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PV Array based DSTATCOM using Bidirectional Converter and Control

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ABSTRACT: A DSTATCOM consisting of a switched capacitor based MLI and is used for the load compensation in a three-phase system is presented in this paper. The time domain SRF control technique is used for the PFC and ZVR under DTT MLI topology. This MLI power conversion system consists of a course DC–AC inverter. The course DC–AC inverter involves a full-connect inverter and a T-type inverter. To lessen the dc-connect voltage, a new geography that upgraded the voltage acquire from half to solidarity has been introduced. Double coasting capacitors amidst self-voltage adjusting ability are coordinated to accomplish a voltage-boosting gain of 1.5. In this paper present D-STATCOM hybrid system integrating renewable energy sources (specifically photovoltaic (PV) systems with Maximum Power Point Tracking (MPPT)) and a bidirectional converter for interfacing with a three-phase grid. The proposed model is implement MATLAB programming utilizing SIMULINK and SIMPOWERSYSTEM tool and the power factor is achieved 0.9974 with DSTATCOM and 0.8974 without D-STATCOM.

KEYWORD: T-Type Multi-level inverter (T-Type MLI), Converter, D-STATCOM, Power Factor

I. INTRODUCTION

The essential precepts of the power frameworks that are being used over the past century have been something similar. Although the fundamental tenets have not been revised, technology has significantly altered their performance. The interaction has been driven by a major law of material science. Because of the close to nonappearance of putting away the energy in a primary way in an electrical matrix, at each second the quantum of energy delivered must be comparable to the energy that is taken up by the heaps. The inertia of large generators actually contains some of the energy. This inertia can compensate for some minor imbalances in the continuum that can cause minor deviations in frequency and voltage under certain constraints. However, when these are violated, electromechanical oscillations, significant frequency shifts, and voltage fluctuations may occur.

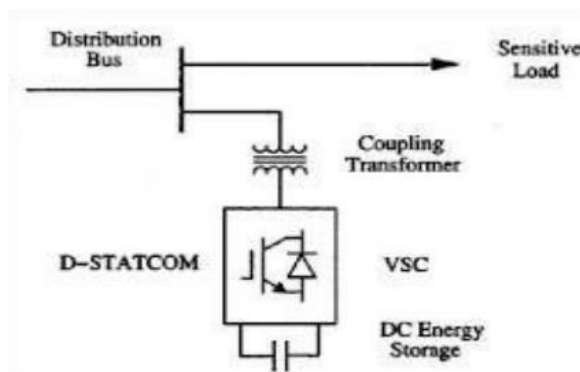


Figure 1: DSTATCOM

It may result in widespread blackouts if adequate care is not taken to implement corrective measures at the appropriate times. Automation allows for the determination and implementation of these measures through generator control [1, 2].

The Distribution Static Compensator (DSTATCOM), which is based on a voltage source inverter and is used to correct bus voltage sags, is similar to the Dynamic Voltage Restorer (DVR) in many ways. A standard power conveyance transformer is utilized for shunting to the conveyance organization. Constantly changing inductive or capacitive association remuneration can be produced by DSTATCOM at a step up its top MVA rating. The AC signal serves as a reference as the DSTATCOM continuously examines the line waveform. As a result, it can provide the appropriate amount of leading/lagging relative current compensation to reduce voltage fluctuations. The primary components of the DSTATCOM are depicted in Figure 1. These include a DC capacitor, at least one component of the inverter, and a transformer that can match the inverter's output to the line voltage. Additionally, a PWM-based control strategy is required. In this DSTATCOM implementation, a three-phase AC voltage is created from a DC voltage. This is synchronized and associated with the air conditioner line through a capacitor (AC channel) and a little tie reactor [3, 4].

II. MULTILEVEL INVERTER

Well before, the expression MLI was planned. There are a few applications where these MLIs are utilized including fans, transports, blowers, modern drives, laminators and inexhaustible sources. MLIs can endure better nature of force, diminished misfortune in exchanging, more noteworthy electromagnetic similarity, better voltage, and lesser number of music. Initially the flowed MLIs (CMLI) have been formed, which was followed later by the advancement of diode clamped MLIs which were again trailed by flying capacitor MLIs. The first geography, the CMLI involves a series association of the H spans. In the flying capacitor MLIs, for bracing the result voltage, drifting capacitors are utilized while a series capacitor bank is utilized in the diode braced MLI. Using distinct mechanisms, the three topologies produce the required output. There are disengagement transformers that are related with the H-span. The H-bridge cascaded MLIs were used to differentiate the DC input sources. Nonetheless, flying capacitors or bracing diodes were not required. The absence of voltage imbalance is the main advantage of employing the cascaded MLI. In correlation with the flying capacitor MLIs and diode clamped MLIs, there are less parts that are utilized by the CMLI [5, 6].

In the last ten years, a significant amount of money has been invested in renewable energy sources (RES) to reduce carbon emissions. These initiatives have resulted in utility-scale wind and solar farms. Due to the fact that megawatt-scale plants' operations necessitate high-voltage MLIs, there has been an increase in their use. MLIs fall into three main categories: Neutral Point-Clamped (NPC), Flying-Capacitor (FC) and cascaded H-bridge (CHB) geographies. However, some of the researchers have also suggested hybrids of the aforementioned types. MLIs have a number of advantages over their two-level counterparts, including lower loads' dv/dt stress, lower electromagnetic interference, lower filter requirements, and improved power quality. Geographies that need least number of switches, diodes, door drivers and DC sources, with the expansion in the voltage levels, have been the focal point of consideration for the new MLIs in the new years.

The clever geographies endeavor to accomplish least voltage weight on switches as well as the quantity of switches in the ongoing way or the misfortunes. Several of the new CHB topologies require the generation of higher voltage levels by utilizing the Switched-Capacitor (SC) or Switched Source (SS) MLI configurations. The MLIs aim to generate higher voltage output levels by employing a series of self-balancing capacitors and a single power supply or a small number of power supplies.

Due to the increased number of series diodes, they also suffer from the disadvantage of absorbing more power and voltage stress from switches. Numerous SS MLIs have been recommended; In contrast to the SC configuration, which has capacitors switched in series/parallel combinations, the SS configuration can achieve voltage levels using multiple DC sources [8, 9].

III. PROPOSED METHODOLOGY

Depends on the nature of the application MLI is selected, in this paper Switched-Capacitor Based Multilevel Inverter and SRF control technique for DSTATCOM is used to extract ref.

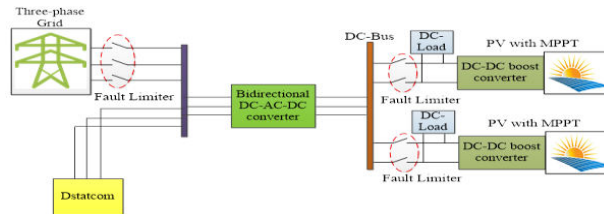


Fig. 2: Structure of Proposed Methodology

Currents to generate pulses (PWM) for the proposed topology represented in fig 2.

Three-Phase Grid: The three-phase power supply system is connected to the hybrid energy system through a **fault limiter** to manage abnormal conditions such as overcurrent during faults.

DSTATCOM: A DSTATCOM (Distribution Static Compensator) is a power electronic device used in power distribution networks to improve power quality. Here's an explanation of its purpose and functionality:

Purpose of DSTATCOM

1. **Voltage Regulation:** Maintains a stable voltage profile at the point of connection, especially under fluctuating load conditions.
2. **Power Factor Correction:** Improves the power factor by compensating for reactive power (both inductive and capacitive).
3. **Harmonic Mitigation:** Reduces harmonics in the current drawn by nonlinear loads, enhancing power quality.
4. **Load Balancing:** Balances unbalanced loads to reduce the negative impact on the power system.

How DSTATCOM Works

- **Basic Structure:**
 - It consists of a Voltage Source Converter (VSC), a DC energy storage device (capacitor), and coupling equipment like a transformer.
- **Operation:**
 - The VSC generates a controllable AC voltage that is in phase with the grid voltage or adjusted as required.
 - By varying the magnitude and phase of this generated voltage, the DSTATCOM can inject or absorb reactive power to/from the grid.
 - It responds to voltage sags, swells, or imbalances by quickly injecting the required compensation.

Fault Limiter: Located both at the grid connection and the DC loads. This device is essential for protecting the system by limiting fault currents that could damage components.

Bidirectional DC-AC-DC Converter: Acts as a central unit for power exchange:

- Converts AC power from the grid to DC (rectification) to supply the DC bus.
- Converts DC power from the DC bus to AC (inversion) to feed into the grid or supply AC loads when needed.
- Facilitates bidirectional power flow for grid integration, allowing power to flow to/from the grid based on demand and supply.

DC-Bus: A centralized DC power line that connects the various energy sources (PV panels), storage systems, and loads. It acts as a backbone for distributing DC power.

DC-Load: Devices or systems that operate directly on DC power, such as battery charging systems or DC motors.

PV with MPPT (Maximum Power Point Tracking): Photovoltaic (solar panel) systems equipped with MPPT controllers to maximize the energy harvested by continuously adjusting the operating point of the PV system for optimal power output.

DC-DC Boost Converter: Increases the DC voltage from the PV panels to a higher level suitable for the DC-bus or other loads. Works in conjunction with the MPPT is to ensure efficient energy transfer.

CIRCUIT TOPOLOGY

For the most part, the inverter circuits are delegated VSI and CSI in light of the info source. VSI Innovation is generally skillful for medium voltage and high force applications [9]. The CSI is fundamentally utilized in additional powerful applications, which is equipped for securing the framework against hamper.

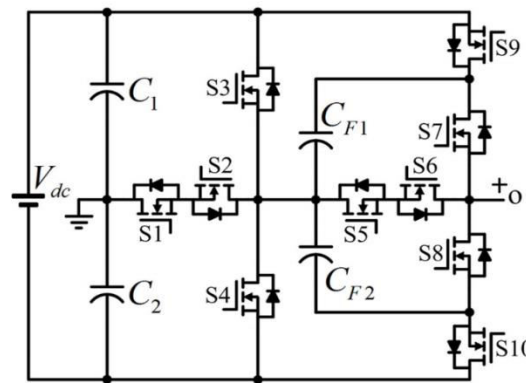


Fig 3: Proposed Circuit Configuration of MLI Connected to Per Phase of the System

The VSI can be sorted into two kinds dependent on control techniques utilized: PulseWidth Modulated (PWM) inverters and Square Wave (SW) Inverters.

Among these two, PWM inverters have more predominance and have broad applications. Due to its advantages over conventional inverters, A DSTATCOM with switched Capacitor-based MLI topology is prospective in this paper to reduce the layout complicity of the system (i.e., transformer less system) and dc-link voltage (in this case 250v), shown in figure 3. This topology consists of 10 IGBTs and two Floating capacitors connected per phase to attain voltage earnings of 1.5. It produces seven levels from $-1.5V_{dc}$ to $1.5V_{dc}$. Symmetrical operation of two floating capacitors for each half rhythm results in their self-balancing voltages.

Table I: Voltage across Switches during each Voltage Level

	[0]	[+1]	[+2]	[+3]	[-1]	[-2]	[-3]
S _{W1}	Z	V*/2	Z	Z	Z	Z	V*/2
S _{W2}	Z	Z	Z	0.5V*	0.5V*	Z	Z
S _{W3}	V*/2	V*	V*/2	0	0	V*/2	V*
S _{W4}	0.5V*	Z	0.5V _{dc}	V*	V*	V*/2	Z
S _{W5}	0	Z	0	0	V*	V*	V*
S _{W6}	0	V*	V*	V*	0	0	0
S _{W7}	V*	Z	Z	Z	2V _{dc}	2V _{dc}	2V _{dc}
S _{W8}	V*	2V _{dc}	2V _{dc}	2V _{dc}	Z	Z	Z
S _{W9}	V*/2	Z	V*/2	V*	V*	V*/2	Z
S _{W10}	V*/2	V*	V*/2	Z	Z	V*/2	V*

Z = Zero, * = DC

Table II: Flow of Current through Switches during Each Voltage Level

	[0]	[+1]	[+2]	[+3]	[-1]	[-2]	[-3]
SW ₁	I _L	[0]	I _L	Z	Z	I _L	Z
SW ₂	I _L	Z	i _L	Z	Z	I _L	Z
SW ₃	Z	Z	Z	I _L & I _C	I _L	Z	Z
SW ₄	Z	I _C	Z	Z	Z	Z	I _L & I _C
SW ₅		Z	Z	Z	Z	Z	Z
SW ₆	I _L	Z	Z	Z	Z	Z	Z
SW ₇	Z	i _L	i _L	I _L	Z	Z	Z
SW ₈	Z	Z	Z	Z	I _L	I _L	I _L
SW ₉	Z	I _L & I _C	Z	Z	Z	Z	I _L
SW ₁₀	Z	Z	Z	I _L	I _L & I _C	Z	Z

The Control logic of switches is given in Table I and Table II. Switches are classified into five pairs, (SW₁, SW₂), (SW₃, SW₄) (SW₅, SW₆), (SW₇, SW₈), (SW₉, SW₁₀). These switch pairs perform symmetrical operations and produce equal power losses. During level or State [0], Four switches are in conduction mode namely, S₁, S₂, S₅, S₆, and producing V_o=0. For State [+2] [-2], load current flows through three switches namely (S₁, S₂, S₃) and (S₁, S₂, S₈) producing V_o=V_{dc} & -V_{dc} respectively, Now During level [+1], [-1], [+3], [-3], only two switches remain in conduction mode i.e. load current flows through two switches only, namely (S₄, S₉), (S₃, S₈), (S₃, S₇), (S₄, S₈), and producing V_o=0.5V_{dc}, -0.5V_{dc}, 1.5V_{dc}, -1.5V_{dc} respectively.

PROPOSED CONTROL TECHNIQUE

The Synchronous Reference Frame (SRF) controller is employed to transform the system's three-phase signals (voltages or currents) from the stationary reference frame (abc) into the rotating reference frame (dq), making it easier to separate and control active and reactive components.

Key Functions of the SRF Controller in DSTATCOM:

- **Reactive Power Compensation:**
 - The SRF controller separates the reactive component from the load current, allowing the DSTATCOM to inject or absorb reactive power as needed.
- **Harmonic Mitigation:**
 - By extracting only the fundamental components in the dq frame, the SRF controller can ensure that the DSTATCOM compensates for harmonic currents generated by nonlinear loads.

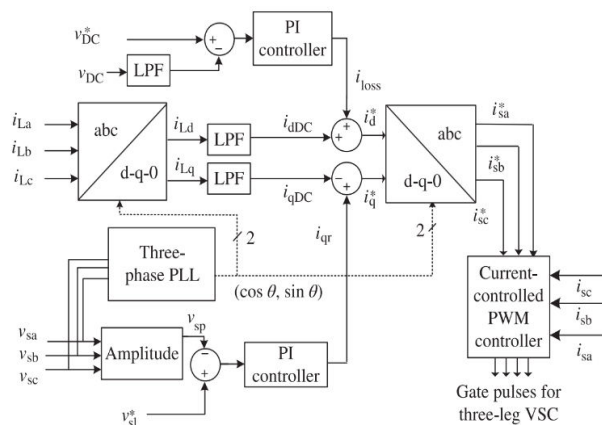


Fig. 4: SRF Control

- **Load Balancing:**
 - It identifies imbalances in load currents, enabling the DSTATCOM to inject compensating currents to balance the system.
- **Voltage Regulation:**
 - The SRF controller maintains the voltage at the point of common coupling (PCC) by controlling the reactive power flow.

The conversion of load currents into dq-0 frame is performed as:

$$\begin{bmatrix} I_{LD} \\ I_{LQ} \\ I_{L0} \end{bmatrix} = \frac{2}{3} \begin{bmatrix} \cos\theta & -\sin\theta & \frac{1}{2} \\ \cos(\theta - \frac{2\pi}{3}) & -\sin(\theta - \frac{2\pi}{3}) & \frac{1}{2} \\ \cos(\theta + \frac{2\pi}{3}) & \sin(\theta - \frac{2\pi}{3}) & \frac{1}{2} \end{bmatrix} \begin{bmatrix} I_{LA} \\ I_{LB} \\ I_{LC} \end{bmatrix}$$

A Phase-locked loop (3-Ø) is used to harmonize grid and system frequencies. DC components of I_{LD} and I_{LQ} are extracted by passing these d-q current intrinsic through an LPF filter. Fundamental and Harmonic intrinsic are as:

$$\begin{aligned} I_{LD} &= I_{dDC} + I_{dAC} \\ I_{LQ} &= I_{qDC} + I_{qAC} \end{aligned}$$

The output of the PI regulator at the DC transport voltage of the DSTATCOM is treated as the current (I_{Loss}) for compensation its misfortunes:

$$I_{Loss}(n) = I_{Loss}(n-1) + K_{pd} \{V_{de}(n) - V_{de}(n-1)\} + K_{id} V_{de}(n)$$

Where $V_{de}(n) = V_{DC}^* - V_{DC}(n)$ is the mistake between the reference (V_{DC}^*) and the detected (V_{DC}) DC voltage at the nth examining moment, and K_{pd} and K_{id} are the corresponding and essential increase constants of the DC transport voltage PI regulator, separately. The reference supply current (direct pivot) is:

$$I_D = I_{dDC} + I_{Loss}$$

In order to keep supply currents in phase with voltages, reverse park's transformation is done with I_D and I_Q , I_0 kept zero.

$$\begin{bmatrix} I_{SA} \\ I_{SB} \\ I_{SC} \end{bmatrix} = \frac{2}{3} \begin{bmatrix} \cos\theta & \sin\theta & 1 \\ \cos(\theta - \frac{2\pi}{3}) & \sin(\theta - \frac{2\pi}{3}) & 1 \\ \cos(\theta + \frac{2\pi}{3}) & \sin(\theta + \frac{2\pi}{3}) & 1 \end{bmatrix} \begin{bmatrix} I_D \\ I_Q \\ I_0 \end{bmatrix}$$

Phase-Locked Loop (PLL):

A PLL is essentially a closed-loop system designed to maintain a constant phase difference between its output signal and a reference input signal.

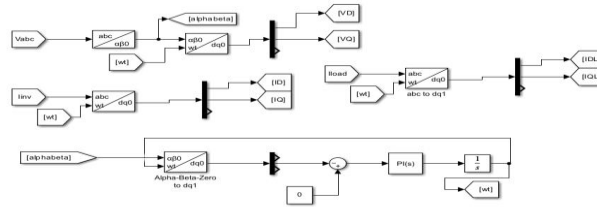


Fig. 5: Phase Locked Loop

This is achieved through adjustments made by its internal components, ensuring the output frequency is "locked" to the reference frequency.

Components of a PLL

1. **Phase Detector (PD):**
 - a. Compares the phase of the reference signal and the feedback signal.
 - b. Outputs an error signal proportional to the phase difference.
2. **Low-Pass Filter (LPF):**
 - a. Smooths the error signal by filtering out high-frequency noise.
 - b. Converts it into a steady control voltage for the oscillator.
3. **Voltage-Controlled Oscillator (VCO):**
 - a. Generates an oscillating signal whose frequency is controlled by the voltage from the LPF.
 - b. The core of the PLL.
4. **Feedback Loop:**
 - a. The output signal is fed back into the phase detector, completing the loop.
 - b. May include frequency dividers for scaling the feedback signal.

IV SIMULATION RESULT

In a three-phase electrical system, voltage and current are distributed across three conductors, each carrying an alternating current (AC) signal with the same frequency but separated in phase by 120 degrees. Figure 6 is an explanation of the key aspects of three-phase voltage and current. The voltage in each phase (Phase A, Phase B, Phase C) is sinusoidal. The three waveforms are phase-shifted by 120 degrees relative to each other.

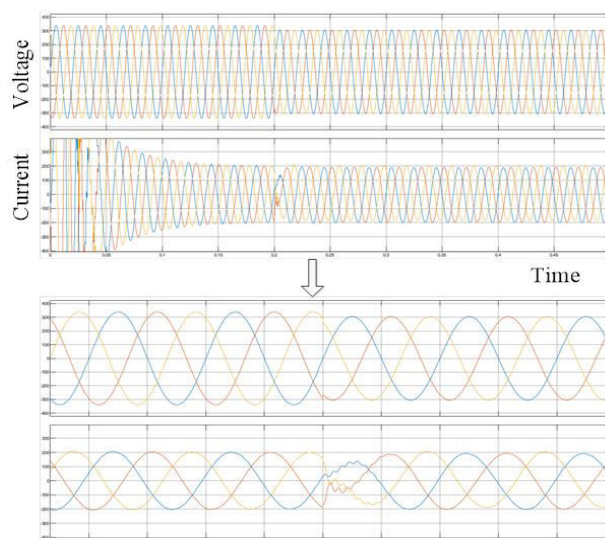


Fig. 6: Waveform of three phase voltage and current

For a three-phase AC load, the voltage and current characteristics depend on the type of connection (Star or Delta) and the load type (balanced or unbalanced).

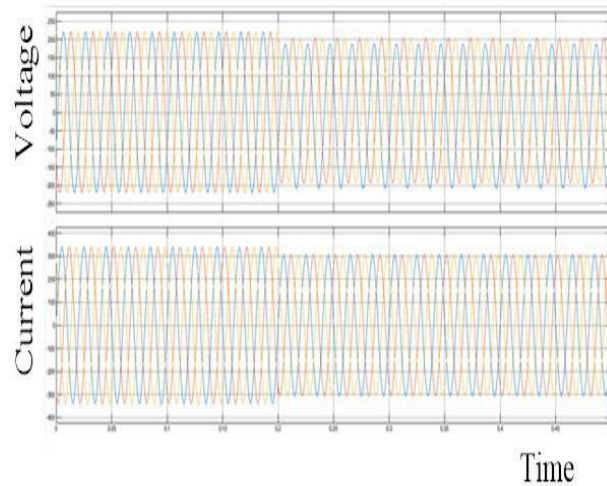


Fig. 7: Waveform of three phase AC load voltage and current

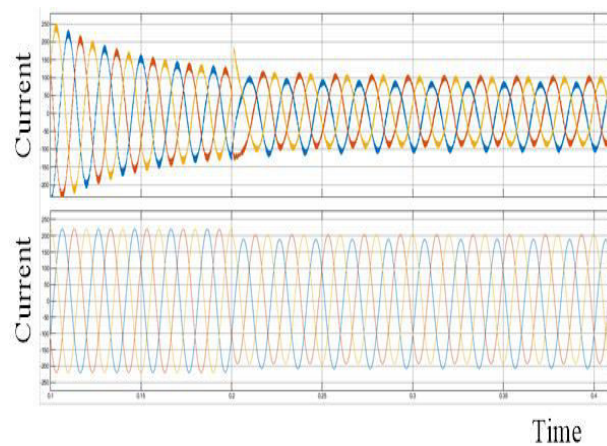


Fig. 8: Waveform of three phase AC inverter current and load current

Power factor (PF) without DSTATCOM: The power factor is a measure of how effectively electrical power is being converted into useful work output. It is the ratio of the real power (P) to the apparent power (S) in an AC circuit.

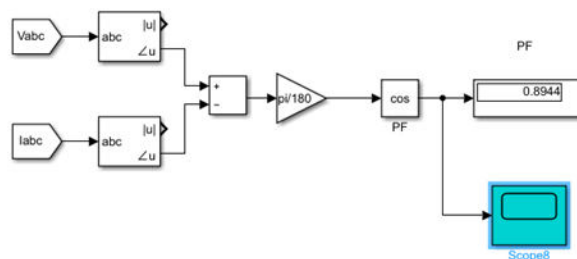


Fig. 9: Display of PF without DSTATCOM

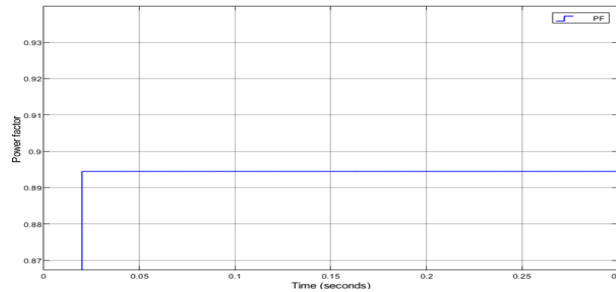


Fig. 10: Waveform of PF without DSTATCOM

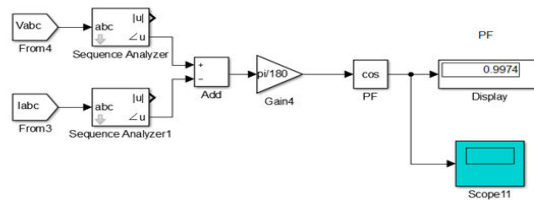


Fig. 11: Display of PF with DSTATCOM

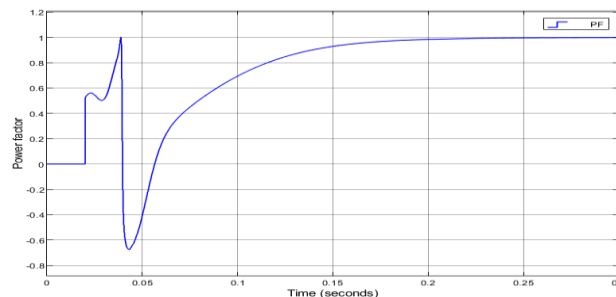


Fig. 12: Waveform of PF with DSTATCOM

THD: **Total Harmonic Distortion (THD)** is a measure of the distortion in a waveform caused by the presence of harmonics. Harmonics are multiples of the fundamental frequency of an AC signal that arise due to nonlinear loads or devices. THD quantifies the deviation of a waveform from its ideal sinusoidal shape.

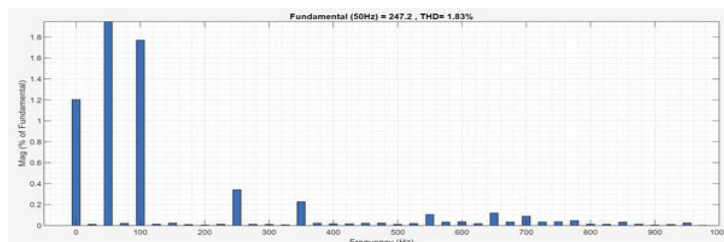


Fig. 13: THD for Phase-I

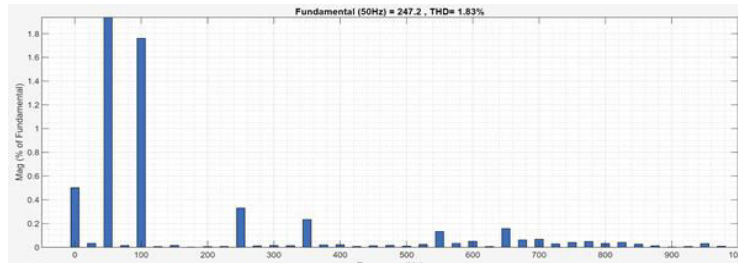


Fig. 14: THD for Phase-II

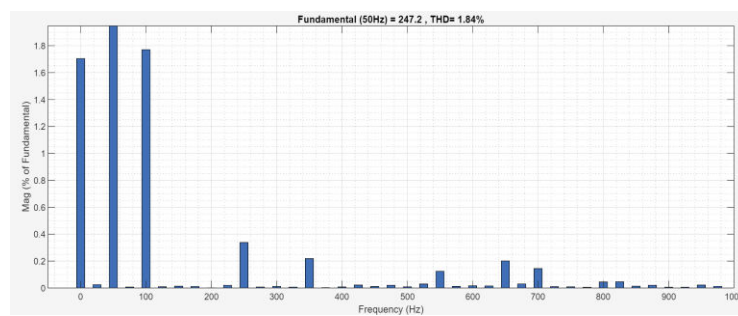


Fig. 15: THD for Phase-III

Table III: Comparison Result

	Power Factor		THD%		
	Without DSTATCOM	With DSTATCOM	Without DSTATCOM	With DSTATCOM (Base paper)	With DSTATCOM (Proposed)
Isa	0.89	0.99	49.32	2.78	1.83
Isb	0.89	0.99	49.32	2.78	1.83
Isc	0.89	0.99	49.32	2.71	1.84

V. CONCLUSION

The performance of a proposed DSTATCOM using switched-based capacitor MLI is analyzed using SRF based control scheme under nonlinear balanced /unbalanced load. The exhibition of the proposed control procedure is contrasted and the consequences of the framework in which no strategy are utilized. From recreation results, it tends to be seen that the DSTATCOM compensates supply harmonics and maintains power factor at unity. Results, showing a reduction in dc-link voltage, switching losses, and total harmonic distortion as well. SRF can be used for both PFC and ZVR. Further research can be extended to use proposed work in distribution side for distribution of stable power to the end users. PV power used as source power in the existing work can be enhanced by applying MPPT method in PV panel to yield better performance and high gain. The results obtained with study can also be verified by applying it in real time applications like solar pumping, battery charging and infrastructure less area.

REFERENCES

1. Ramyani Chakrabarty, Ravindranath Adda, "DSTATCOM implementation using Reduced Switch Single DC Source Cascaded H-bridge Multilevel Inverter", Electric Power Systems Research, ScienceDirect 2021.
2. M. Kashif, M. Hossain, F. Zhuo, S. Gautam, Design and implementation of a three-level active power filter for harmonic and reactive power compensation, Electric Power Systems Research 165 (2018) 144–156.
3. H. Khoun Jahan, M. Abapour, K. Zare, Switched-Capacitor-Based Single-Source Cascaded H-Bridge Multilevel Inverter Featuring Boosting Ability, IEEE Trans. Power Electron. 34 (2) (2019) 1113–1124

4. A.K. Yadav, K. Gopakumar, K.R. R, L. Umanand, S. Bhattacharya, W. Jarzyna, A hybrid 7-level inverter using low-voltage devices and operation with single dc-link, *IEEE Trans. Power Electron.* 34 (10) (2019) 9844–9853
5. Bhim Singh and Sunil kr., "Control of D-STATCOM Using ICOSQ Algorithm ", Department of Electrical Engineering, Indian Institute of Technology, New Delhi IEEE, 2009.
6. Bhim Singh & Jitendra Solanki, "A comparative study of Control Algorithms for DSTATCOM for load compensation", Department of Electrical Engineering, Indian Institute of Technology, New Delhi IEEE, 2006
7. T.sukanth1, D.Srinivas, M. Zefree Lazarus, K.Pritam Satsangi, "Comparative Study of Different Control Strategies For Dstatcom", Mahabubnagar-509001, Department of EEE, Dayalbagh Educational Institute, Agra-282110, India, *IJAREEIE* 2012.
8. H. Akagi, E.H. Watanable and M. Aredes, "Instantaneous power theory and application to power conditioning," Jhon Wiley & sons, New Jersey, USA, 2007.
9. B. Singh, P. Jayaprakash, and D.P. Kothari, "Three-phase four-wire dstatcom with H-bridge VSC and star/delta transformer for power quality improvement," in *Proc. of INDICON 2008*, Vol. 2, Dec. 2008, pp.412 - 417.
10. Hurng- Liahng Jou, Jinn- Chang Wu, Kuen- Der Wu, Wen- Jung Chiang and Yi- Hsun Chen, "Analysis of zig-zag Transformer applying in the three-phase Four- Wire Distribution Power System," *IEEE Trans. on Power Delivery*, vol. 20, no. 2, pp.1168- 1173, April 2005.
11. Sze Sing Lee and Kyo-Beum, "Lee Dual-T-Type Seven-Level Boost Active-Neutral-Point-Clamped Inverter", *IEEE Transactions on Power Electronics*, vol. 34, no. 7, July 2019.
12. Asmaa EL-Hosainy, Hany A. Hamed, Haitham. Z. Azazi³, E. E. El-Kholy, "A Review of Multilevel Inverter Topologies, Control Techniques, and Applications", *MEPCON, IEEE*, 2017.
13. W. Sheng and Q. Ge "A novel seven-level ANPC converter topology and its commutating strategies" *IEEE Trans. Power Electron.* vol. 33 no. 9 pp. 7496-7509 Sep. 2018.
14. A.K. Sadigh, V. Dargahi, K.A. Corzine, "Analytical determination of conduction and switching power losses in flying-capacitor-based active neutral-point-clamped multilevel converter", *IEEE Trans. Power Electron.*, vol. 31, no. 8, pp. 5473–5494, Aug. 2016.



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