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Fault Ride-Through Capability Enhancement of PV System with Voltage Control Strategy

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***Abstract*— This paper introduces a novel utilization of continuous mixed -norm (CMPN) calculation based versatile control methodology with the motivation behind improving the low voltage ride through (LVRT) capacity of framework associated photovoltaic (PV) control plants. The PV clusters are associated with the point of common coupling (PCC) through a DC-DC help converter, a DC-interface capacitor, a matrix side inverter, and a three-stage step up transformer. The DC-DC converter is utilized for a greatest power point following operation in view of the fragmentary open circuit voltage technique. The matrix side inverter is used to control the DC-connect voltage and terminal voltage at the PCC through a vector control plot.**

The CMPN calculation based versatile relative necessary (PI) controller is used to control the power electronic circuits because of its quick joining. The implemented calculation refreshes the PI controller increases online without the need to calibrate or streamline. The viability of the implemented control procedure is contrasted and that acquired utilizing Taguchi approach based an ideal PI controller considering subjecting the framework to symmetrical, unsymmetrical shortcomings, and unsuccessful reclosing of circuit breakers because of the presence of permanent fault. The legitimacy of versatile control technique is broadly checked by the reproduction comes about, which are completed utilizing MATLAB/SIMULINK programming. With the implemented versatile controlled PV control plants, the LVRT capacity of such framework can be progressed.

***Index Terms*— Adaptive control, low voltage ride through (LVRT), photovoltaic (PV) power systems, power system control, power system dynamic stability.**

I. INTRODUCTION

Being an important part of the modern energy infrastructure, distributed renewable energy (DRE) systems have been developed at a fast rate. For example, in latest years, suitable to the continuous reduction of the photovoltaic (PV) module price and the strong global demand for environment-friendly energy conversion systems, the solar PV markets have been particularly booming. The capability of solar PV was improved by 25% in 2014 (i.e., approximately 50 GW), bring the overall total to 227 GW. The yearly promote in 2015 was almost 10 times the world's cumulative solar PV capacity of the last decade.

In future, the DRE systems convince the necessities for the generation closer to the consumption points. However, with the fast growth of distributed renewable power generations, stability and security have been attracting extensive attention. To manage with the challenge due to a high saturation stage of PV systems, various investigate behavior have been conduct newly to advance the combination of PV systems. In summary, it is expected that the grid-friendly PV systems should be multiple-functional. That is, for case, reactive power control, maximum power point tracking (MPPT), fault islanding detection, harmonic compensation, and fault ride-through (FRT) operation are required for PV systems.

Actually, some PV power systems on today's market are already able to provide such services. Nevertheless, the PV frameworks ought to be shrewder in light of network security, unwavering quality, and fault protection at a high entrance level. An immediate impression of the expanding requests for PV frameworks is that numerous nations have updated or have been reconsidering the national lattice controls, where the distributed generations are required to provide advanced grid fault-handling functionalities. As indicated by the necessities, the PV frameworks ought to stay associated under network deficiencies, and furthermore give responsive power if requested.

This is likewise alluded to as the low-voltage ride-through (LVRT) ability. In outrageous cases, i.e., the matrix voltage plunges to zero, and the separation from the network is additionally not permitted inside a predefined brief time interim (e.g., 150 ms), known as the zero-voltage ride-through (ZVRT) ability. So also, in zero-voltage conditions, the PV frameworks ought to likewise bolster the lattice recuperation by methods for responsive current infusion. In spite of the fact that the ZVRT operation can be taken as a unique instance of LVRT, a more committed control methodology ought to be performed amid the FRT operation. Particularly in single-stage network associated PV frameworks, when the blame happens, the frameworks still infuse sinusoidal

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responsive current to help the lattice without matrix data. Testing issues for the ZVRT operation in the single-stage PV framework incorporate how to distinguish the lattice voltage hangs rapidly, how to change to the ZVRT operation mode with no network data, and after the blame, how to resynchronize quickly without setting off the over current assurance.

As previously mentioned, the single-stage matrix associated PV framework is required to work in various modes precisely and quickly in muddled circumstances. Versatile separating calculations have been used to solve several engineering problems in different applications such as signal processing, electronics engineering, audio, speech, and language applications. Recently, these algorithms were explored in electric power systems, since affine projection algorithm was utilized to adapt the PI controller parameters in a wind energy conversion system. In these algorithms, a compromise should be taken into consideration between the algorithm complexity and the convergence speed. Many comparisons have been made among the implemented CMPN algorithm and other adaptive filtering algorithms. The results have proven the high joining velocity of the CMPN calculation over these calculations for various applications.

In this paper, a novel use of the CMPN calculation based versatile control methodology is displayed for improving the LVRT capacity of matrix associated PV control plants. The DC-DC support converter is utilized for a most extreme power point following operation in view of the partial open circuit voltage strategy. The lattice side inverter is used to control the DC-interface voltage and terminal voltage at the point of common coupling (PCC) through a vector control conspires.

The CMPN calculation based versatile PI controller is utilized to control the power electronic circuits because of its quick joining. The implemented calculation refreshes the PI controller increases online with no compelling reason to tweak or enhancement. The PV control plant is associated with the IEEE 39-transport New England test framework. The adequacy of the implemented control methodology is contrasted and that acquired utilizing Taguchi approach-based an ideal PI controller considering subjecting the framework to symmetrical, unsymmetrical deficiencies, and unsuccessful reclosing of circuit breakers due to the existence of permanent fault.

II. SYSTEM MODELING

In the low-voltage DRE system, the single-phase configuration is a more competitive solution. A generic control structure of the single-phase grid-connected PV system is shown in Figure 1, with an option of a DC-DC converter, which is used to boost up the PV panel voltage to a appropriate level of the following-stage DC-AC converter. The choice of single- or two-stage (i.e., without or with the DC-DC converter) is dependent on the control strategy, efficiency, cost, size and weight, etc. To guarantee a high-quality sinusoidal grid current, the inductor–capacitor–inductor (LCL) filter is adopted to improve the switching harmonic with lighter and smaller inductors.

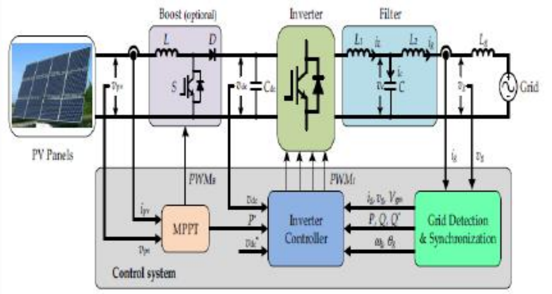

Fig:1. Generic control structure of the single-phase grid-connected photovoltaic (PV) system. Maximum power point tracking (MPPT).

In ordinary conditions, the PV framework draws the most extreme power from the PV exhibits (i.e., in MPPT operation) and exchanges it to the matrix at solidarity control factor by utilizing control system. The broadly utilized control procedure in single-stage inverters has two fell control circles. The inward circle is a present circle, in which the network current quality can be ensured and the over current insurance is likewise guaranteed. The external circle is a voltage or power control circle, in which the voltage of the DC-side can be guaranteed and a reference of the internal current circle is ascertained at the same time in the external circle.

The PV clusters are associated with transport 18 of the test framework through a DC-DC support converter, a DC-interface capacitor of 15 mF, a network side inverter, three-stage venture up transformers, and twofold circuit transmission lines, as appeared in Fig. 2.

This system is considered a compact version of the original New England System and it is used for realistic responses study. The IEEE 39-bus system includes 39 buses out of which 19 are load buses. There are 10 generators in the system. Bus 31 at which generator 2 are connected is defined as the slack bus. The total load and generation of the system is 6098.1 and 6140.81 MW, respectively. The load model is considered to be constant current and constant admittance load. In order to test the PV power plant with the IEEE 39-bus system, the PV power plant is connected to bus 18.

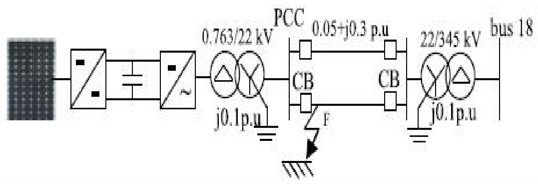

Fig.2. Grid-connected PV power plant Connection of PV power plant.

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A DC-DC boost converter is used to control the output voltage of the PV plant in order to satisfy the maximum output power condition. This is done by controlling the duty cycle of insulated gate bipolar transistor (IGBT) switch of the converter, as indicated in Fig. 3. The fractional open circuit voltage method is applied to fulfill the maximum power condition.

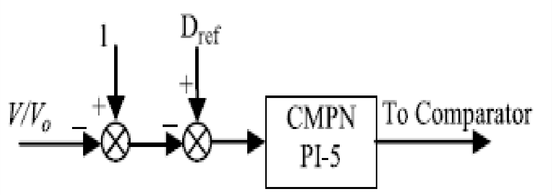

Fig. 3. Control of the DC-DC converter.

A CMPN-based adaptive PI controller is used for this purpose. The controller output signal is compared with a triangular carrier waveform signal of 4-kHz frequency to generate the firing pulses of IGBT switch. A two-level, three-phase, six IGBT switches inverter is implemented in this study. The grid-side inverter is utilized to control the DC-link voltage and terminal voltage at the PCC through a vector control scheme, as illustrated in Fig. 4.

The CMPN algorithm-based adaptive PI controllers are developed for this purpose. A phase locked loop (PLL) is dedicated to detect the transformation angle from the three-phase voltages at the PCC.

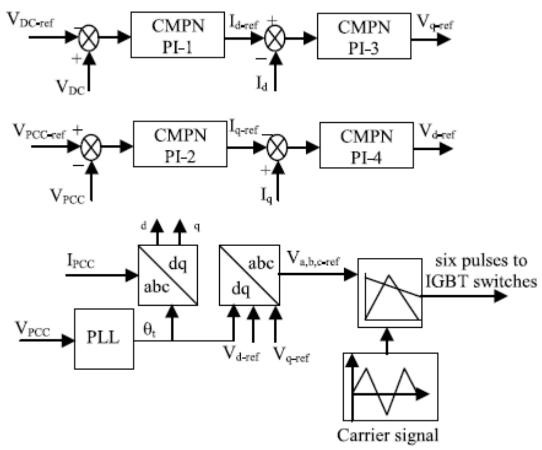

Fig. 4. Control block diagram of the grid-side inverter.

One family of the adaptive filtering algorithms is the mixed-norm adaptive filters that have various forms. In the least mean mixed-norm (LMMN) adaptive filter was presented, where it combined the least mean square (LMS) and the least mean fourth (LMF) algorithms. Moreover, a robust mixed-norm (RMN) algorithm was implemented and it combined the LMS algorithm with the least absolute deviation (LAD) algorithm.

Then, a normalized RMN algorithm Once the grid phase-to-ground fault is detected by the grid synchronization, the photovoltaic (PV) system should switch to the grid fault operational mode with reactive power injection to support the grid recovery. In different countries, to fulfill various local conditions under national realities, the suitable grid code has been implemented. Figure 5 exemplifies the voltage profiles for the possible fault condition in some countries, where the PV systems should operate under the specific condition when the grid voltage is above the curves.

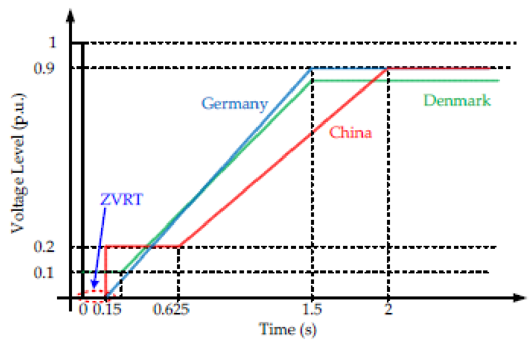

Fig: 5. Low-voltage (and zero-voltage) ride-through requirements for grid-connected systems in different countries.

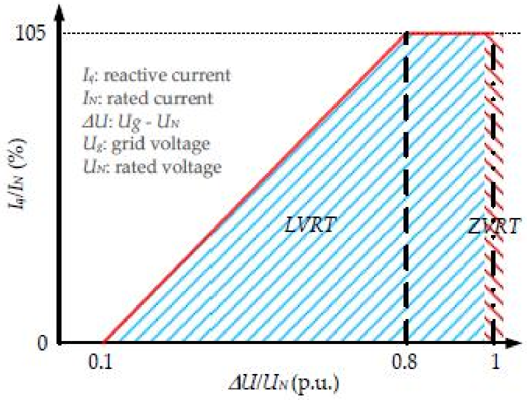

Fig: 6. Reactive current injection requirements under low-voltage ride-through/zero-voltage ride-through (LVRT/ZVRT) operations.

III. SIMULATION RESULTS

The detailed model of a grid-connected PV power plant is presented. The model involves a complete switching model of the power electronic circuits with the implemented adaptive control strategy for obtaining realistic responses. The simulation results are performed using the powerful power system computer aided design (MATLAB/SIMULINK) software.

In this scenario, a three-line to ground (3LG) temporary fault takes place at time t=0.1 s with duration of 0.1 s at fault point F. The CBs on the faulted lines are opened at t=0.2s to clear fault. Then, the CBs are reclosed

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again at t=1s. Successful reclosure of the CBs means reclosure under no fault condition.

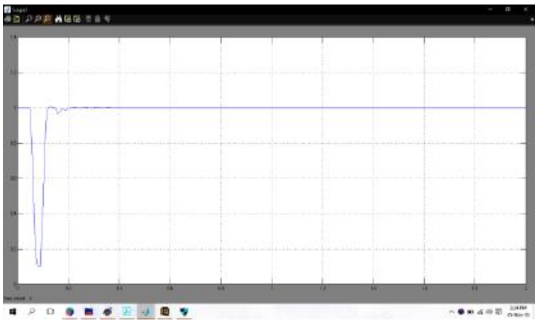

Fig:7(a)

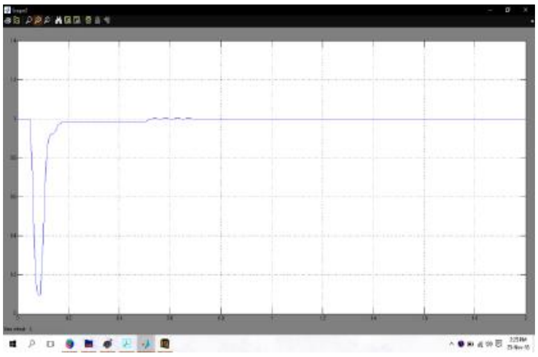

Fig: 7(b)

Fig:7(c)

Fig:7(d)

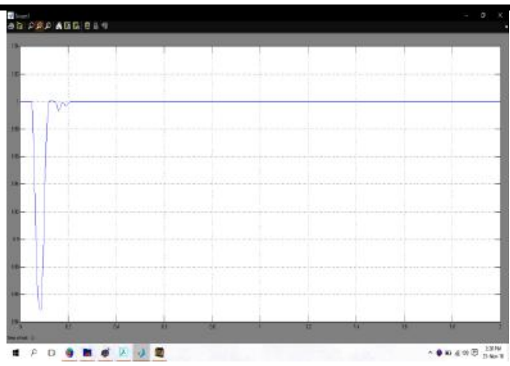

Fig:7(e)

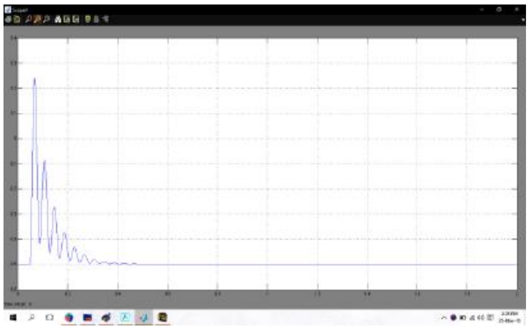

Fig:7(f)

Fig. 7. Responses of implemented system for 3LG temporary fault. (a) Vpcc. (b) Real power out of the PCC. (c) Reactive power out of the PCC. (d) Vdc. (e) Voltage at bus 18. (f) Inverter currents with the implemented controller.

Fig:8(a)

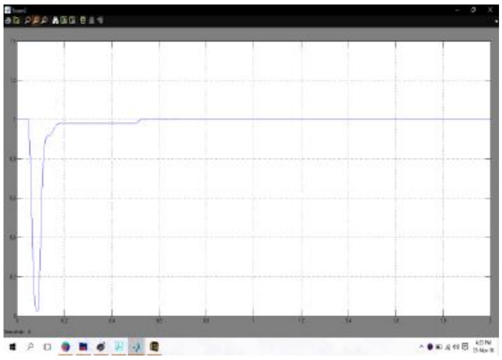

Fig:8(b)

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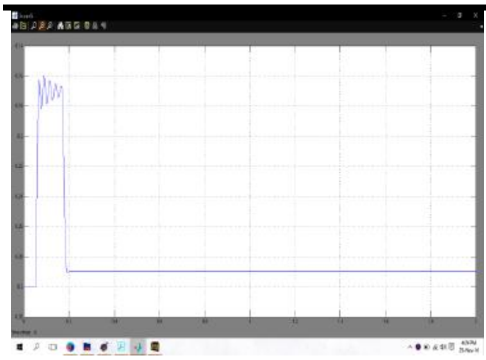

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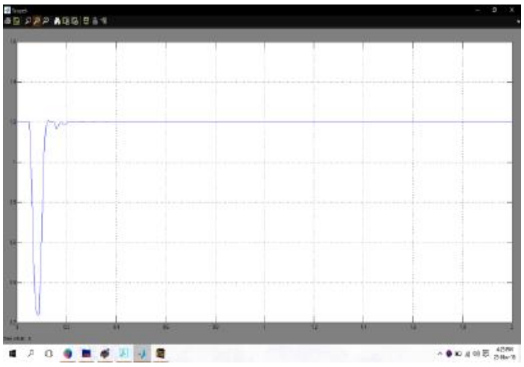

Fig:8(d)

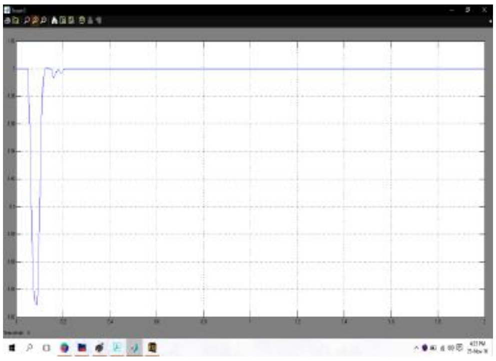

Fig:8(e)

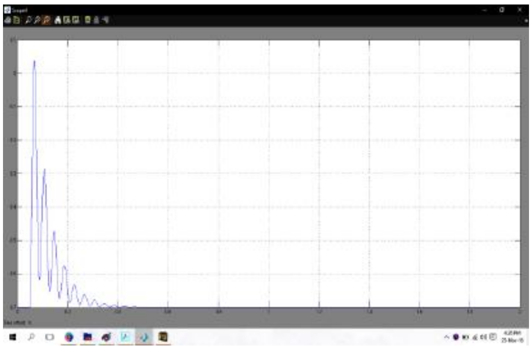

Fig:8(f)

Fig. 8. Responses of conventional system for 3LG temporary fault. (a) Vpcc. (b) Real power out of the PCC. (c) Reactive power out of the PCC. (d) Vdc. (e) Voltage at bus 18. (f) Inverter currents with the implemented controller.

The Vpcc drops immediately from the rated value (1 p.u) due to the effect of network disturbance and the grid side inverter delivers a good amount of reactive power that helps the Vpcc to return back to the rated value, as indicated in Fig. 7 & 8 (a). It is worth to note here that the Vpcc response using the CMPN-adaptive PI control strategy is better damped than that of using Taguchi approach-based an optimal PI control scheme, where it has lower maximum percentage undershoot, lower maximum percentage overshoot, lower settling time, and lower steady state error. Fig. 7 & 8 (b) points out the real power out of the PCC. It can be realized that the implemented controlled DC-DC converter controls efficiently the maximum output power of the PV plant at 1 p.u. The real power out of the PCC reaches final 0.96 p.u due to the converter, inverter, and transformer losses. The reactive power out of the PCC, the Vdc , and voltage at bus 18 are shown in Fig. 7 & 8 (c)–(e), respectively. It can be noted that the responses using the implemented adaptive control strategy are very fast with minimum fluctuations. The online CMPN adaptive algorithm distinguishes a high speed convergence that updates the controller gains in an expedite way. Fig. 7 & 8 (f) indicates the direct axis and quadrature axis components of the inverter output currents (Id and Iq). It can be realized that the implemented controller limits the rms inverter currents during the network disturbance to a value of 1.2 p.u, which lies in an acceptable range.

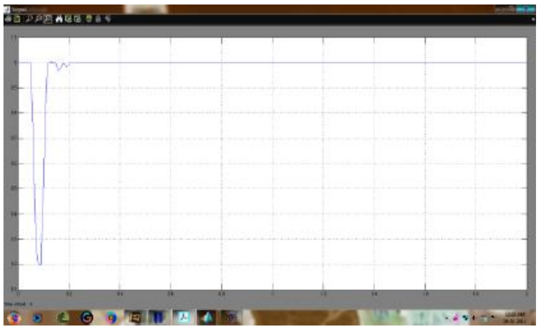

Fig:9(a)

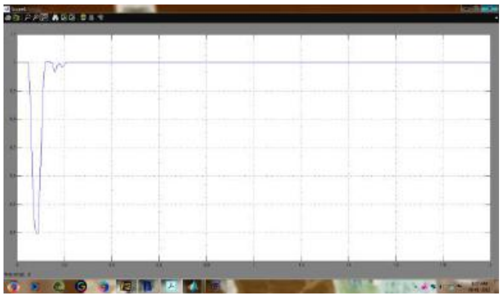

Fig:9(b)

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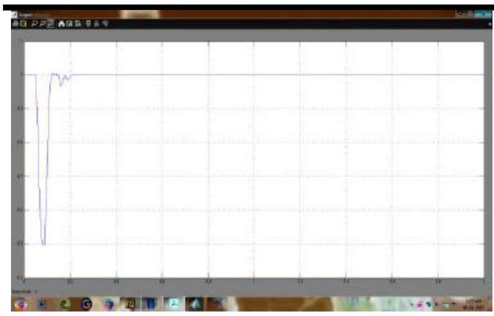

Fig:9(c)

Fig. 9. Vpcc response for unsymmetrical faults of implemented system. (a) 2LG fault. (b) LL fault. (c) 1LG fault.

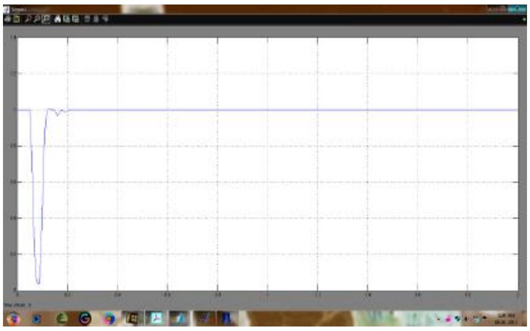

Fig:10(a)

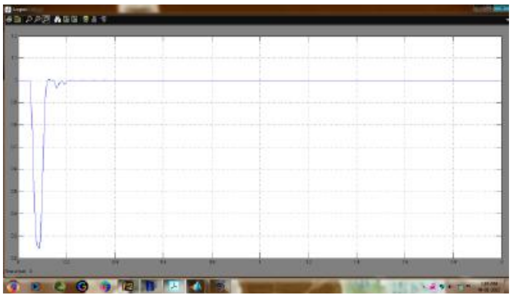

Fig:10(b)

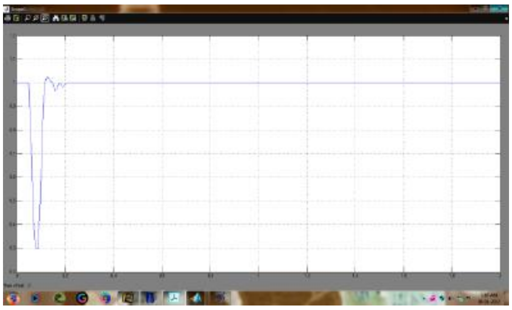

Fig:10(c)

Fig. 10. Vpcc response for unsymmetrical faults of conventional system. (a) 2LG fault. (b) LL fault. (c) 1LG fault.

Moreover, the implemented adaptive control strategy is extensively verified by subject the system to different types of unsymmetrical faults such as double-line to ground (2LG), line-to-line (LL), and single-line to ground (1LG) faults. Fig. 8 & 10(a)–(c) shows the Vpcc response under these types of faults. All the transient responses using the implemented control strategy are superior to that obtained using Taguchi approach-based an optimal PI control scheme. Therefore, the LVRT capability of the grid connected PV power plants can be further enhanced using the CMPN algorithm-based adaptive PI control strategy.

B. Unsuccessful Reclosure of CBs

This scenario proposes a 3LG permanent fault occurring at point F in Fig. (a). The fault happens at t=0.1s and its duration is assumed to be 6.9 s. The CBs on the faulted lines are opened at t=0.2s and reclosed again at t=1s. Unfortunately, the CBs are closed on a permanent fault condition at this instant and this means unsuccessful reclosure of CBs. Therefore, the CBs are opened again at t=1.1s and closed at t=7.1s, which means after the fault duration.

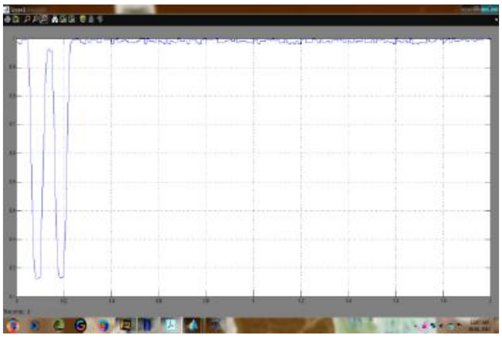

Fig:11(a)

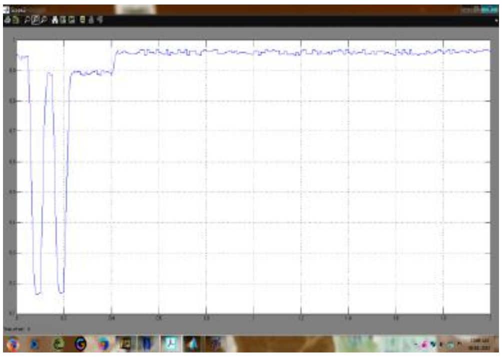

Fig:11(b)

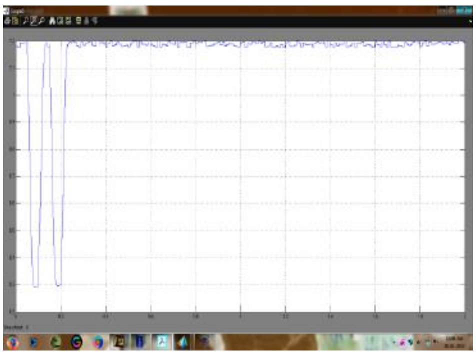

Fig:11(c)

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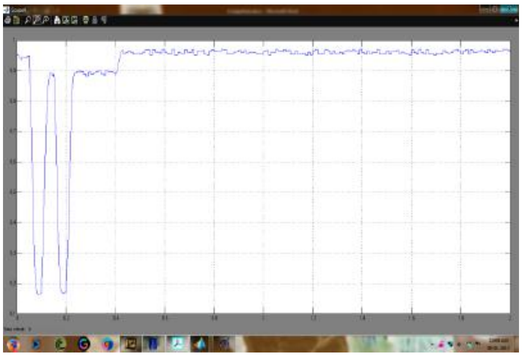
Fig:11(d)

Fig. 11. Responses for 3LG permanent fault of conventional system. (a) Vpcc. (b) Real power out of the PCC. (c) Reactive power out of the PCC. (d) Vdc.

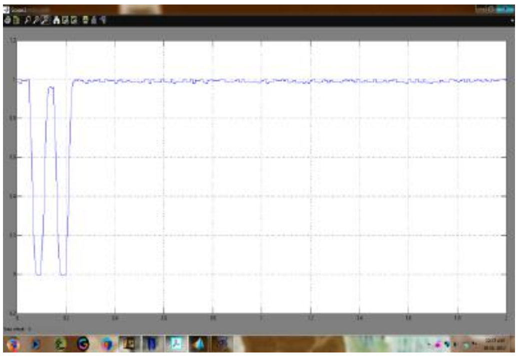
Fig:12(a)


Fig:12(b)

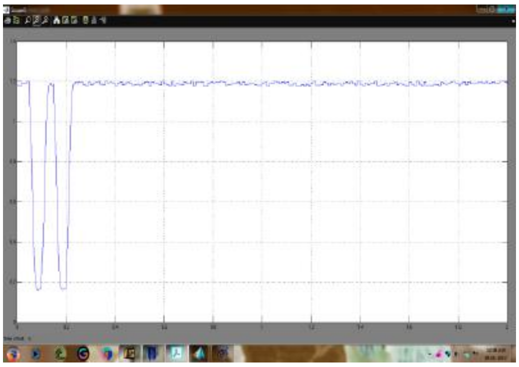
Fig:12(c)

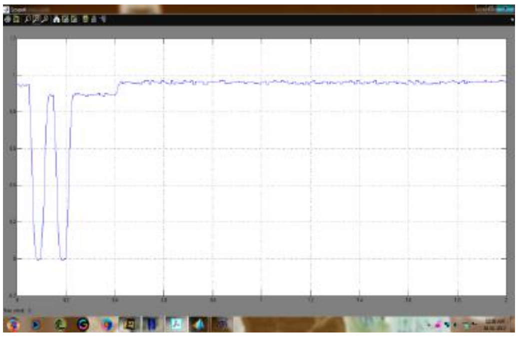
Fig:12(d)

Fig. 12. Responses for 3LG permanent fault of conventional system. (a) Vpcc. (b) Real power out of the PCC. (c) Reactive power out of the PCC. (d) Vdc.

Fig. 11 & 12(a)–(d) indicates the responses of Vpcc, real and reactive powers out of the PCC, and Vdc, respectively. All responses have faster and better damped using the CMPN-based adaptive PI control strategy. Moreover, through permanent fault period, the Vpcc response lies in an acceptable range that agrees with the PV power plant grid codes. In addition, after permanent fault clearance and CBs final closure, the returns back with a fast response to its rated value. All system responses can return to their pre-fault values. Therefore, the implemented control strategy results in an enhancement of the LVRT capability of grid-connected PV power plants whatever under grid temporary or permanent fault condition. The high performance, accuracy, and superiority of the implemented CMPN algorithm-based adaptive PI controller to Taguchi-based an optimal PI controller are due to its proper design, its high convergence speed, and its flexibility to update the controller gains automatically online to minimize the error signals obtaining better results.

IV. CONCLUSION

This project has introduced a new function of the CMPN algorithm-based adaptive PI control strategy for enhancing the LVRT capability of grid-connected PV power plants. The implemented control strategy was useful to the DC-DC boost converter for a maximum power point tracking operation and also to the grid-side inverter for controlling the Vpcc and Vdc. The CMPN adaptive filtering algorithm was used to update the proportional and integral gains of the PI controller online lacking the require to fine tune or optimize. For practical response, the PV power plant was connected to the IEEE 39-bus New England test system. The simulation results have proven that the system responses using the CMPN algorithm-based adaptive control strategy are faster, better damped, and superior to that obtained using Taguchi approach-based an optimal PI control scheme during the following cases:

1) subject the system to a symmetrical 3LG temporary fault;
2) subject the system to different unsymmetrical faults;
3) subject the system to a symmetrical 3LG permanent fault and unsuccessful reclosure of CBs.

It can be claimed from the simulation results that the LVRT capability of grid-connected PV power plants can be further enhanced using the implemented adaptive control strategy whatever under grid temporary or permanent fault condition. By this way, the PV power plants can contribute to the grid stability and reliability, which represents a greater challenge to the network operators. Moreover, the implemented algorithm can be also applied to other renewable energy systems for the same purpose.

V. REFERENCES

[1] PV Power Plants 2014 Industry Guide [Online]. Available: http://www.pvresources.com
[2] D. L. Brooks and M. Patel, "Panel: Standards & interconnection requirements for wind and solar generation NERC integrating variable generation task force," in *Proc. IEEE Power Eng. Soc. General Meeting 2011*, Jul. 2011, pp. 1–3.
[3] G. J. Kish, "Addressing future grid requirements for distributed energy resources," M.Sc. thesis, Dept. Elect. Comput. Eng., Univ. Toronto, Toronto, ON, Canada, 2011.
[4] Y. Yang, F. Blaabjerg, and Z. Zou, "Benchmarking of grid fault modes in single-phase grid-connected photovoltaic systems," *IEEE Trans. Ind. Applicat.*, vol. 49, no. 5, pp. 2167–2176, Sep./Oct. 2013.
[5] Y. Yang, F. Blaabjerg, and H. Wang, "Low-voltage ride-through of single-phase transformerless photovoltaic inverters," *IEEE Trans. Ind. Applicat.*, vol. 50, no. 3, pp. 1942–1952, May/Jun. 2014.
[6] K. Kawabe and K. Tanaka, "Impact of dynamic behavior of photovoltaic power generation systems on short-term voltage stability," *IEEE Trans. Power Syst.*, vol. 30, no. 6, pp. 3416–3424, Nov. 2015.
[7] M. S. El Moursi, W. Xiao, and J. L. Kirtley, "Fault ride through capability for grid interfacing large scale PV power plants," *IET Gener., Transm., Distrib.*, vol. 7, no. 5, pp. 1027–1036, 2013.
[8] Y. Wu, C.-H. Chang, Y. Chen, C. Liu, and Y. Chang, "A current control strategy for three-phase PV power system with low-voltage ridethrough," in *Proc. IET Int. Conf. Advances on Power System Control, Operation, Management (APSCOM)*, 2012, pp. 1–6.
[9] M. K. Hossain and M. H. Ali, "Low voltage ride through capability enhancement of grid connected PV system by SDBR," in *Proc. IEEE PES T&D Conf. Expo.*, 2014, pp. 1–5.