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A Novel Method for Reactive Power Management For Grid Connected Cascaded Photovoltaic Systems

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Abstract—Cascaded multilevel converter structure can be appealing for high-power solar photovoltaic (PV) systems thanks to its modularity, scalability, and distributed maximum power point tracking (MPPT). However, the power mismatch from cascaded individual PV converter modules can bring in voltage and system operation issues. This paper addresses these issues, explores the effects of reactive power compensation and optimization on system reliability and power quality, and proposes coordinated active and reactive power distribution to mitigate this issue. A vector method is first developed to illustrate the principle of power distribution. Accordingly, the relationship between power and voltage is analyzed with a wide operation range. Then, an optimized reactive power compensation algorithm (RPCA) is proposed to improve the system operation stability and reliability, and facilitate MPPT implementation for each converter module simultaneously.Furthermore, a comprehensive control system with the RPCA is designed to achieve effective power distribution and dynamic voltage regulation. Simulation and experimental results are presented to demonstrate the effectiveness of the proposed reactive power compensation approach in grid-interactive cascaded PV systems.

Index Terms—Cascaded photovoltaic (PV) system, power-voltage distribution, reactive power compensation, unsymmetrical active power.

I.INTRODUCTION

World Wide renewable energy resources, especially solar energy, are growing dramatically in view of energy shortage and environmental concerns. Large-scale solar photovoltaic (PV) systems are typically connected to medium voltage distribution grids, where power converters are required to convert solar energy into electricity in such a grid-interactive Reactive power refers to the circulating power within utility grids that does no useful work. It results from energy storage elements in the utility grid, mainly transformers, transmissions lines, and motors that generate lagging power factor (consume reactive power). It has a strong effect on system voltages and must be maintained in balance in order to prevent voltage problems. Significant capacitance is employed to offset the reactive loads and line voltages must be raised to push power through the lines. The greater the distance from the transmission of power to consumption, the higher the voltage needs to be raised. The reactive power is generated or consumed in every component of the system generation, transmission and distribution and eventually by loads. To achieve direct medium-voltage grid access without using bulky medium-voltage transformer, cascaded multilevel converters are attracting more and more attraction due to their unique advantages such as enhanced energy harvesting capability implemented by distributed maximum power point tracking (MPPT), improved energy efficiency, lower cost, higher power density, scalability and modularity, plug-N-power operation, etc. Although cascaded multilevel converters have been successfully introduced in medium- to high-voltage applications such as large motor drives, dynamic voltage restorers, reactive power compensations, and flexible ac transformation system devices and their applications in PV systems still face tough challenges because of solar power variability and the mismatch of maximum power point from each converter module due to manufacturing tolerances, partial shading, dirt, thermal gradients,etc. In a cascaded PV system, the total ac output voltage is synthesized by the output voltage from each converter module in one phase leg, which must fulfill grid codes or requirements. Ideally, each converter module delivers the same active power to grid; hence, symmetrical voltage is distributed among these modules. However, in the event of active power mismatch from these modules, the converter module with higher active power generation will carry more proportion of the whole ac output voltage, which may result in overmodulation if the system is not oversized design. In serious scenario, the synthesized output voltage may not be enough to meet the system requirement. As a result, the active power mismatch may not only result in losses in energy harvesting but also system instability and unreliability due to the inadequate output voltage or overmodulation issues. Motivations are toward addressing the aforementioned issues and approaching to mitigate the negative effect of active power mismatch.MPPT is achieved for each module in these approaches to enhance energy harvesting. However, only unity powerfactor

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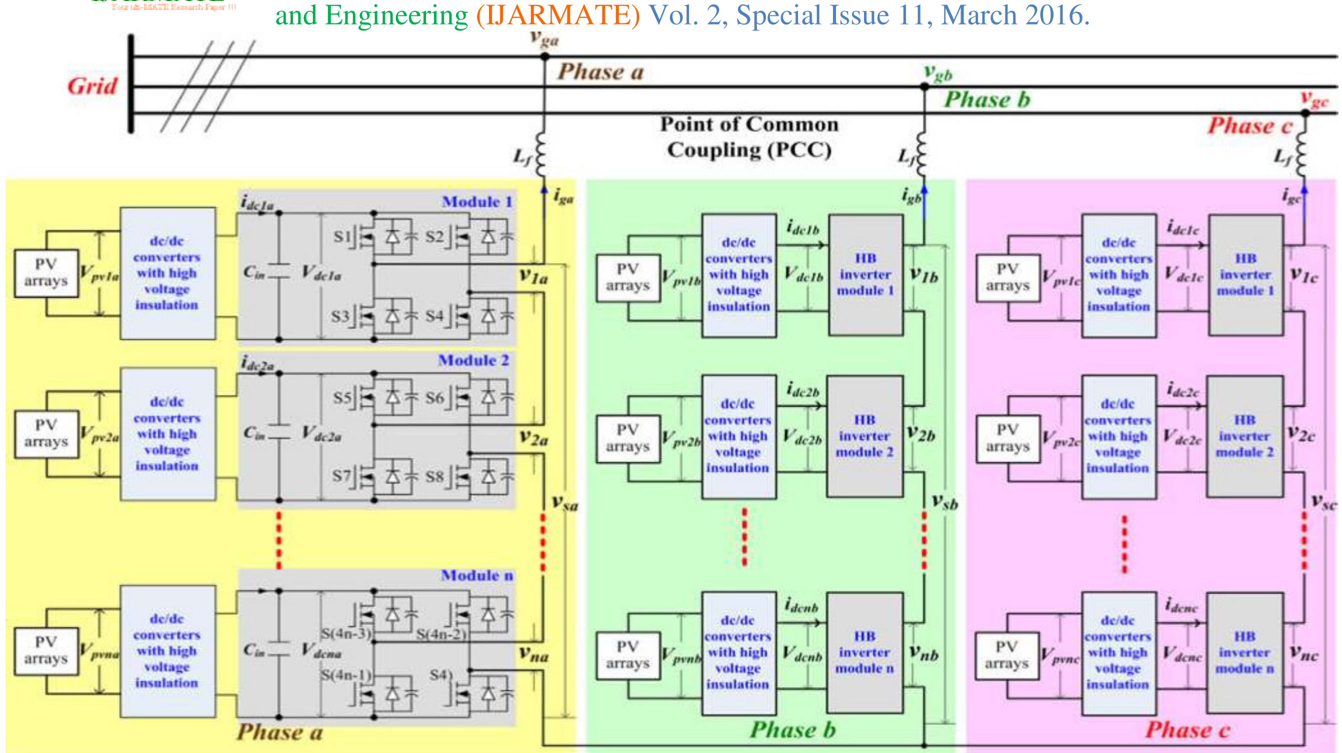

Fig. 1. Grid-interactive PV system with cascaded PV converters

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control was considered and the inherent reactive power compensation capability of the cascaded PV system is ignored. As a result, the PV system still surfers from the degraded power quality and system reliability. It is recognized that reactive power compensation is able to provide strong voltage support in a wide range. Proper reactive power compensation can significantly improve the system reliability, and in the meantime help the MPPT implementation for the cascaded module under unsymmetrical condition as well as comply with the system voltage requirement simultaneously. All of these have spurred growing interest in reactive power compensation for the cascaded PV system. A reactive power compensation strategy is integrated in the control system of the cascaded PV system . However, this approach fails to consider the effect of voltage or current distortion caused by unsymmetrical active power on the power detection and distribution, and the converter module with high active power generation is not required to provide reactive power, which has limited the capability of reactive power compensation. Therefore, optimized solutions have yet to be found and it is very critical to develop an effective reactive power compensation strategy for the grid interactive cascaded PV system.

This paper proposes an optimized reactive power compensation method and evaluates the effect of reactive power compensation on system reliability and power quality in the grid-interactive PV system with cascaded converter modules. A proper reactive power compensation and distribution is considered to eliminate the overmodulation caused by unsymmetrical active power. In the proper reactive power management, one first emphasizes that the output voltage from the cascaded PV system must to meet the grid code. The maximum reactive power Compensation will be activated to mitigate this issue once active power mismatch occurs and voltage and current distortion are detected. In this way, correct active and reactive power can be calculated, and MPPT for each module can be achieved and grid code can be met simultaneously. However, overcompensation of reactive power may be provided, which increases the system burden. Therefore, reactive power compensation among modules is optimized and redistributed considering their respective active power contribution on the premise that MPPT can be achieved and grid code is fulfilled. As a result, the system reliability will be enhanced. The rest of this paper is organized as follows. In Section II, the cascaded PV system configuration is presented and a vector diagram is first derived to help illustrate the principle of active and reactive power distribution between each module. Correspondingly, the relationship between power and output voltage for each module is analyzed under different conditions. A reactive power

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compensation algorithm (RPCA), which is inherently suitable for different types of cascaded PV system, is developed in Section III to improve system operation performance in view of point of common coupling (PCC) voltage range and MPPT implementation. Accordingly, a control system with the proposed RPCA is designed to achieve dynamic voltage regulation and optimized power distribution. The proposed reactive power compensation method is implemented in the MATLAB/ Simulink and PSIM co simulation platform and a 10 kVA grid-interactive laboratory prototype. Simulation and experimental results at 2 kVA are given to confirm the validity of the proposed reactive power compensation method in Sections IV and V, respectively, followed by conclusion in Section VI.

II. SYSTEM CONFIGURATION AND POWER-VOLTAGE DISTRIBUTION:

A. System Configuration

Fig. 1 describes the system configuration of one two-stage grid-interactive PV system with n cascaded converter modules for each phase, which is very suitable for the medium/high voltage application. It can be immune to the leakage current and PV potential induced degradation issues. In this paper, threephase PV converters are connected in "wye" configuration. They also can be connected in "delta" configuration. In the two-stage PV system, the first-stage dc/dc converters with high voltage insulation can achieve the voltage boost and MPPT for the segmented PV arrays. The second stage three-level H-bridge converter modules are cascaded to augment the output voltage, deliver active power to grid, and provide reactive power compensation. The dc-link voltage can be controlled to be constant and the same in each converter module. For the low voltage application, single-stage system configuration can be considered, where the dc/dc converters in Fig. 1 can be replaced by Quasi-Z-Source network or be removed according to system requirement.

The single-stage PV system features simple configuration and fewer devices integration in each module. However, additional methods need be developed to solve the leakage current issues.

In addition, the system may need to be oversized to accommodate the wide input voltage variation. In these configurations, unsymmetrical active power may be harvested from the cascaded modules due to PV module mismatch, orientation mismatch, partial shading, etc. In this case, improper power distribution and control are prone to an intrinsic instability problem if MPPT is still desired, which results in a limited operation range for the system. Moreover, it may also seriously deteriorate the system reliability and power quality. Particularly, appropriate reactive power compensation is very helpful to improve the operation of the cascaded PV system. Considering active power is produced by PV arrays and reactive power injection or absorption is regardless of PV arrays, one expects an independent active and reactive power control for each module. By this way, effect of reactive power compensation on system reliability and power quality can be investigated. In this paper, efforts are focused on the intelligent reactive power compensation method and optimized reactive power distribution from each module.

B. Power and Voltage Distribution Analysis

In the cascaded PV system, the same ac grid current flows through the ac side of each converter module. Therefore, the output voltage distribution of each module will determine the active and reactive power distribution. In order to clarify the power distribution, four modules are selected in the cascaded PV converters in each phase as an example. Vector diagrams are derived to demonstrate the principle of power distribution between the cascaded converter modules in phase a. The same analysis can be extended to phases b and c. It means that active and reactive power will be independently controlled in each phase. Therefore, a discrete Fourier transform phase locked loop (PLL) method is adopted in this paper, which is only based on single-phase grid voltage orientation and can extract fundamental phase, frequency, and amplitude information from any signal [8]. Considering that the PCC voltage is relatively stable, v_{ga} is first used as the PLL synchronous signal of the cascaded PV system as shown in Fig. 2(a). v_{ga} is transformed into αβ stationary reference frame quantities $v_{ga\alpha}$ and $v_{ga\beta}$ which is the virtual voltage with π/2 phase shift to $v_{ga\alpha}$. They are converted to v_{gad} and v_{gaq} in the dq synchronous reference frame, where v_{ga} is aligned with the d-axis by PLL control [8]. Ideally, v_{gad} is equal to the magnitude of PCC voltage V_{ga} and v_{gaq} is zero. Once the phase-shift angle θ_{iga} between v_{ga} and grid current i_{ga} is detected, the new d_q_ synchronous reference frame can be defined. In this frame, i_{ga} is aligned with the d_-axis. Therefore, the d_-axis component $v_{sad\_}$ of the whole PV system output voltage v_{sa} directly decides the active power injection. The contribution of each module output voltage on q_-axis component $v_{saq\_}$ is closely related to the reactive power compensation. Fig. 2(b) illustrates voltage distribution of four cascaded converter modules under unsymmetrical active power generation in phase a. The output voltage of the total converter V_{sa} is synthesized by the four converter module output voltage with different amplitude and angles. The voltage components of each module in d_q_ frame, $v_{jad\_}$ and $v_{jaq\_}$ (j = 1, 2, . . . , 4), can be independently controlled to implement the decoupled

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active and reactive power control. Because of the same grid current through each convert module, the distributed d_-axis and q_-axis voltage components in d_q_ frame determine the active and reactive power distribution in these converter modules, respectively. The $v_{1a\,d\_} > v_{2a\,d\_} > v_{3a\,d\_} > v_{4a\,d\_}$ indicates that module 1 generates the maximum active power and module 4 generates the minimum active power. The $v_{1a\,q\_} = v_{2a\,q\_} = v_{3a\,q\_} = v_{4a\,q\_}$ reveals that the same reactive power is provided by these modules. The previous analysis further clarified the relationship between the previous voltage components and power distribution.

III. PROPOSED REACTIVE POWER COMPENSATION METHOD

A. RPCA

As aforementioned, appropriate reactive power compensation will enhance the cascaded PV system reliability and improve power quality, especially for unsymmetrical active power generation. Fig. 9 shows the proposed RPCA for the cascaded PV system in phase a. The same algorithm can be used in phases b and c. The reactive power compensation requirement Q^*_{ga} is associated with modulation index of output voltage from cascaded PV converter modules, PCC voltage, and MPPT control implementation which will determine the active power reference P^*_{ga}. In the initial state, MPPT control for each PV converter module is enabled and unity power factor is implemented considering symmetrical operation condition acts on these cascaded modules. In this scenario, Q^*_{ga} is zero and P^*_{ga} is derived from the sum of maximum active power from the individual PV arrays_n j=1 P_{pvja} subtracting power loss, which is defined as $k_1 P_{ga\ rated}$. Considering the known $P_{ga\ rated}$, k_1 can be calculated as $P^*_{ga}/P_{ga\ rated}$. It is determined by the MPPT control and dc voltage control, whichwill be introduced in Section III-B. During the system operation, unsymmetrical active power may be generated from these modules due to PV module mismatch, orientation mismatch, partial shading, etc. As a result, overmodulation may occur on the PV converters output voltage,especially for the converter module with higher active power output, which seriously impairs the MPPT of each module and system reliability. Once the overmodulation is identified, the intentional reactive power compensation is activated to mitigate the overmodulation with grid code authorization. If PCC voltage is high, maximum reactive power will be absorbed from grid to bring down the PCC voltage with the normal voltage range according to the IEEE Std. 1547, as well help possible MPPT implementation for each converter module

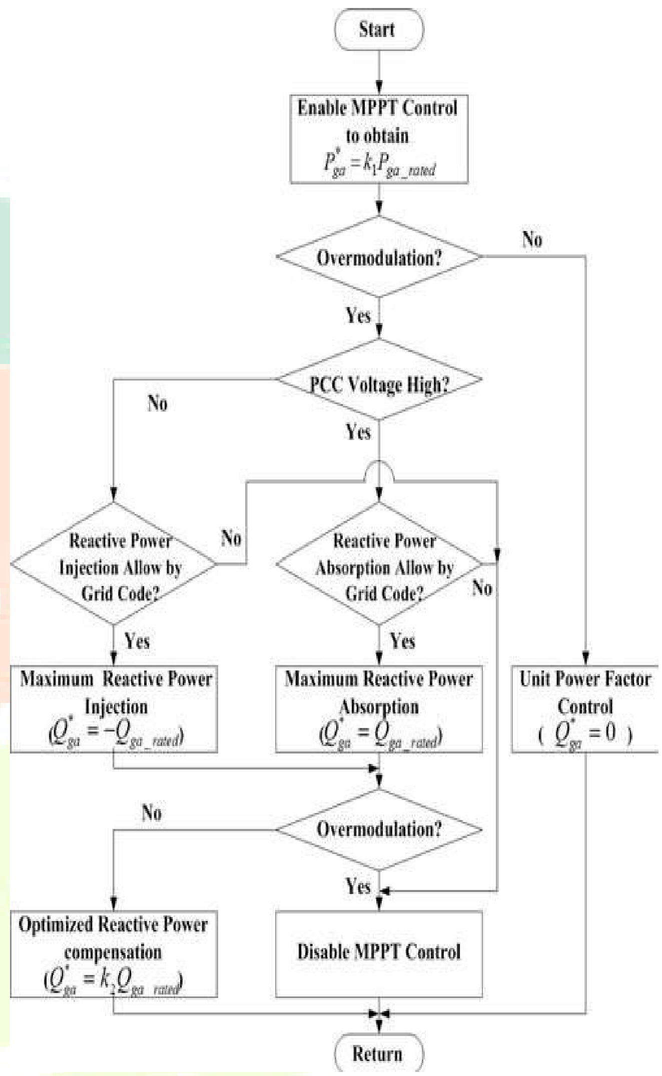

Fig.2. Flowchart of the proposed RPCA.

simultaneously. $k_2 = 1$ is designated to achieve the maximum reactive power absorption. The PV system operates like an inductor. Otherwise, the maximum reactive power is injected into grid to provide the PCC voltage support. $k_2 = -1$ is designated to execute the maximum reactive power injection. The PV system operates like a capacitor. If the maximum reactive power compensation still cannot eliminate the overmodulation, MPPT control will be disabled to ensure the security and stability of the cascaded PV system. Instead, reactive power compensation can be optimized, that is the selection of k_2, to reduce the risk of overvoltage or under voltage caused by the maximum reactive power compensation. There are different ways to optimize reactive power distribution in the cascaded PV converter modules In either way, the limited condition.

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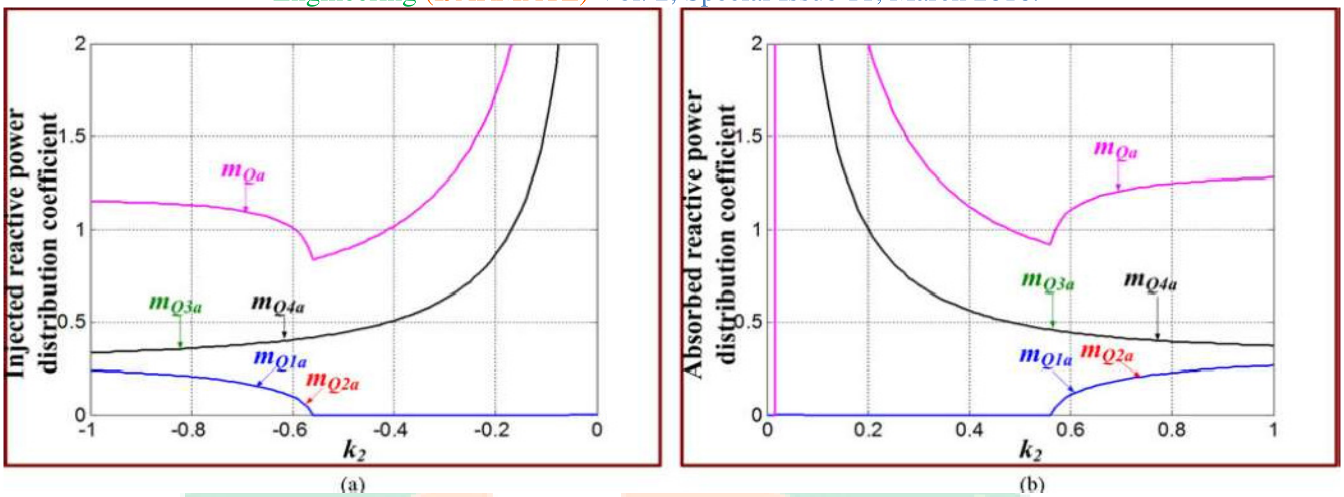

Fig. 3. Voltage distribution among four cascaded converter modules with $k_1 = 0.6$ and k_2 changes. (a) Reactive power injection. (b) Reactive power absorption.

must be satisfied to avoid the overmodulation. It is noted that the selected dc voltage and allowed voltage ripple will also impact on the reactive power compensation optimization. In this paper, the boundary condition is selected to achieve the optimized reactive power distribution, which can limit the unity modulation voltage output for the converter module with high active power generation, even help to possible equivalent apparent power being extracted from each PV converter module. The selection of k_2 is related to k_1 and the level of unsymmetrical active power, which can be obtained A specific example in Fig will be provided to demonstrate the proposed RPCA in Section II.

B. Control System Design

A cascaded PV control system with the proposed RPCA in phase a is depicted in Fig. 10. The same control system is applied in phases b and c. Particularly, the proposed PRCA can be applied for any type of the cascaded PV system, such as singlestage and two-stage PV system The active and reactive power is regulated in the dq synchronous reference frame. PLL is used to synchronize the output voltage of the cascaded PV converters v_{sa} , grid current i_{ga} with v_{ga} so that the desired power control can be achieved. The RPCA provides the desired reactive power Q^*_{ga} during unsymmetrical active power from the cascaded PV converter modules. The q-axis component command of grid current i^*_{gaq} can be derived from the desired Q^*_{ga} . The maximum active power harvesting from each module can be implemented by MPPT control and dc-link voltage control. In the one-stage cascaded PV system, the dc-link voltage reference V^*_{dc} is obtained by the MPPT control for individual PV arrays. In the two-stage cascaded PV system, V^*_{dc} is designated based on the grid voltage requirement. The V_{dcja} on each PV converter module is controlled to track V^*_{dc} to generate the daxis component command of grid current i^*_{gad} , which will coordinate the MPPT implementation. The decoupled current control loop is developed to implement the current track of i_{gad} and i_{gaq} and generates the d−q components v_{sad} and v_{saq} of v_{sa} in the dq synchronous reference frame. In order to achieve the independent control of active and reactive power from each module, v_{sad} and v_{saq} are converted to $v_{sad\_}$ and $v_{saq\_}$ in the d_q_ synchronous reference frame . The active power from each module P_{pvja} can be obtained from the MPPT control. Therefore, the voltage $v_{jad\_}$ for the jth converter module with respect to the active power is calculated. The $v_{jaq\_}$ related to reactive power can be obtained based on the $v_{jad\_}$ and . Consequently, the output voltage v_{ja} (j = 1, 2, . . . , n) from each converter module can be synthesized. The modulation index of output voltage can be obtained by $m_{ja} = v_{ja} V_{dcja}$. As a result, the active and reactive power can be properly distributed in each converter module, which achieves the MPPT and augments the security and stability of the cascaded PV system operation simultaneously.

IV. SIMULATION RESULTS

In order to explore the performance of grid-interactive cascaded PV system with the proposed reactive power compensation approach, simulations were first conducted in a cosimulation platform of MATLAB/Simulink and PSIM. A 3 MW/12 kV three-phase two-stage cascaded PV system as shown in Fig. 1 is applied in this paper. The system parameters in simulation are summarized. The active and reactive power distribution, grid voltage and current change, voltage distribution among four cascaded PV converter modules with reactive power

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injection and absorption during different scenarios in phase a, respectively. the power distribution with reactive power injection considering the low grid voltage. At the beginning, the MPPT control is enabled and each module harvests maximum power from the segmented PV arrays. At 0.5 s, the active power from four modules P_{1a}−P_{4a}, changes from 50 kW to 250 kW. Active power to grid P_{ga} increases from 200 MW to 1 MW. The grid current magnitude I_{ga} increases from 40 A to 200 A. The system does not need the reactive power compensation because the symmetrical active power can equalize the output voltage from these modules. There is no overmodulation, and grid current and PCC voltage have good quality as shown in Fig. The modulation indices from our modules, m_{1a} − m_{4a}, are within [−1, 1]. At 1 s, different active power is generated from the four modules due to the different irradiation. Modules 1 and 2 keep 250 kW active power output but the active power from modules 3 and 4 reduces to 50 kW, which results in big power fluctuation during transient. Moreover, the overmodulation caused by the unsymmetrical active power seriously distorts the grid current i_g and degrades system operation performance as shown in Fig. The module indices from modules 1 and 2, m_{1a} and m_{2a}, are in the range [−1, 1]. After 1.5 s, 1 MVAR reactive power Q_{ga} is injected to grid, which means that k_2 = −1, and reactive power from four modulesQ_{1a}−Q_{4a} is controlled to the same first. It shows that the dynamic performance of reactive power is poor, which is caused by the distorted grid current and measurement module in PSIM. By the reactive power compensation, the system returns to the steady operation although active power distribution among the four modules is still unsymmetrical. P_{ga} keeps at 600 kW, which means that k_1 = 0.6. Once the system operates in safety and steady status, the maximum active power output from the four modules can be accurately controlled and detected. The dynamic performance of grid current, PCC voltage V_{ga}, and individual dc voltage, V_{dc1a}−V_{dc4a}, can be seen in Fig. It takes 5 cycles to bring the system back to be stable. At 2 s, the reactive power from the four modules is redistributed and optimized to reduce the risk of over voltage. Fig. shows the voltage and current waveforms before and after reactive power compensation optimization. The reactive power injection can improve system reliability but also increase the grid voltage magnitude V_{ga} from 9.7 to 10 kV. In order to limit the voltage rise, the optimized reactive power injection is reduced to −600 kVAR, that is, k_2 = −0.6 which is obtained. In this case, the unsymmetrical reactive power is arranged between the four modules, Q_{1a} = Q_{2a} = −95 kVAR and Q_{3a} = Q_{4a} = −220 kVAR. The filter inductor loss is also provided by the PV system. By the reactive power optimization, V_{ga} decreases from 10 to 9.9 kV; the grid current still has good quality and total harmonic distortion (THD) is less than 5%. The RPCA is verified in this simulation.

The power distribution with reactive power absorption considering the high grid voltage. The same active power as ones in and changes in each stage. At 1.5 s, 1MVAR reactive power Q_{ga}, that is, k_2 = 1, is absorbed from grid to eliminate the overmodulation andQ_{1a}−Q_{4a} is controlled to the same first. P_{ga} keeps at 600 kW, which means that k_1 = 0.6. Once the maximum active power P_{1a}−P_{4a} is accurately captured at new steady system, Q_{1a}−Q_{4a} is rearranged to reduce the risk of under voltage at 2 s. The reactive power absorption can improve system reliability but also lower the grid voltage magnitude V_{ga} from 9.9 to 9.7 kV as depicted .

In order to limit the voltage drop, the total reactive power injection is reduced to 700 kVAR, that is, k_2 = 0.7 which is obtained. In this case, optimized reactive power distribution can be derived based on (6): Q_{1a} = Q_{2a} = 100 kVAR and Q_{3a} = Q_{4a} = 230 kVAR. The filter inductor loss is provided by a grid. By the reactive power optimization, V_{ga} increases from 9.7 to 9.8 kV, good grid current is guaranteed, and THD is less than 5%.

V. EXPERIMENTAL RESULTS

The experiments were conducted in the laboratory to verify the aforementioned theoretical analysis and the proposed reactive power compensation control performance. A two-stage cascaded PV system prototype with two 5 kW converter modules has been developed and the block scheme is shown in Fig. The control algorithm is implemented in DSP + FPGA control platform. The downscaled circuit parameters are listed in Table III. Considering the power loss, actual line impedance and grid equivalent impedance, per units in experiments, are a little different from ones in simulations as shown in fig indicates active power distribution, reactive power distribution, grid voltage, and current change before and after enabling the proposed approach with reactive power injection, respectively. In the initial stage, two modules generate the same active power, P_{1a} = P_{2a} = 710 W, and 1.4 kW active power considering the loss is delivered to grid. The reactive power compensation is disabled because the symmetrical active power ensures the same output voltage from the two modules and stable system operation. Subsequently, P_{2a} decreases from 710 to 140 W and P_{1a} keeps 710 W, and Q_{ga} is still controlled to be zero as shown in Fig. Therefore, the first module with P_{1a} = 710 W assumes more voltage

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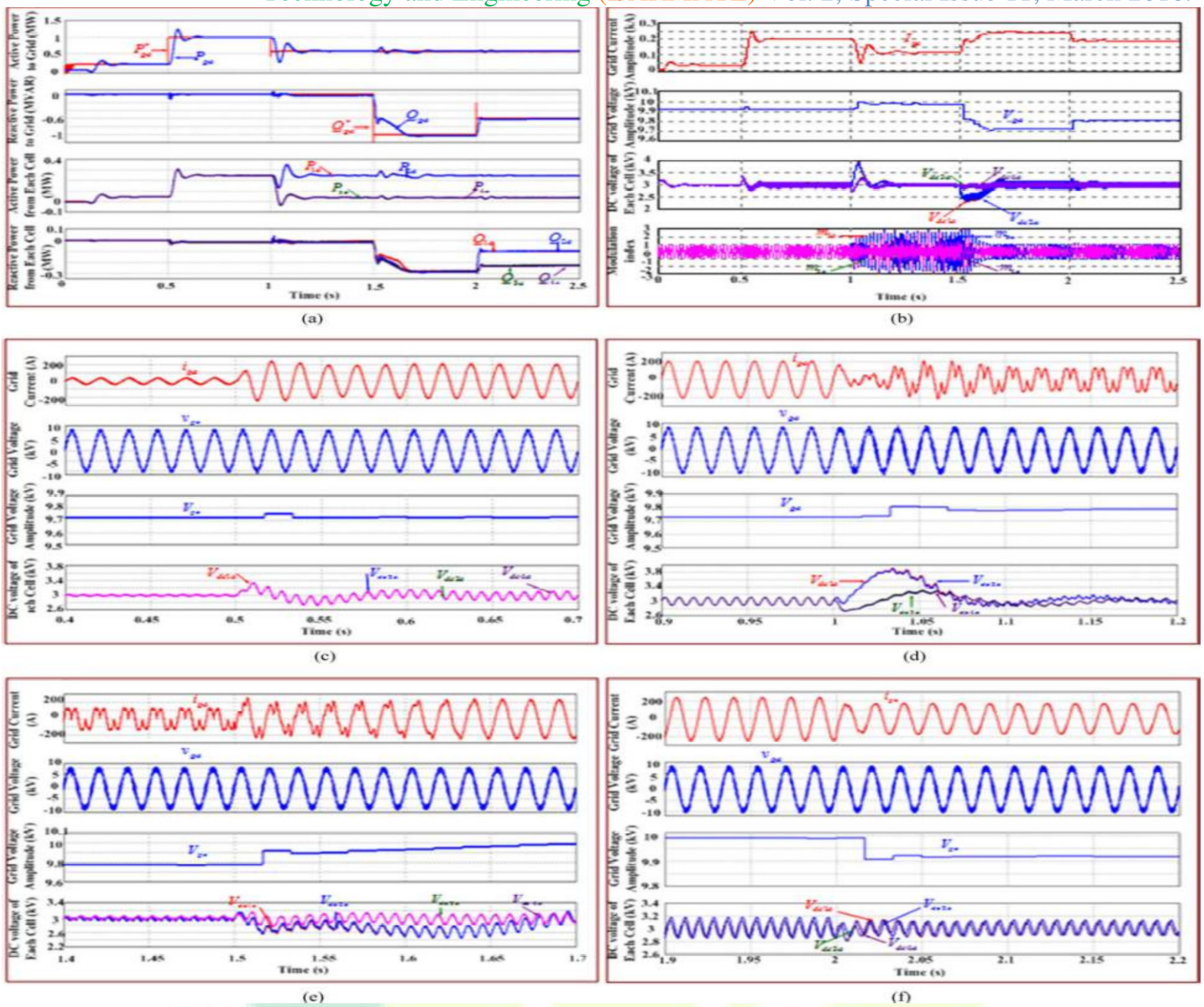

Fig. 4. Simulation results with the proposed approach in reactive power injection. (a) Active and reactive power distribution. (b) Voltage and current changes. (c)Zoomed voltage and current waveforms at 0.5 s. (d) Zoomed voltage and current waveforms at 1 s. (e) Zoomed voltage and current waveforms at 1.5 s. (f)Zoomed voltage and current waveforms at 2 s.

output to fulfill the system requirement, which results in overmodulation with the dc voltage limit. As a result, the grid current is distorted and serious active power mismatch will lead to the system breakdown as shown in the left zoomed waveforms .Afterward, the proposed RPCA is activated, and maximum reactive power $Q_{ga} = -1.4$kVAR is injected into grid and equal reactive power$Q_{1a} = Q_{2a} = -730$VAR is generated from the two modules to eliminate the overmodulation.The loss on the filter inductor is provided by the PV system. The grid current i_{ga} retrieves good quality and THD is 4.5%. However, the −1.4 kVAR reactive power compensation incurs the grid voltage V_{ga} increase from 280 to 290 V. In order to avoid the overvoltage, the optimized reactive power compensation is introduced and Q_{ga} decreases from − 1.4 to −1.1 kVAR. The reactive power distribution ratio between the two modules is 3:7 based on (6). The first module outputs high active power but provides less reactive power. The reactive power sharing does not only

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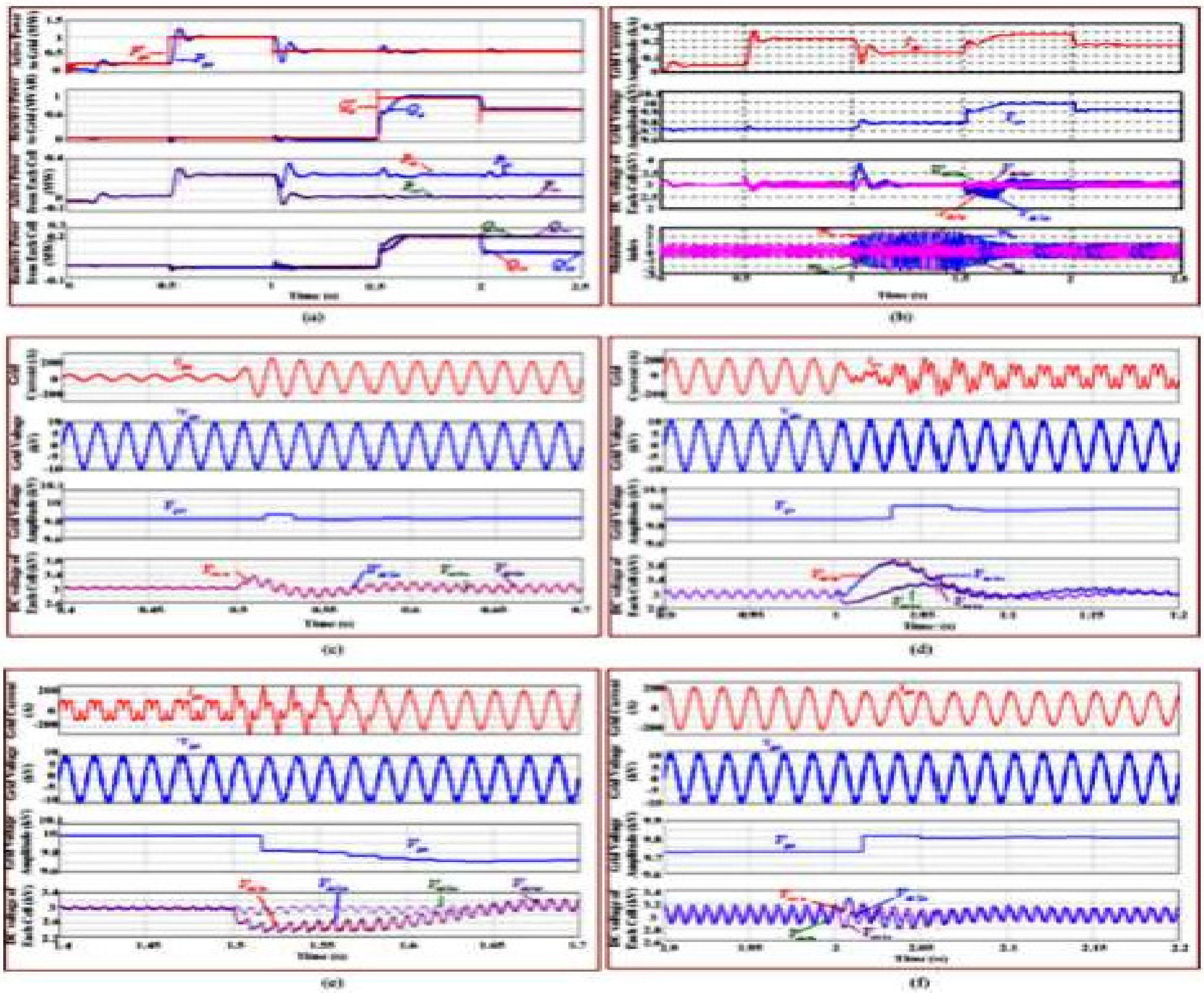

Fig. 5. Simulation results with the proposed approach in reactive power absorption. (a) Active and reactive power distribution. (b) Voltage and current changes. (c)Zoomed voltage and current waveforms at 0.5 s. (d) Zoomed voltage and current waveforms at 1 s. (e) Zoomed voltage and current waveforms at 1.5 s. (f)Zoomed voltage and current waveforms at 2 s.

reduce the burden of the second module but also effectively suppresses the overmodulation. As depicted, the Vga decrease from 290 to 285 V and iga still keeps good quality. Fig. illustrates active power distribution, reactive power distribution, grid voltage, and current change before and after enabling the proposed approach with reactive power absorption, respectively. Initially, two modules generate the same active power, $P_{1a} = P_{2a} = 760$ W, and1.5 kW active power considering the loss is delivered to grid as shown in Fig.. The reactive power compensation is disabled.Subsequently, P_{2a} decreases from 760 to 150 W andP $_{1a}$ keeps 760 W, andQ_{ga} is still controlled to be zero, which causes serious grid current distortion as shown in the left zoomed waveforms. In order to ensure the safe and stable system operation, the maximum reactive power Q_{ga} = 1.45kVAR is first absorbed from grid and the same reactive power$Q_{1a} = Q_{2a} = 700$ VAR is absorbed by the two modules as shown in Fig.The loss on the filter inductor is provided by grid. The iga recovers good quality and THD is 4.68%. However, the 1.45 kVAR reactive power compensation incurs the grid voltage Vga decrease from 300 to 285 V. In order to avoid the undervoltage, the optimized reactive power

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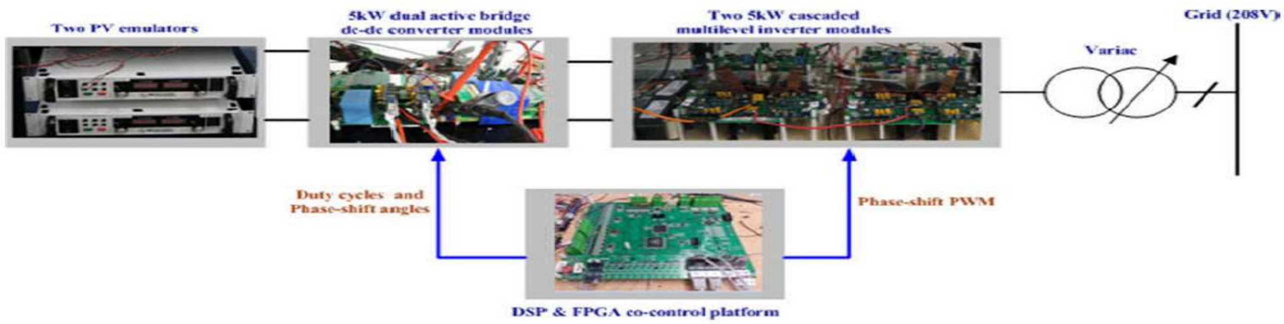

Fig.6. Two-stage cascaded PV system prototype with two 5 kW converter modules.

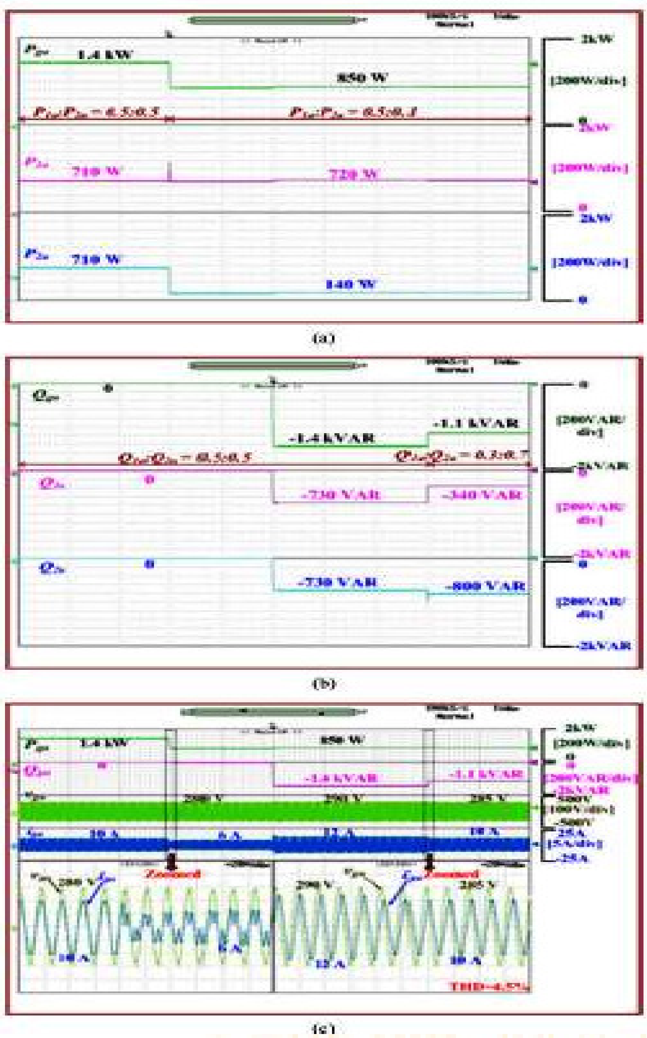

Fig. 7. Experimental results with the proposed approach in reactive power compensation injection. (a) Active power distribution. (b) Reactive power distribution. (c) Voltage and current waveforms with and without reactive power compensation.

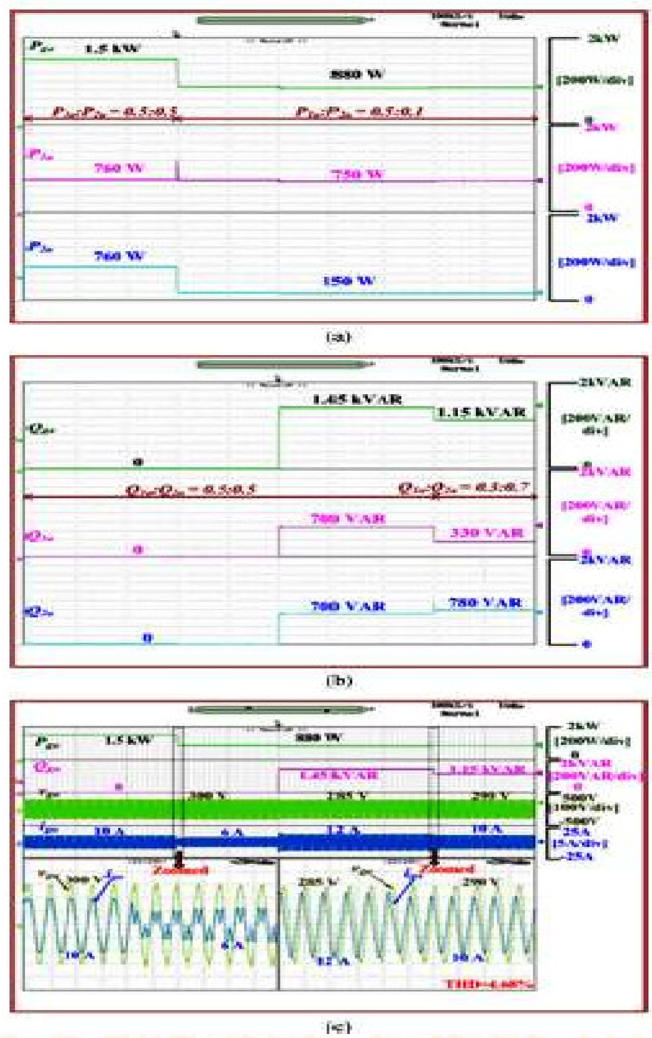

Fig. 8. Experimental results with the proposed approach in reactive power absorption. (a) Active power distribution. (b) Reactive power distribution. (c)Voltage and current waveforms with and without reactive power compensation.

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compensation is enabled and Qga decreases from 1.45 to 1.15 kVAR. The reactive power distribution ratio between the two modules is 3:7 based on (6). The first module with high active power shares less reactive power generation, which contributes on undervoltage elimination and system reliability. It can be seen that Vga increase from 285 to 290 V andigastill maintains good quality. The previous experimental results are consistent with the simulation results shown in Figs.

VI. CONCLUSION

This paper addressed the effect of reactive power compen- sation on system operation performance in grid-interactive cascaded PV systems. The system stability and reliability issue caused by unsymmetrical active power was specifically analyzed. Reactive power compensation and distribution was introduced to mitigate this issue. The output voltage of each module was verified to directly determine the power distribution. The relationship between voltage distribution and power distribution was illustrated with a wide power change range. An optimized RPCA was proposed considering the MPPT implementation, grid voltage, and overmodulation. Moreover, the RPAC was eligible to be integrated into different types of the cascaded PV system. Correspondingly, the control system with MPPT control and optimized RPCA was developed and validated by the simulation and experimental results under different scenarios. The proposed approach was demonstrated to be able to effectively enhance system operation stability and reliability, and improve power quality.

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