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Power Quality Improvement using Three Phase Four Switch Inverter Based Dynamic Voltage Restorer with Ant Colony Optimization

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Abstract - electricity is one of the goals of electric power networks. Any disruption to electrical distribution networks results in voltage disruptions. Therefore, to minimize these disruptions for sensitive clients, a range of tactics and instruments may be employed. Dynamic voltage restorers, or DVRs, are applied in this work to handle sensitive loads' voltage swings. Ant Colony Optimization (ACO) is used to manage the coefficients of PI controllers in order to optimize voltage sag and THD in sensitive loads at the same time. The entire project was validated in MATLAB/Simulink to demonstrate how successfully the suggested solution smoothed the distorted voltage. The proposed ACO technique achieved a higher efficiency of 95.6% with a reduced THD of 1.16% when compared to the Cuckoo Search Algorithm (CSA).

***Key Words*:** Dynamic Voltage Restorer; Voltage Source Inverter, Pulse Width Modulation, Ant Colony Optimization

1. INTRODUCTION

Access to sustainable and high-quality electric power has expanded along with the sensitive industrial and residential users' continual expansion. Economic losses may be displayed in a number of ways, such as lost manufacturer competitiveness, lower manufacturing efficiency and cost, poorer quality, shorter gadget lifespan, greater maintenance costs, power outages, and power interruptions. Therefore, a manufacturing company may cut capital incredibly effectively by having access to high-quality electricity [1]. A Destructive distribution system disruptions include flicker, voltage sag, voltage swell, and power outages are caused by disturbances to the electric distribution system. One of the most significant disruptions is voltage sag, which is defined by IEEE standards as an abrupt decline in voltage magnitude of 10–90% between 0.5 cycles to 1 minute [2]. Dynamic voltage restorers (DVRs) are one sort of gadget that can deal with the impacts of voltage hang and swell in delicate situations. The most basic version of this compensator is found in the voltage source inverter, coupling transformer, and energy storage. When voltage hang is detected in a feeder finishing in a delicate burden, DVR adjusts to voltage drop by supplying enough voltage via a coupling transformer in series with the delicate purchaser. For inclusion voltage control to function effectively, a few control frameworks are used, such as sliding-mode control [4], powerful control [5], and prescient control [3]. This work presents a particular approach to deal with confront the ideal guarantee of PI regulator settings, in light of the insect provincial streamlining (ACO) computation. The model for this computation was a trade between a teacher and pupils in a homeroom. DVR execution is broke down inside the sight of diverse voltages, and the outcomes of the advised regulator are appeared differently in reference to the CSA technique to deal with exhibit the appropriateness of the proposed calculation.

2. DYNAMIC VOLTAGE RESTORER

The DVR is a vital part in the decrease of PQ worries as it effectively settle these issues and shown in Fig. 1. Really making up for voltage enlarges and lists is a definitive target of DVR in a dispersion framework. It additionally assists with things like line-voltage symphonious adjustment, transient voltage decrease, and shortcoming current limit. The recommended strategy involves DVR related to ACO to improve the framework's power quality.

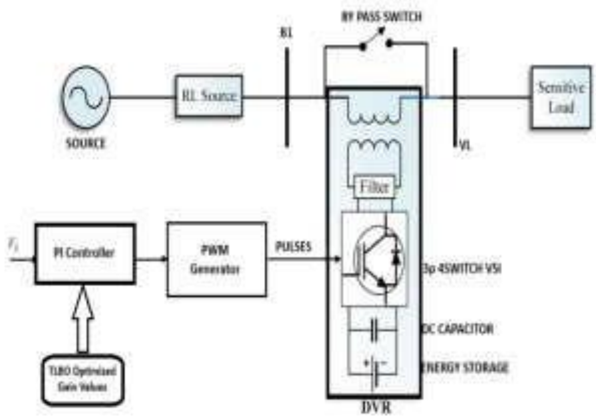


Fig. 1. Proposed DVR

2.1. OPERATING MODES

The circuit diagram in Fig. 2 shows the operation modes of DVR's

2.1.1 Protection Mode

The DVR encounters a large load current and an inrush current when the heap is in a short out scenario. To isolate the DVR from the circulation framework in case of a fault, open detour switches designated S_2 and S_3 are utilized. It utilizes change S_1's shut status to generate an alternate load current path.

2.1.2 Mode Standby Mode (VD = 0)

In this mode, the DVR short-circuits or injects less voltage to minimize losses or voltage drop across the transformer reactance. This DVR's standby mode is frequently the one that is most popular. VD is a representation of the DVR's injected voltage.

2.1.3 Injection Mode (VD > 0)

The DVR switches to infusion mode when voltage hang is detected. To finish compensation, an air conditioner voltage with the appropriate wave shape, stage, and greatness was supplied in series with the dispersion framework. Where VD is the DVR's injected voltage.

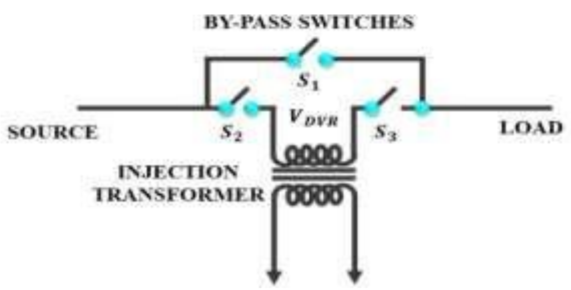


Fig. 2. Operating mode of DVR

3 3φ VSI4 WITH SWITCHS

Six power electronic switches are essential for typically working while employing a customary 3φ inverter layout. When thinking about a power circuit, it is more prudent to replace the six switches with four switches. As found in Fig. 3, this 3φ inverter design with a set number of switches brings down the inverter cost. It also displays reduced conduction errors and more straightforward door driving hardware.

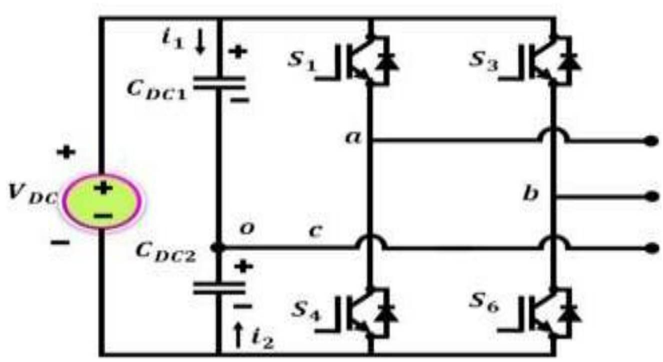


Fig. 3. 3φ 4-switch VSI

Here, the four switches are symbolized by S_1, S_2, S_4, and S_6, while the two split capacitors are shown by CDC_1 and CDC_2. The DC source voltage that was obtained from the energy stockpile is shown by the voltage V_{dc}. Stage C is linked between the split capacitors, whilst stages A and B are connected to the two inverter legs. The reciprocal conditions of the upper and lower switches are $S_4 = 1 - S_1$ and $S_6 = 1 - S_3$, respectively. The terminal voltages of the inverter are addressed by Va_1, Vb_1, and Vc_1, which are as follows:

$$V_{a1} = \frac{V_c}{3}(4S_3 - 2S_1 - 1) \tag{1}$$

$$V_{b1} = \frac{V_c}{3}(-2S_3 + 4S_1 - 1) \tag{2}$$

$$V_{c1} = \frac{V_c}{3}(-2S_3 - 2S_1 + 2) \tag{3}$$

Vc represents the voltage across the split capacitors. The exchanging capabilities linked with every leg stage are denoted by S_1 and S_3. where the inverter yield voltages are represented by Va_1, Vb_1, and Vc_1. The PWM generator offers the beats expected to the VSI modifications to work. A LC channel with the accompanying plan condition is necessary for the inverter:

$$L = \frac{Z_0}{4\pi f_c} \tag{4}$$

$$C = \frac{1}{4Z_0\pi f_c} \tag{5}$$

The PWM generator's control signals were generated using an ACO-tuned PI controller, and the associated control strategy is described below.

4 PI CONTROLLER FOR DVR

The controller is a crucial component of the DVR. In a rotating dq reference frame, closed-loop technology was used to regulate the DVR system. The PI controller supplied the necessary pulses to the PWM generator during the disruptions. Figure 5.8 depicts the DVR's PI controller circuit. In order to get the dq0 coordinate structure, which is provided as, the abc coordinate structure is altered using Eqn’s. (1), (2), and (3).

$$V_d = \frac{2}{3}\left[V_a sin\omega t + V_b \sin\left(\omega t - \frac{2\pi}{3}\right) + V_c \sin\left(\omega t + \frac{2\pi}{3}\right)\right] \tag{6}$$

$$V_q = \frac{2}{3}\left[V_a cos\omega t + V_b \cos\left(\omega t - \frac{2\pi}{3}\right) + V_c \cos\left(\omega t + \frac{2\pi}{3}\right)\right] \tag{7}$$

$$V_0 = \frac{1}{3}[V_a + V_b + V_c] \tag{8}$$

To determine the disturbance in the dq coordinates, the dq values were compared to the reference values. We also use a phase-locked loop (PLL) to detect the system's frequency.

$$error_d(t) = V_{dref} - V_{dact} \tag{9}$$

$$error_q(t) = V_{qref} - V_{qact} \tag{10}$$

The previously mentioned error signals that arise between the reference and actual values of the dq voltage are fed into the PI controller; the corresponding control circuit is shown in Fig. 4. V_{Load} displays the load voltage once it has been measured and converted to the dq_0 coordinates. The divergence between the two sets of dq voltages. The real and the reference was the PI controller input. The PWM circuit is utilized to provide proper VSI pulses by translating the outputs into ABC coordinates.

The PI controller was able to function more effectively by changing its settings. The PI parameters may be fine-tuned using a number of standard ways, but all have their downsides and nonlinearities.

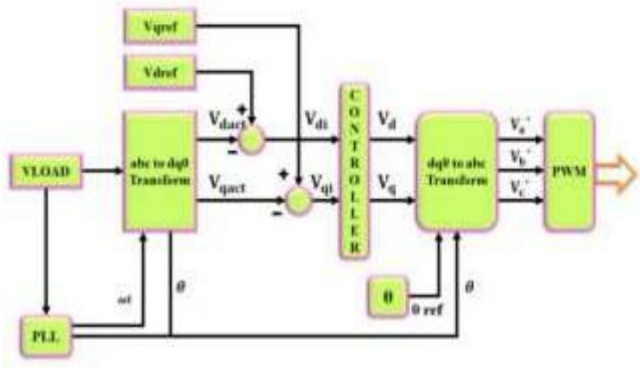


Fig. 4. Circuit diagram of PI controller

5 ANT COLONY OPTIMIZATION

In essence, the Ant Colony Optimization (ACO) approach is an agent-based system that imitates ant behavior, including cooperation and adaptability. This technology mimics the abilities of ant colonies to determine the fastest paths to food. Using pheromone information, true ants can discover food sources and swiftly return to their nests. They may also communicate indirectly without the need of visual cues. As the ant goes along, it leaves a pheromone trail, which other ants are more likely to follow in proportion to the pheromone density. Ants will discover the quickest way using this technique. Artificial ants can imitate genuine ants' every step and solve far more difficult problems, whereas natural ants use their sense of smell and movement to find food.

(i) There is a potential answer to a problem for every ant's journey.
(ii) The quantity of pheromones laid down along a trail by an ant is directly related to the quality of the associated potential solution to the situation at hand.
(iii) A higher concentration of pheromone is associated with a higher likelihood of an ant choosing one of many possible routes.

6 MODELLING OF DVR

6.1 System Configuration

Figure 5.1 displays the hybrid power distribution system. There have been various attempts to fix PQ problems because of the damage they do to the distribution system. Because it gets away of PQ problems for good, DVR is a tremendous assistance when trying to decrease their influence. Effectively adjusting for voltage spikes and dips is the end aim of DVR in a distribution system. It also aids in adjusting for line voltage harmonics, reducing transient voltage, and controlling fault current. The proposed approach combines DVR and ACO to improve the power quality of the system. The proposed strategy yielded improved results in both transient and steady-state settings. Fig.5 depicts the suggested technique as a block diagram. The system parameters are shown in Table 1.

TABLE 1. System parameters

Parameters	Values
Source voltage	$415\ V$
Frequency	$50\ Hz$
Resistance	$1000\ \Omega$
Inductance	$9.24\ mH$
Load	$16.8\ MW$
V_{DC}	$800\ V$
L_f, C_f	$5mH, 7000\ \mu F$
Switching frequency	$10\ KHz$

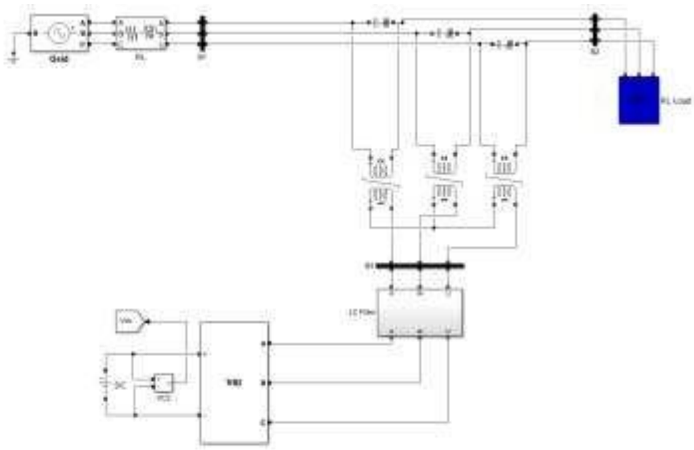


Fig. 5. System with ACO Optimized PI controller

7 SIMULATION RESULTS AND DISCUSSIONS

The output current is consistently maintained at 30A, as seen in the waveforms of the AC current and voltage for an input voltage of 400V shown in Fig. 6. The enhanced control approach of the DVR maintains a steady acquired current even when the voltage drops from 25ms to 35ms. On the other hand, the suggested method generates both the real and reference voltages, which lessen the influence of the voltage drop.

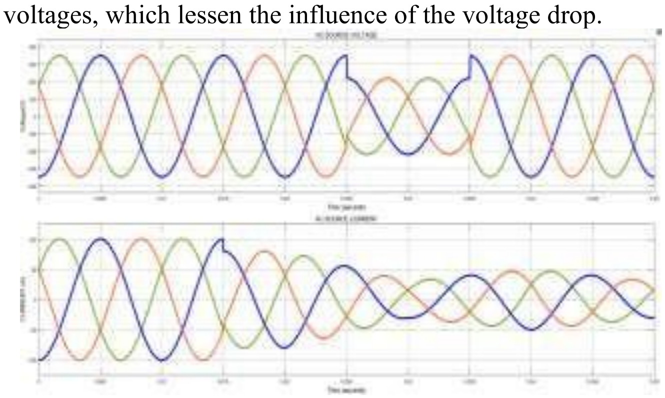
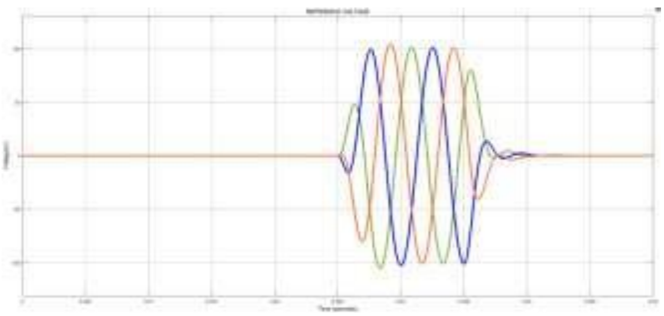
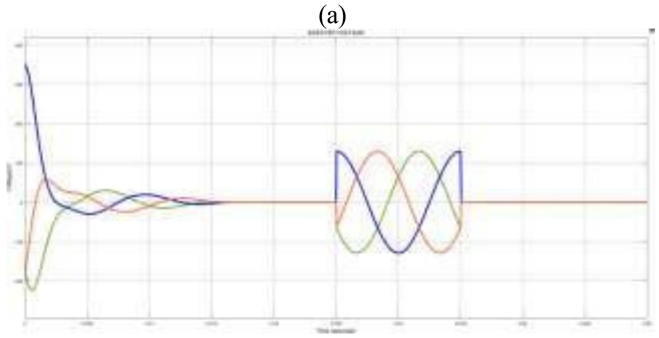


Fig. 6. AC source waveforms (a) Voltage 350V (b) Current

Fig. 7 depicts the reference and actual voltage waveforms. To determine the change in error voltage and error voltage values, the reference and actual values were compared. The voltage sag concerns with the source voltage were handled throughout the time period of 25ms to 35ms, when the reference and real voltages were established. In order to attain the greatest fitness values, ACO further optimizes these values.



(a)



(b)

Fig. 8. Waveforms for (a) reference voltage (b) actual voltage

The DC-link voltage measured by the PI controller that was adjusted for the CSA is shown in Fig. 9. A PWM generator turns the ideal outputs generated by the PI controller—thanks to the specified CSA in to pulses. These pulses control the operation of the 3-switch VSI, maintaining a constant DC link voltage. An effectively controlled DC link voltage is generated without fluctuations, and the settling time is found to be 002s. The controlled DC link voltage provides better voltage correction and fewer issues with power quality. The real power levels and reactive power are shown in Fig. 10.

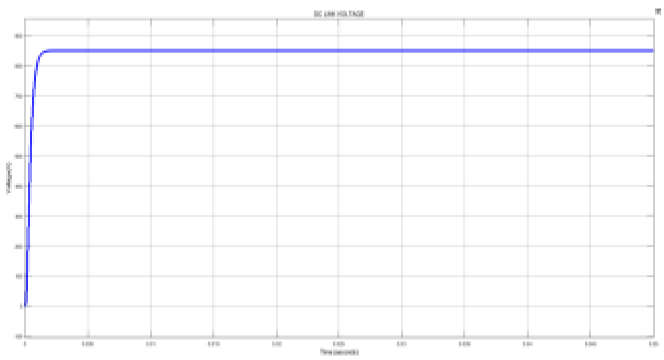
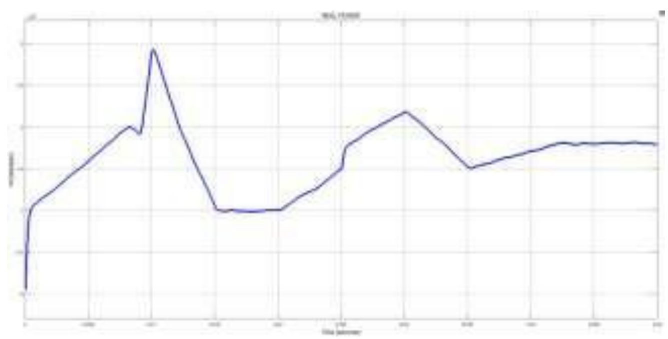
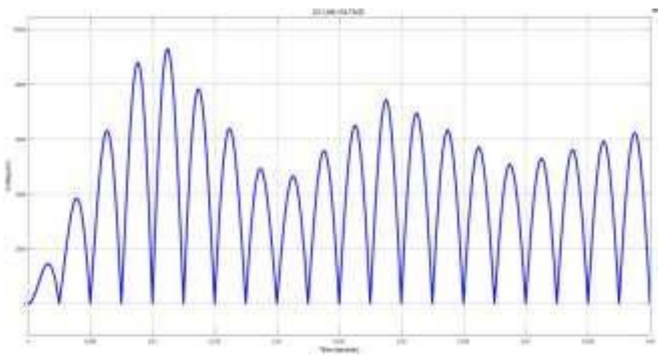


Fig. 9. Waveform for DC link voltage with CSA tuned PI controller



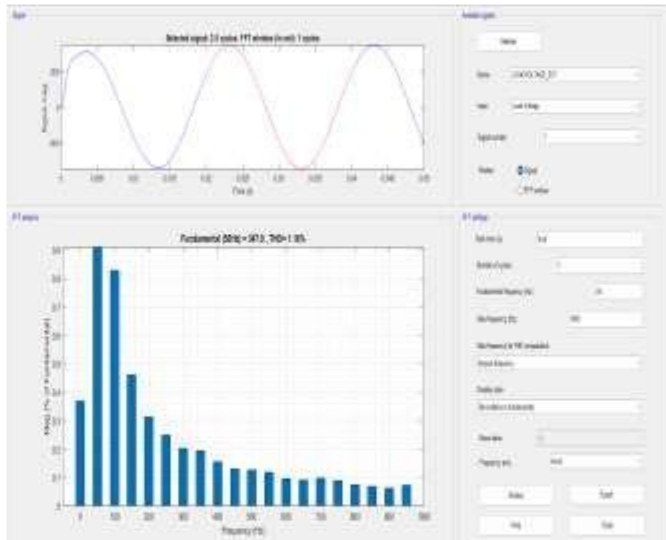
(a)



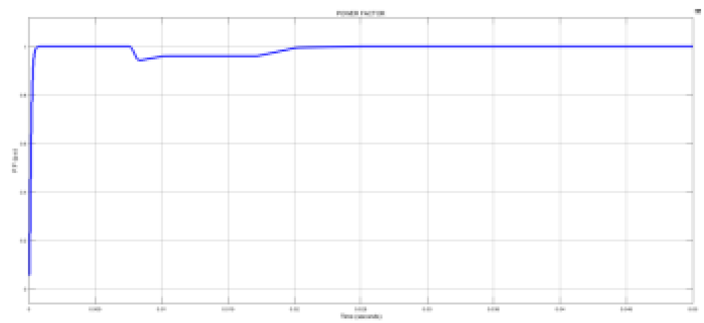
(b)

Fig. 10. Waveforms for (a) real power (b) reactive power

As seen in Fig. 11 (a), achieving a power factor of one reduces power quality issues and improves compensating. The computed THD value is 1.16%, as shown in Fig. 11 (b). The power quality and THD readings have both improved, demonstrating the effectiveness of the recommended ACO approach in lowering power quality issues. You can observe the difference between the load voltage with CSA and with ACO supporting the DVR in Table 2. Reducing voltage spikes, dips, and harmonics at the source is a breeze with the suggested ACO approach.



(a)



(b)

Fig. 11. (a) Waveforms for power factor (b) THD obtained

TABLE 2. THD Comparison

	Existing system (CSA)	Proposed system (ACO)
Load Voltage (THD %)	2.98%	1.16%

8 CONCLUSION

According to the proposed ACO algorithm, improving consumer power quality is a feasible alternative. Having a decent model is tough because, as is clear, power systems operate dynamically under both normal and fault circumstances. Consequently, clever control algorithms are required for the compensators to function swiftly and correctly. In the test settings, the recommended controller has shown good performance. While the major purpose of designing the ACO controller was to boost its performance with regard to the voltage drop of sensitive loads, it has been proven that this may also lead to improved compensation in the THD index. This controller does not need a particularly difficult design. It is worth highlighting that the offered procedure provides good results without utilizing any specialist extra equipment, which might lead to cost savings. It follows that the suggested ACO strategy beats the CSA method in terms of performance, with a reduced THD of 1.16%.

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