A solar PV-fed MF-DVR for compensation of grid-islanding issues and power-quality issues in grid-connected distribution system

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Article Info

Article history:

Received Dec 9, 2024
Revised Apr 10, 2025
Accepted Jul 3, 2025

Keywords:

Dynamic voltage restorer
Grid-islanding
Power-quality enhancement
Solar-PV system
Voltage-interruptions
Voltage sags-swells
Voltage harmonics

ABSTRACT

Difficulties with the quality of power come up as an effect of the inte-conneted renewable energy through grid called as distribution generation (DG) scheme. The voltage harmonics and swell-sag are happened in the utility grid as a result of power quality issues, affecting end-level consumers. Moreover, grid islanding issues is considered the most affected problem in distribution system for affecting the uninterrupted energy-flow to respective load demand. The main aim of this paper provides affective designing of the suitable cost-effective multi-functional dynamic voltage restorer (MF-DVR) has been proposed for resolving the problems. The major objective is mitigation of voltage-interruptions during grid-islanding, voltage-sag, voltage-swell and voltage-harmonics, any voltage quality in the utility grid, by utilizing the solar photovoltaic (PV) integrated MF-DVR as DG scheme through synchronous reference frame (SRF) control theory. Also, it can regulate the voltage and phase of the distribution system during sudden voltage interruptions occurred in grid-islanding. The performance of the proposed SRF controlled MFDVR for power-quality (PQ) improvement and DG integration during grid-islanding has been validated via Matlab/Simulink computing tool; the simulation findings are shown with an appealing comparison analysis.

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1. INTRODUCTION

The key motivations for creating more power production units to supply the required power need are the introduction of emerging industries, fast population increase, and deterioration of resources from the earth. To accommodate peak demand, several million crores are invested on new energy-generation facilities and transmission corridors [1]. Major initiatives have been undertaken across the world to encourage the adoption of renewable energy for electric power generation as distributed generation (DG) scheme [2]-[5]. The DG is generally utilized as an alternative source of energy, providing uninterrupted power to end-user customers when power failures or grid islanding circumstances. The DG delivers constant energy in relation to the needed demand of the load, with advantages such as lower transmission losses and costs and higher efficiency [6]. Solar photovoltaic (PV) is an essential component of the DG-supplied distribution network due to its abundance, virtue, ecological sustainability, and noiselessness [7]. Under DG procedures, received solar-generated energy is linked directly to the common point (PCC) pf the electrical supply network’s by means of power-electronic conversions and a suitable management structure [8].

The effective functioning of DG systems in distribution lines requires a variety of limitations, notably a flexible energy source, continuous assistance, and power-quality (PQ) criteria [9], [10]. Obtaining quality power is an important factor in secondary distribution lines since it has substantial ramifications for end-user customers and utility-grid. It is growing due to the extensive usage of large PE conversion loads such as commercial speed drives, switched-convertible load equipment, arc burners, and massive inductive loads. The introduction of PQ difficulties has major consequences for the power distribution system, influencing source current, voltage, and its system frequency [11]. The primary reasons of inadequate power quality include voltage source disturbances, voltage harmonics, and sags-swells [12]. Furthermore, grid islanding difficulties are recognized as an extremely serious problem, influencing the constant delivery of electricity to load in relation with the peak demand [13].

Many researchers and electrical engineers are currently developing the new PQ elimination devices based on custom-power device techniques (CPD) [14], [15]. Multiple CPD apparatus can be easily accessible to address certain PQ difficulties, leading to maintain the sinusoidal in form, well-balanced, linear form and fundamental in nature of the distribution system. Static compensators, distributed static compensator (DSTATCOM) [16], active power filter (APF) [17], dynamic voltage restorer (DVR) [18], and others are examples of prominent CP devices. According to the literature, the DVR is the best CPD because it is inexpensive, small in size, and responds rapidly to voltage disturbances [18], [19].

The main aim of this work is, developing the suitable cost-effective multi-functional dynamic voltage restorer (MF-DVR) has been proposed for resolving the problems. The MF-DVR play an important role in reducing voltage problems in grid-connected distribution networks. In grid powered distribution networks, an energy-effective solar PV fed MF-DVR paired with a PI controller and a novel DC to DC boosting converter regulates grid changes [20], [21] which contributes the generation of clean, energy while decreasing harmful pollutants. It can handle critical loads in an instance of a grid disruption, improving dependability while also solving energy-related problems. The proposed solar-PV fed MF-DVR requisite voltage-source inverter (VSI) linked via series form powered by solar-PV system, the maximum solar-PV power is extracted by INC-MPPT control algorithm.

Utilizing an appropriate control technique, the suggested MF-DVR minimizes voltage concerns in grid-islanding as well as other voltages-related PQ problems in utility-grid linked distribution systems. The suggested solar-PV based MF-DVR is designed to extract viable voltage data by monitoring both the utility-source and non-linear load voltages. In broadly, the synchronous reference frame (SRF) control concept [22], [23] is usually utilized to determine the best voltage reference for possible restoration performed by a series linked MF-DVR equipment. The major objective is mitigation of voltage-interruptions during grid-islanding, voltage-sag, voltage-swell and voltage-harmonics, any voltage quality in the utility grid, by utilizing the solar PV integrated MF-DVR as DG scheme through suitable control scheme. Also, it can regulate the voltage and phase of the distribution system during sudden voltage interruptions occurred in grid-islanding. The performance of the proposed SRF controlled MFDVR for PQ improvement and DG integration during grid-islanding has been validated via Matlab/Simulink computing tool; the simulation findings are shown with an appealing comparison analysis.

2. PROPOSED METHOD

The block diagram of proposed solar-PV fed MF-DVR device for compensation of grid-islanding and PQ issues is depicted in Figure 1. The designed solar-PV fed MF-DVR is integrated to grid powered distribution system in a series fashion for regulating the voltage related PQ issues. It consists of series connected VSI, control scheme, gate drive circuitry, solar-PV arrays, DC-DC boost converter, and line interfacing filters.

Furthermore, series VSI of MF-DVR served as an active filtering, it reducing all voltage-related issues and balancing the load demand. The MF-DVR's series-VSI is linked to the PCC distribution network through a 1:1 line coupled transformer equipped with outside RC filtering devices that reduce irregular notching influences. The available solar-PV output has been delivered directly into the MF-DVR to eliminate voltage quality concerns and to regulate load voltage changes when voltage disturbances. The accessibility of solar-PV energy is immediately incorporated into the MF-DVR with a DC-DC boosting converter, resulting in a significant boost voltage that is managed through INC-MPPT controller. It increases the extraction of solar-PV power under fluctuating temperature and irradiance conditions. The available solar PV power is distributed to the electrical distribution line using the series-VSI integrated MF-DVR apparatus has been controlled by using the SRF control unit.

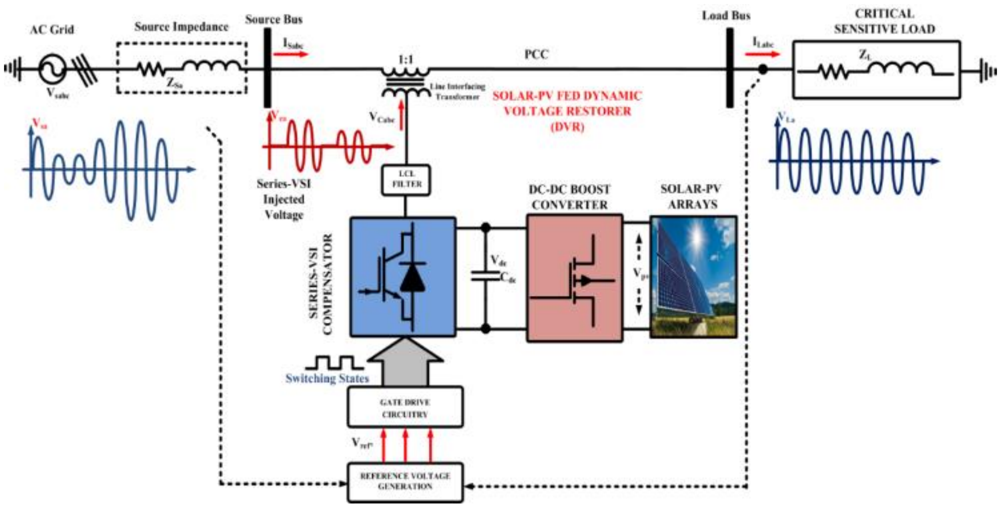

Figure 1. Block diagram of proposed solar-PV fed MF-DVR device for compensation of grid-islanding and power-quality issues

3. PROPOSED CONTROL ALGORITHM

The MF-DVR's series integrated VSI is used to correct for all voltage-related PQ difficulties as well as grid-islanding difficulties at the PCC, resulting in continuous power delivery incorporated into a utility-grid network. The appropriate emergence of the MF-DVR's series-integrated VSI is based on the development of a highly effective voltage reference via an SRF control using a suitable proportion of the precise voltage. Park's transformation technique converts the precise voltage of the supply in an ordinary abc-frame (VL.abc) into the rotational dq-frame (Vdq0.act) axis.

$$\begin{bmatrix} V_{d.act} \\ V_{q.act} \\ V_{0.act} \end{bmatrix} = \frac{2}{3} \begin{bmatrix} cos\theta & cos\left[\theta - \frac{2\pi}{3}\right] & cos\left[\theta + \frac{2\pi}{3}\right] \\ sin\theta & sin\left[\theta - \frac{2\pi}{3}\right] & sin\left[\theta + \frac{2\pi}{3}\right] \\ \frac{1}{2} & \frac{1}{2} & \frac{1}{2} \end{bmatrix} \begin{bmatrix} V_{L.a} \\ V_{L.b} \\ V_{L.c} \end{bmatrix} \quad (1)$$

$$\theta = \int \omega . dt \quad (2)$$

Where θ denotes the translation factor, ω indicates the velocity of the axis, $V_{L.abc}$ is the precise NL load voltage in abc frame, and Vdq0.abc denotes the translated dq frames, respectively. The voltage that is acts as a reference remains constant during operation, then the voltages that are part of the dq-frame as 1p.u., 0p.u. Following transformation, the original voltage ($V_{dq.act}$) may be distinct from voltage reference ($V_{dq.ref}$) to provide adequate compensating voltages as well as specific error occurrences. These error occurrences can be decreased using a proportional-integral PI controller with properly calibrated gain levels. The transfer function of PI control loop is listed below:

$$U_{err}(s) = k_{pa} + \frac{k_{ia}}{s} E_{err}(s) \quad (3)$$

Figure 2 depicts the schematic arrangement of the SRF control for the series integrated VSI of the MF-DVR device. Although error occurrences has been reduced, the output of the PI controller is interpreted as a final reference signal (Vdq.ref*). The reference signals are re-translated as dq-abc frame by using the inverse translation approach, as given in (5),

$$V^*_{dq.ref} = (V_{dq.ref} - V_{dq.act}) \quad (4)$$

$$\begin{bmatrix} V_{a.ref} \\ V_{b.ref} \\ V_{c.ref} \end{bmatrix} = \frac{2}{3} \begin{bmatrix} cos\theta & sin\theta & 1 \\ cos\left[\theta - \frac{2\pi}{3}\right] & sin\left[\theta - \frac{2\pi}{3}\right] & 1 \\ cos\left[\theta + \frac{2\pi}{3}\right] & sin\left[\theta + \frac{2\pi}{3}\right] & 1 \end{bmatrix} \begin{bmatrix} V^*_{d.ref} \\ V^*_{q.ref} \end{bmatrix} \quad (5)$$

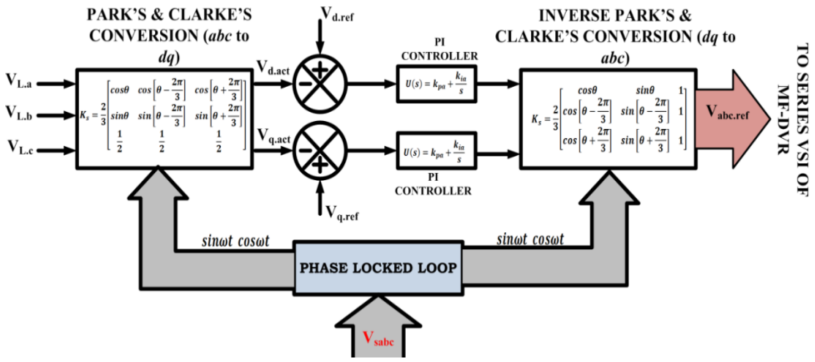

Figure 2. Schematic design of SRF controller for series-connected VSI of MF-DVR

Finally, the generated reference signals from substantial SRF controller is forwarded to sinusoidal pulse-width modulation (SPWM) for furnishing the feasible pulses to VSI of MF-DVR for mitigation of grid-islanding issues as voltage interruptions, voltage sag-swells, voltage harmonics and active-power regulation by employing solar-PV system. The overall schematic diagram of proposed solar-PV fed MF-DVR device for compensation of grid-islanding and PQ issues is depicted in Figure 3. The performance of the proposed SRF controlled MFDVR for PQ improvement and DG integration during grid-islanding has been validated via Matlab/Simulink computing tool; the simulation findings are shown with an appealing comparison analysis. The simulation data are shown in Table 1.

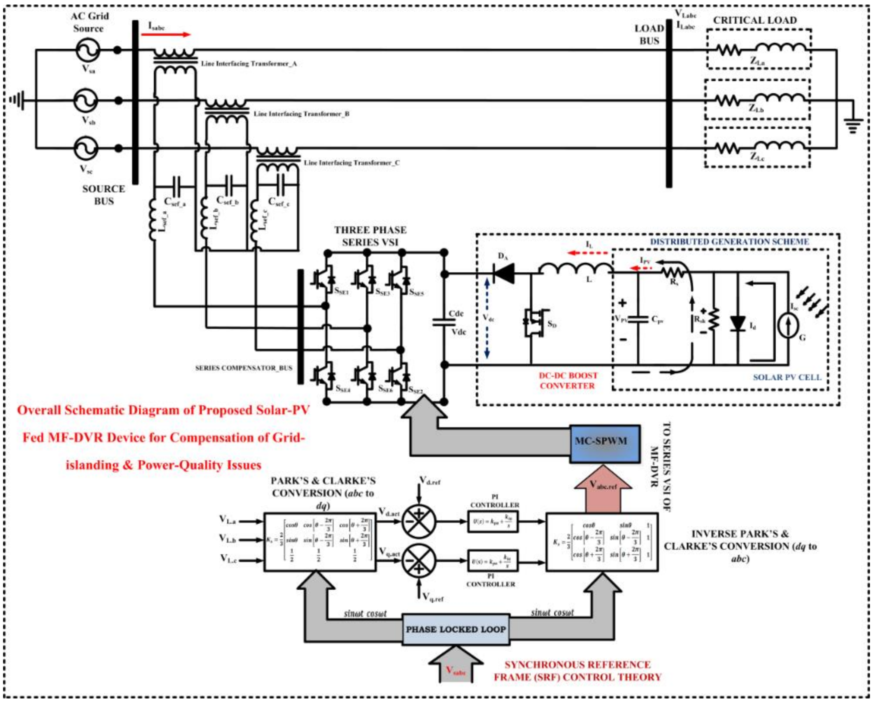

Figure 3. Overall model of solar-PV fed proposed MF-DVR device for compensation of grid-islanding and power-quality issues

Table 1. Simulation data

S. No	Simulation parameters	Values
1	Supply voltage	V_{sabc}-415 V, F_S-50 Hz
2	Supply impedance	Rs-0.1 Ω, Ls-0.9 mH
3	Load impedance	R-20 Ω, L-30 mH
4	DC capacitor	V_{dc}-880 V, C_{dc}-1,500 µF
5	MF-DVR VSI's filter	R_f-1 Ω, C_f-100 µF
6	Solar-PV values	V_{pv}-440 V, I_{pv}-25 A, P_{pv}-11 KW
7	PI controller	K_p-1, K_i-0.1

4. RESULTS AND DISCUSSION

4.1. Performance analysis of solar-PV integrated MF-DVR for compensation of grid-islanding issues

As shown in Figure 4, the simulated results of solar-PV integrated MF-DVR for compensation of grid-islanding issues. In this case, the grid connected distribution system is powered by a utility-grid supply voltage of 415 Vrms with a supply frequency of 50 Hz to drive the critical load system. The supply voltage is affected by grid-islanding issue due to sudden voltage interruptions occurred in between the 0.1 sec <t<0.3 sec, causing a serious voltage-drop in grid connected distribution system. The load system doesn't function continuously in this time-period due to grid comes under islanding mode. During this time, the series-connected SRF controlled solar-PV powered VSI of MF-DVR injects requisite supply voltage via in-phase injection principle to furnish the required voltage to the load to make load voltage as constant, sinusoidal and balanced in nature. During pre-islanding case before time t=0.1 sec, the source voltage is kept constant at a value of 340 V. As well as the voltage interruptions of 0 p.u on supply voltage are occurred in between 0.1 sec <t<0.3 sec, the supply voltage has been zero 0 value due to grid-islanding is shown in Figure 4(a). When grid-islanding has been occurred, the series-connected SRF controlled solar-PV powered VSI of MF-DVR injects requisite supply voltage of 340 V to keep load voltage as constant and balanced nature of 340V is shown in Figures 4(b) and 4(c). The above compensation has been initiated by energizing the DC-link capacitor through extracted solar-PV voltage of 880V with a solar-PV current of 12.5 A to furnish required solar-PV power of 11KW is shown in Figures 4(d)-(f). The INC-MPPT control algorithm is employed for extraction of maximum solar-PV power which delivers to critical load power as constant. During the grid-islanding period, the utility-grid supply power drops to 0W and then the solar-PV powered VSI of MF-DVR injects the requisite active-power of nearly 9.5 KW to achieve the critical load power of 9.9 KW as depicted in Figure 4(g).

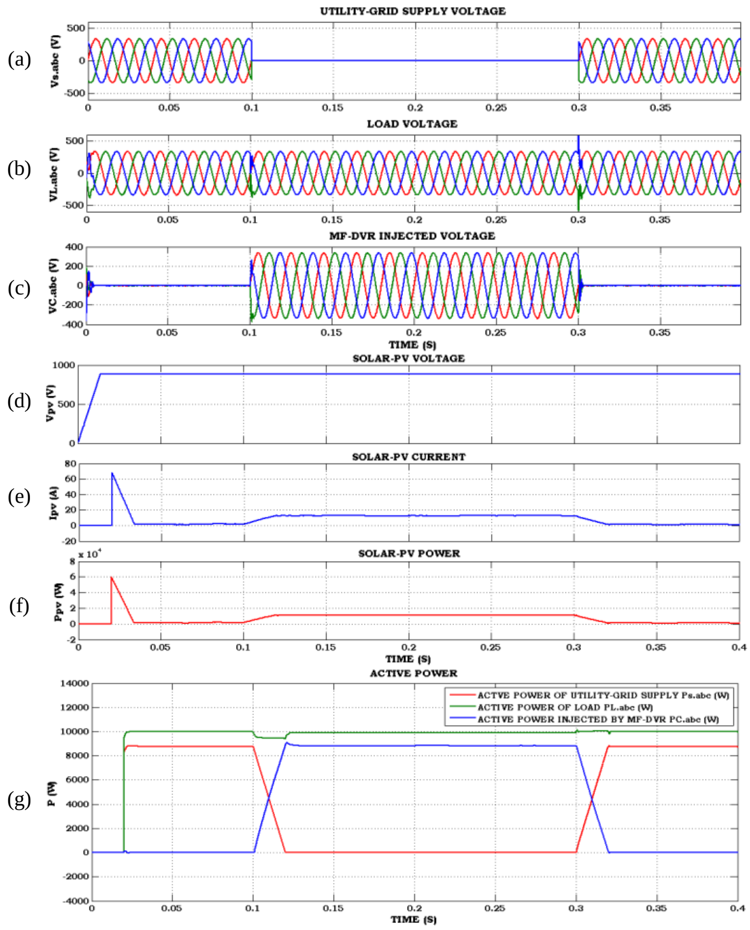

Figure 4. Simulation results of solar-PV integrated MF-DVR for compensation of grid-islanding issues, (a) utility-grid supply voltage, (b) load voltage, (c) MF-DVR injected voltage, (d) solar-PV voltage, (e) solar-PV current, (f) solar-PV power, and (g) active power

4.2. Solar-PV integrated MF-DVR for compensation of voltage-related PQ issues

As shown in Figure 5, the simulated results of solar-PV integrated MF-DVR for compensation of voltage-related PQ issues. The grid connected distribution system is powered by a supply voltage of 415 Vrms with a supply frequency of 50 Hz to drive the critical load system. In this case, the voltage related PQ issues are occurred in utility-grid supply such as voltage sag-swells and voltage harmonics under certain transition time-period affecting the critical load voltage. During pre-sag case before time t=0.4 sec, the supply voltage is kept constant at a value of 340 V and the voltage sag of 0.5p.u of supply voltage has been applied in between 0.4 sec <t<0.6 sec, the source voltage is slightly decreased with a value of 170 V. During this time period, the SRF controlled solar-PV fed MF-DVR injecting the required voltage of 170 V to keep load voltage as constant with a value of 340 V is depicted in Figures 5(a)-(c). The above compensation has been initiated by energizing the DC-link capacitor through extracted solar-PV voltage of 880 V with a solar-PV current of 7 A to furnish required solar-PV power of 6 KW is shown in Figures 5(d)-(f). The INC-MPPT control algorithm is employed for extraction of maximum solar-PV power which delivers to critical load power as constant. During the voltage-sag period, the utility-grid supply power decreases to 4.4 KW and then the solar-PV powered VSI of MF-DVR injects the requisite active-power of nearly 5.5 KW to achieve the critical load power of 9.9 KW as depicted in Figure 5(g).

During pre-swell case before time t=0.7 sec, the source voltage is kept constant at a value of 340 V and the voltage swell of 1.5 p.u of supply voltage has been applied in between 0.7 sec <t<0.9 sec, the supply voltage is increased with a value of 510 V. During this time period, the SRF controlled solar-PV fed MF-DVR injecting/extracted the required voltage of -170 V to keep load voltage as constant with a value of 340 V is depicted in Figures 5(a)-(c). The above compensation has been initiated by energizing the DC-link capacitor through extracted solar-PV voltage of 880 V with a solar-PV current of -4A to furnish required solar-PV power of -5 KW is shown in Figures 5(d)-(f). The INC-MPPT control algorithm is employed for extraction of maximum solar-PV power which delivers to critical load power as constant. During the voltage-swell period, the utility-grid supply power increased to 12.8 KW and then the solar-PV powered VSI of MF-DVR injects the requisite active-power of nearly -2.9 KW to achieve the critical load power of 9.9 KW as depicted in Figure 5(g).

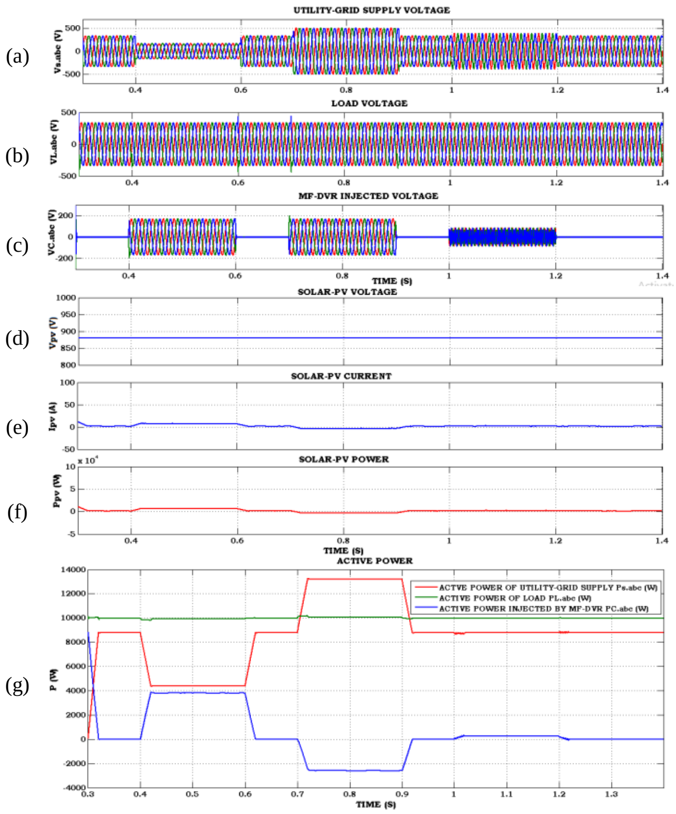

Figure 5. Simulation results of solar-PV integrated MF-DVR for compensation of voltage related power-quality issues, (a) utility-grid supply voltage, (b) load voltage, (c) MF-DVR injected voltage, (d) solar-PV voltage, (e) solar-PV current, (f) solar-PV power, and (g) active power

The supply voltage is affected by 5th and 7th order harmonics during voltage harmonics, between 1 sec <t<1.2 sec, causing a serious voltage harmonics injection into grid connected distribution system. During this time, the series-connected VSI of the SRF controlled solar-PV fed MF-DVR injects requisite voltage based on the operation of in-phase opposition principle to mitigate the voltage harmonics in the load and attains harmonic-free response. The THD analysis of supply voltage during harmonic presence achieves 20.62% and critical load voltage during harmonic compensation by solar-PV fed DVR with a value of 0.58%, which is well within IEEE-519/2014 standards compensated by series connected VSI of SRF controlled solar-PV fed MF-DVR as shown in Figure 6. The THD comparisons of supply voltage and critical load voltage of with and without solar-PV fed MF-DVR are illustrated in Table 2.

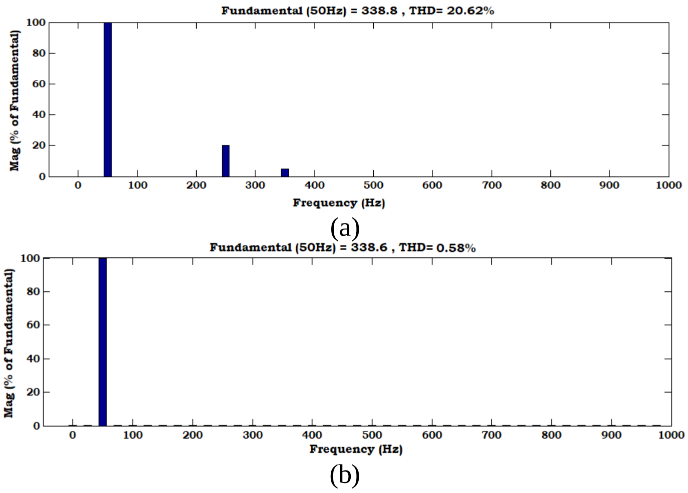

Figure 6. THD spectrum of utility-supply voltage and critical load voltage under SRF controlled solar-PV fed MF-DVR, (a) THD spectrum of utility-supply voltage and (b) THD spectrum of critical load voltage

Table 2. THD comparisons of supply voltage and load voltage of both SRF controlled solar-PV fed MF-DVR

THD (%)	Supply voltage	Critical load voltage
Without MF-DVR	20.62%	20.62%
With SRF controlled MF-DVR	20.62%	0.58%

5. CONCLUSION

The critical evaluation of proposed SRF controlled solar-PV fed MF-DVR enhancing the grid-islanding issues and voltage type PQ issues in the utility-grid linked distribution network. In this work, an efficient solar-PV provides the requisite energy during grid-islanding to make critical load voltage as constant, balanced and sinusoidal wave-shape. Moreover, the solar-PV fed MF-DVR mitigates the voltage related issues such as voltage sags-swells, voltage harmonics in supply voltage to make critical load voltage as balanced nature and sinusoidal wave-shape. The proposed scheme delivering the requisite load demand and enhancing the load voltage which is well within improved PQ specifications and also provides the constant and uninterruptible power support and also have good PQ enhancement features. The THD analysis of supply voltage during harmonic presence has been measured as 20.62% and load voltage during SRF controlled solar-PV fed MF-DVR is measured as 0.58%, which is limited to IEEE-519/2022 limitations.

FUNDING INFORMATION

Authors state no funding involved.

AUTHOR CONTRIBUTIONS STATEMENT

This journal uses the Contributor Roles Taxonomy (CRediT) to recognize individual author contributions, reduce authorship disputes, and facilitate collaboration.

Name of Author	C	M	So	Va	Fo	I	R	D	O	E	Vi	Su	P	Fu
Tharinaematam Bhavani	✓	✓	✓	✓	✓	✓		✓	✓	✓			✓	
Durgam Rajababu		✓				✓		✓	✓	✓	✓	✓		
Md Mujahid Irfan	✓		✓	✓			✓			✓	✓		✓	✓

C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

Authors state no conflict of interest.

DATA AVAILABILITY

Data availability is not applicable to this paper as no new data were created or analyzed in this study.

REFERENCES

[1] M. K. Saini and R. Kapoor, "Classification of power quality events - A review," *International Journal of Electrical Power and Energy Systems*, vol. 43, no. 1, pp. 11–19, Dec. 2012, doi: 10.1016/j.ijepes.2012.04.045.

[2] L. Xuefeng, L. Kaiju, L. Weiqiang, M. Chaoxu, and W. Dan, "A brief analysis of distributed generation connected to distribution network," in *Proceedings - 2018 33rd Youth Academic Annual Conference of Chinese Association of Automation, YAC 2018*, May 2018, pp. 795–799, doi: 10.1109/YAC.2018.8406479.

[3] G. Vikash, A. Ghosh, and S. Rudra, "Integration of distributed generation to microgrid with virtual inertia," in *2020 IEEE 17th India Council International Conference, INDICON 2020*, Dec. 2020, pp. 1–6, doi: 10.1109/INDICON49873.2020.9342377.

[4] K. Vinothkumar and M. P. Selvan, "DG planning method for enhancement of voltage stability margin in distribution system," in *PEDES 2012 - IEEE International Conference on Power Electronics, Drives and Energy Systems*, Dec. 2012, pp. 1–6, doi: 10.1109/PEDES.2012.6484414.

[5] J. Xiong, S. Liu, X. Wang, S. Zhu, J. Zheng, and K. Meng, "A stability enhancement method for inverter-based distributed generation systems," in *IEEE Power and Energy Society General Meeting*, Jul. 2015, vol. 2015-September, pp. 1–4, doi: 10.1109/PESGM.2015.7285737.

[6] J. Sridevi, V. U. Rani, and B. L. Rao, "Integration of renewable DGs to radial distribution system for loss reduction and voltage profile improvement," in *2019 IEEE International Conference on Electrical, Control and Instrumentation Engineering, ICECIE 2019 - Proceedings*, Nov. 2019, pp. 1–6, doi: 10.1109/ICECIE47765.2019.8974670.

[7] M. Shafiullah, S. D. Ahmed, and F. A. Al-Sulaiman, "Grid integration challenges and solution strategies for solar PV systems: a review," *IEEE Access*, vol. 10, pp. 52233–52257, 2022, doi: 10.1109/ACCESS.2022.3174555.

[8] R. Panigrahi, S. K. Mishra, and S. C. Srivastava, "Grid integration of small-scale photovoltaic systems-a review," in *2018 IEEE Industry Applications Society Annual Meeting, IAS 2018*, Sep. 2018, pp. 1–8, doi: 10.1109/IAS.2018.8544503.

[9] B. Banfield, P. Ciufo, and D. A. Robinson, "The technical and economic benefits of utility sponsored renewable energy integration," in *2017 Australasian Universities Power Engineering Conference, AUPEC 2017*, Nov. 2018, vol. 2017-November, pp. 1–6, doi: 10.1109/AUPEC.2017.8282489.

[10] K. Moloi, Y. Hamam, and J. A. Jordaan, "Optimal location of DGs into the power distribution grid for voltage and power improvement," in *2020 IEEE PES/IAS PowerAfrica, PowerAfrica 2020*, Aug. 2020, pp. 1–5, doi: 10.1109/PowerAfrica49420.2020.9219938.

[11] X. P. Zhang and Z. Yan, "Energy quality: a definition," *IEEE Open Access Journal of Power and Energy*, vol. 7, pp. 430–440, 2020, doi: 10.1109/OAJPE.2020.3029767.

[12] J. Yaghoobi, A. Abdullah, D. Kumar, F. Zare, and H. Soltani, "Power quality issues of distorted and weak distribution networks in mining industry: a review," *IEEE Access*, vol. 7, pp. 162500–162518, 2019, doi: 10.1109/ACCESS.2019.2950911.

[13] T. Tarasiuk *et al.*, "Review of power quality issues in maritime microgrids," *IEEE Access*, vol. 9, pp. 81798–81817, 2021, doi: 10.1109/ACCESS.2021.3086000.

[14] S. Singh and S. S. Letha, "Various custom power devices for power quality improvement: a review," in *2018 International Conference on Power Energy, Environment and Intelligent Control, PEEIC 2018*, Apr. 2018, pp. 689–695, doi: 10.1109/PEEIC.2018.8665470.

[15] E. Hossain, M. R. Tur, S. Padmanaban, S. Ay, and I. Khan, "Analysis and mitigation of power quality issues in distributed generation systems using custom power devices," *IEEE Access*, vol. 6, pp. 16816–16833, 2018, doi: 10.1109/ACCESS.2018.2814981.

[16] T. A. Kumar and L. S. Rao, "Improvement of power quality of distribution system using ANN-LMBNN based D-STATCOM," in *2017 Innovations in Power and Advanced Computing Technologies (i-PACT)*, Apr. 2017, vol. 2017-Janua, pp. 1–6, doi: 10.1109/IPACT.2017.8245211.

[17] J. V. Lakshmi* and L. S. Rao, "Power quality improvement using intelligent fuzzy-VLLMS based shunt active filter," *International Journal of Recent Technology and Engineering (IJRTE)*, vol. 8, no. 6, pp. 1004–1012, Mar. 2020, doi: 10.35940/ijrte.f7372.038620.

[18] C. Tu *et al.*, "Dynamic voltage restorer with an improved strategy to voltage sag compensation and energy self-recovery," *CPSS Transactions on Power Electronics and Applications*, vol. 4, no. 3, pp. 219–229, Sep. 2019, doi: 10.24295/CPSSTPEA.2019.00021.
[19] B. Bae, J. Jeong, J. Lee, and B. Han, "Novel sag detection method for line-interactive dynamic voltage restorer," *IEEE Transactions on Power Delivery*, vol. 25, no. 2, pp. 1210–1211, Apr. 2010, doi: 10.1109/TPWRD.2009.2037520.
[20] Vimlesh, V. Mukherjee, and B. Singh, "Hybrid GA-MCS based optimization for integration of DG, DVR, and DSTATCOM planning in distribution networks," *International Transactions on Electrical Energy Systems*, vol. 31, no. 12, Dec. 2021, doi: 10.1002/2050-7038.13223.
[21] M. V. G. Varaprasad *et al.*, "Design and analysis of PV fed high-voltage gain DC-DC converter using PI and NN controllers," *Ain Shams Engineering Journal*, vol. 14, no. 8, p. 102061, Aug. 2023, doi: 10.1016/j.asej.2022.102061.
[22] M. Kesler and E. Ozdemir, "Synchronous-reference-frame-based control method for UPQC under unbalanced and distorted load conditions," *IEEE Transactions on Industrial Electronics*, vol. 58, no. 9, pp. 3967–3975, Sep. 2011, doi: 10.1109/TIE.2010.2100330.
[23] G. Satyanarayana, K. N. V. Prasad, G. R. Kumar, and K. L. Ganesh, "Improvement of power quality by using hybrid fuzzy controlled based IPQC at various load conditions," in *2013 International Conference on Energy Efficient Technologies for Sustainability*, Apr. 2013, pp. 1243–1250, doi: 10.1109/ICEETS.2013.6533565.

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