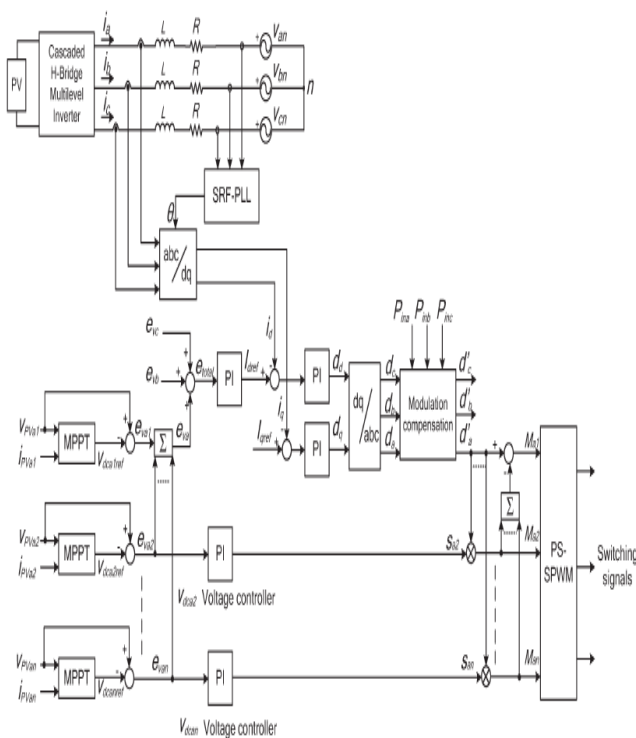

Fig.7. Control scheme for three-phase particular cascaded H-bridge multilevel PV inverter.

The diverse dc interfaces in the cascaded H-bridge multilevel inverter impact independent voltage to control possible. To recognize individual MPPT control in each PV module, the control scheme proposed in is refreshed for this application.

The spread MPPT control of the three-phase cascaded H-bridge inverter is shown in Fig.4.4. In each H-bridge module, a MPPT controller is added to generate the dc-associate voltage reference. Each dc-interface voltage is appeared differently in relation to the contrasting voltage reference, and the total of all missteps is controlled through a total voltage controller that chooses the current reference Idref . The responsive current reference Iqref can be setto zero, or if open power compensation is required, Iqref can similarly be given by a responsive current analyst. The synchronous reference plot phase-catapulted circle (PLL) has been used to find the phase edge of the matrix voltage. As the colossal control scheme in three-phase systems, the matrix currents in abc composes are changed over to dq encourages and oversaw through proportional– imperative (PI) controllers to generate the modulation document in the dq organizes, which is then changed over back to three phases.

The appropriated MPPT control scheme for the single-phase system is almost the same. The aggregate voltage controller gives the extent of the dynamic current reference, and a PLL gives the frequency and phase edge of the dynamic current reference. The current circle then gives the modulation file.

To influence each To pv module work at its own particular MPP, take phase a for instance; the voltages vdca2 to vdc an are controlled exclusively through n − 1 circles. Each voltage controller gives the modulation record extent of one H-bridge module in phase a. After multiplied by the modulation list of phase a, n − 1 modulation files can be acquired. Likewise, the modulation record for the principal H-bridge can be acquired by subtraction. The control schemes in phases b and c are nearly the same. The main contrast is that all dc-interface voltages are directed through PI controllers, and n modulation list extents are gotten for each phase.

A phase-shifted sinusoidal pulse width modulation switching scheme is then connected to control the switching devices of each H-bridge. It can be seen that there is one H-bridge module out of N modules whose modulation record is acquired by subtraction. For single-phase systems, N = n, and for three-phase systems, N = 3n, where n is the quantity of H-bridge modules per phase. The reason is that N voltage circles are important to oversee distinctive voltage levels on N H-bridges, and one is the aggregate voltage circle, which gives the current reference. In this way, just N − 1 modulation lists can be dictated by the keep going N − 1 voltage circles, and one modulation record has to be gotten by subtraction. Numerous MPPT methods have been produced and executed. The incremental conductance method has been utilized as a part of this paper. It loans itself well to advanced control, which can undoubtedly monitor past estimations of voltage and current and settle on all choices.

B. Modulation Compensation

As specified before, a PV mismatch may make more issues a three-phase particular cascaded H-bridge multilevel PV inverter. With the individual MPPT control in each H-bridge module, the input sun based power of each phase would be unique, which acquaints lopsided current with the grid. To fathom the issue, a zero arrangement voltage can be forced upon the phase legs keeping in mind the end goal to influence the current streaming into each phase.
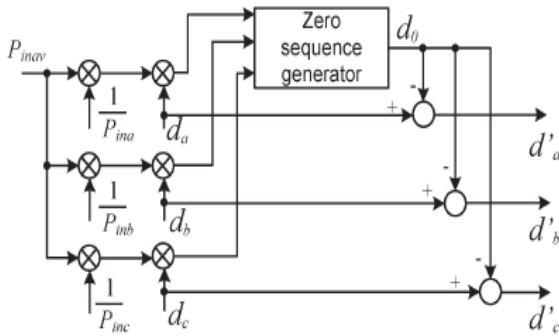

Fig. 8. Modulation compensation scheme.

On the off chance that the refreshed inverter output phase voltage is relative to the uneven power, the current will be adjusted. Thus, the modulation remuneration hinder, as shown in Fig. 4.5, is added to the control arrangement of three-phase measured cascaded multilevel PV inverters. The key is how to refresh the modulation file of each phase without expanding the Fig. 6. Modulation remuneration scheme. many-sided quality of the control system. In the first place, the lopsided power is weighted by proportion rj , which is computed as

rj = Pinav/Pinj - (1)

where Pinj is the info power of phase (j = a, b, c),and Pinav is the average input power.

Then, the injected zero sequence modulation index can be generated as
d0=1/2[min(ra · da, rb · db, rc · dc)+ max(ra · da, rb

 · db, rc · dc)]---------(2)

where dj is the modulation index of phase j (j = a, b, c) and is determined by the current loop controller.
The modulation index of each phase is updated by

d'j = dj − d0 ---------(3)

Only simple calculations are needed in the scheme, which will not increase the complexity of the control system. An example is presented to show the modulation compensation scheme more clearly. Expect that the info power of each phase is unequal

Pina = 0.8 Pinb = 1 Pinc = 1. (4)

By infusing a zero grouping modulation record at t = 1 s, the adjusted modulation file will be refreshed, as shown in Fig. 7. It can be seen that, with the remuneration, the refreshed modulation record is uneven relative to the power, which implies that the output voltage (vjN) of the three-phase inverter is unequal, yet this delivers the coveted adjusted network current.

V. Simulation AND EXPERIMENTAL RESULTS:

Simulation and experimental tests are completed to approve the proposed thoughts. A measured cascaded multilevel inverter model has been worked in the research center. The MOSFET IRFSL4127 is chosen as inverter switches working at 1.5 kHz. The control signs to the H-bridge inverters are sent by a dSPACE ds1103 controller.

A three-phase seven-level cascaded H-bridge inverter is reenacted and tried. Each H-bridge has its own 185-W PV board (Astronergy CHSM-5612M) related as a free source. The inverter is related with the system through a transformer, and the phase voltage of the discretionary side is 60 Vrms. The system parameters are shown in Table I.

A. Simulation Results:

To check the proposed control scheme, the three-phase grid associated PV inverter is reproduced in two unique conditions. To start with, all PV boards are worked under a similar irradiance S = 1000 W/m2 and temperature T = 25 ∘C. At t = 0.8 s, the sunlight based irradiance on the first and second boards of phase an abatements to 600 W/m2, and that for the other boards remains the same. The dc-interface voltages of phase an are shown in Fig. 8. Around the beginning, all PV sheets are worked at a MPP voltage of 36.4 V. As the irradiance changes, the first and second dc-Fig. 8. DC-interface voltages of phase a with dispersed MPPT (T = 25 ∘C). (a) DC-associate voltage of modules 1 and 2. (b) DC-interface voltage of module 3.Fig. 9. PV currents of phase a with passed on MPPT (T = 25 ∘C).link voltages reduction and track the new MPP voltage of 36 V, while the third board is still worked at 36.4 V. The PV current waveforms of phase an are shown in Fig. 9. After t = 0.8 s, the currents of the first and second PV sheets are much smaller due to the low irradiance, and the lower swell of the dc-interface voltage can be found in Fig. 9(a).
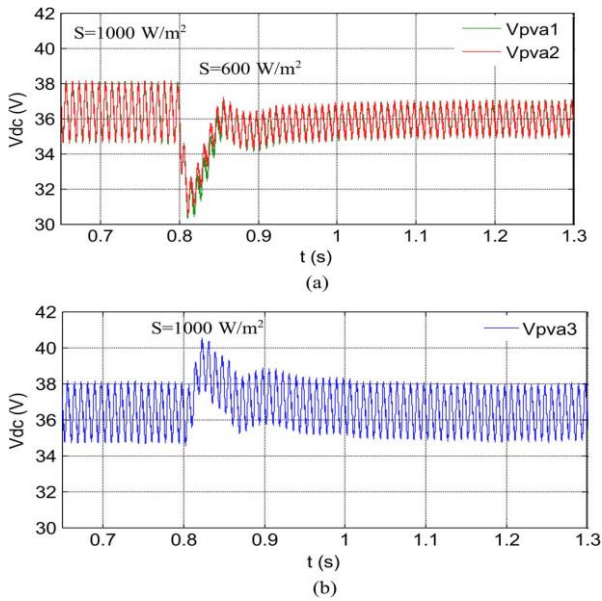
Fig. 9. DC-link voltages of phase *a* with distributed MPPT (T = 25 ∘C). (a)   DC-link voltage of modules 1 and 2. (b) DC-link voltage of module 3.

The dc-associate voltages of phase b are shown in Fig. 10. All phase-b sheets track the MPP voltage of 36.4 V, which shows that they are not affected by other phases. With the coursed MPPT control, the dc-interface voltage of each H-bridge can be controlled independently. In other words, the related PV leading body of each H-bridge can be worked at its own MPP voltage and won't be affected by the sheets related with other H-bridges. Thus, more sun based essentialness can be removed, and the profitability of the general PV system will be extended.
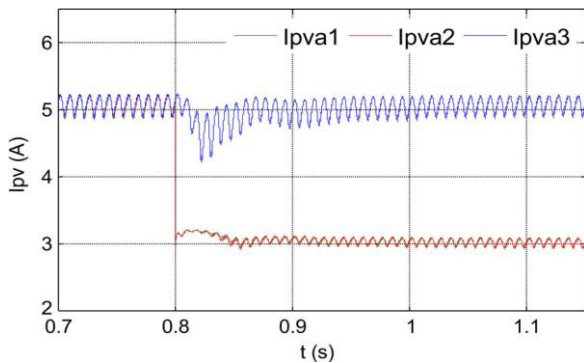

Fig. 10. PV currents of phase *a* with distributed MPPT (T = 25 ∘C).

Fig. 11 shows the power removed from each phase. At the beginning, all sheets are worked under irradiance S = 1000 W/m2, and each phase is creating a most outrageous power of 555 W. After t = 0.8 s, the power harvested from phase a decreases to 400 W, and those from the other two phases continue as before. Unmistakably, the power provided to the three-phase system related inverter is uneven. However, by applying the modulation pay scheme, the power injected to the lattice is up 'til now balanced, as shown in Fig. 12
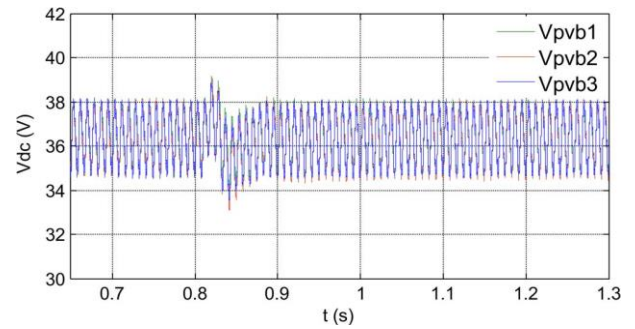

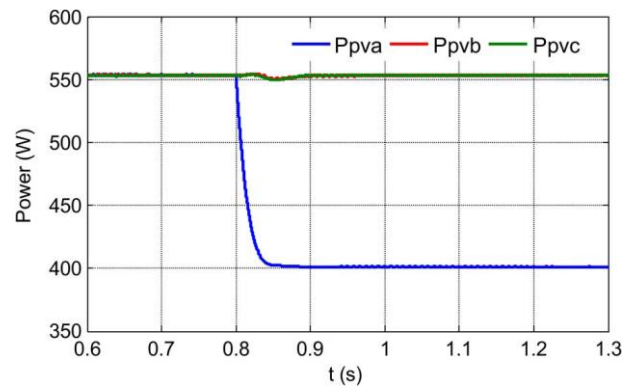Fig. 11. DC-link voltages of phase *b* with distributed MPPT (T = 25 ∘C).

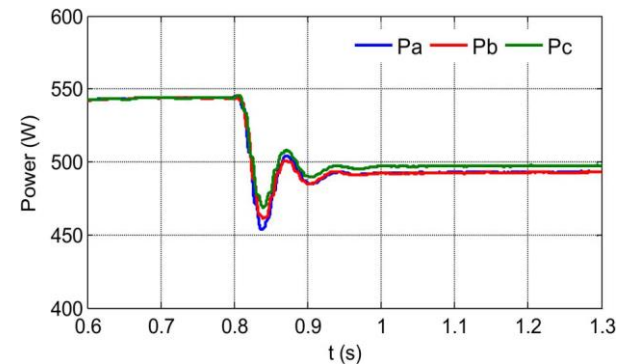Fig. 12. Power extracted from PV panels with distributed MPPT.

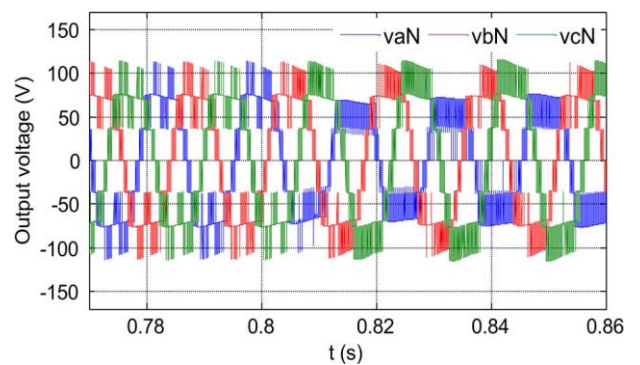Fig. 13. Power injected to the grid with modulation compensation.

Fig. 14. Three-phase inverter output voltage waveforms with modulation compensation.

In addition, by comparing the total power extracted from the PV panels with the total power injected to the grid, it can be seen that there is no extra power loss caused by the modulation compensation scheme. Fig. 13 shows the output voltages (vjN) of the three-phase inverter. Due to the injected zero sequence component, they are unbalanced after t = 0.8 s, which help to balance the grid current.
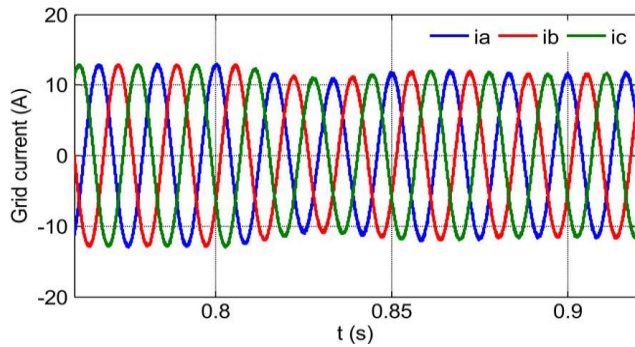

Fig. 15. Three-phase grid current waveforms with modulation compensation.

VI. CONCLUSION

In this paper, a specific cascaded H-bridge multilevel inverter for system related PV applications has been exhibited. The multilevel inverter topology will help to enhance the utilization of related PV modules if the voltages of the diverse dc joins are controlled self-rulingly. Thus, a passed on MPPT control scheme for both single- and three-phase PV systems has been associated with fabricate the general efficiency of PV systems. For the three-phase lattice related PV system, PV mismatches may display uneven provided power, achieving unequal implanted matrix current. A modulation compensation scheme, which won't extend the unconventionality of the control system or cause extra power misfortune, is added to modify the network current.

A specific three-phase seven-level cascaded H-bridge inverter has been worked in the research focus and attempted with PV sheets under different fragmented shading conditions. With the proposed control scheme, each PV module can be worked at its own specific MPP to increase the sunlight based imperativeness extraction, and the three-phase lattice current is balanced even with the unequal provided sun arranged power.

REFERENCES

[1] M. Calais, J. Myrzik, T. Spooner, and V. G. Agelidis, "Inverter for single phase grid connected

[2] J.M. A.Myrzik and M. Calais, "String and module integrated inverters for single-phase grid connected photovoltaic systems—A review," in Proc.IEEE Bologna Power Tech Conf., 2003, vol. 2, pp. 1–8.

[3] F. Schimpf and L. Norum, "Grid connected converters for photovoltaic, state of the art, ideas for improvement of transformer less inverters," in Proc. NORPIE, Espoo, Finland, Jun. 2008, pp. 1–6.

[4] B. Liu, S. Duan, and T. Cai, "Photovoltaic DC-building-module-based BIPV system—Concept and design considerations," IEEE Trans. Power Electron., vol. 26, no. 5, pp. 1418–1429, May 2011.

[5] L. M. Tolbert and F. Z. Peng, "Multilevel converters as a utility interface for renewable energy systems," in Proc. IEEE Power Eng. Soc. Summer Meet., Seattle, WA, USA, Jul. 2000, pp. 1271–1274.

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