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# Dynamic Voltage Restorer to Mitigate Voltage Sag/Swell using Black Widow Optimization Technique with FOPID Controller

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## Abstract

The efficiency with which electrical equipment use electricity is essential for several reasons. First, superior power quality (PQ) improves efficiency and facilitates peak performance in electronic equipment. This article's goal is to make the advantages of installing a Dynamic Voltage Restorer (DVR) to enhance PQ for energy users clearer. To improve DVR dependability and user friendliness, the suggested technique uses a hysteresis voltage control system that works with variable switching frequency. Simulation findings show that voltage compensation is successful under disturbances when a black widow optimization (BWO) based Factional order proportional derivative (FOPID) controller is used. This paper proposed is to improve PQ using a BWO- FOPID controller and compare the outcomes to those achieved from a previously developed PI controller in a distribution power system using MATLAB.

**Keywords:** DVR, BWO technique, FOPID controller

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## 1. Introduction

The current power system is complicated; it is made up of a large number of producing units and loads. This complexity creates issues in terms of providing electricity that is both optimum and of high quality [1]. The availability of a stable and high-quality power supply is the primary issue of load centres; this ensures that their equipment can perform to their full potential. Nevertheless, in spite of developments in the power industry, the distribution of high-quality electricity continues to be a difficult task [2]. This is because distribution-side irregularities, such as those induced by non-linear loads, motor starting, load variations, faults, and load switching, continue to be a problem [3].

The majority of PQ problems are often voltage sags or swells, which are responsible for a considerable number of losses and also contribute to system faults [4]. DVR is used during failures in order to prevent trips and increase Fault Ride Through (FRT) performance. This is done in order to alleviate all of these issues. The capacity for

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voltage injection as well as the quantity of energy that is readily accessible are the two primary accountable aspects that define the DVR's ability to compensate [5]. The controller takes a reading of the necessary compensating voltage and then injects it using a transformer [6]. DVR is the most common method for resolving these kinds of problems because of its many advantages, including its compact size, cheap price, and rapid dynamic reaction to disruptions.

In this study, a DVR that is supplied with a DC link capacitor and a feed forward compensation approach is employed in order to alleviate PQ concerns such as voltage sag and voltage swell. The research looks at modelling, analysis, and simulation of a DVR using feed-forward vector control using MATLAB and Simulink. It also compares the DVR's performance when faults arise. A FOPID controller equipped with a DVR is being offered as a means of regaining the Low Voltage Ride Through (LVRT). The most important thing to take away from this is that you absolutely need to have a high ESS-DVR rating; else, your performance will suffer [7]. A zero active power strategy for increasing DVR performance that provided better results than the typical in-phase compensation with DVR was also offered as a way for improving DVR performance [8-9].

In addition, several nations have solved issues with their transmission and distribution systems by using Flexible AC Transmission Systems (FACTS) and Distribution FACTS (D-FACTS) devices. The expansion of power generating and transmission capabilities has become an urgent need in light of the growing demand for energy.

The contributions of this paper are, Section II describes block diagram of DVR, Section III describes BWO Technique, Section IV about FOPID controller, Section V simulation result, Section VI conclusion.

## 2. Importance of DVR

To maintain a high voltage quality, DVR is used to make adjustments to the voltage's magnitude, shape, and phase. Figure. 1 represents the architecture of the proposed DVR. Voltage restoration involves pumping the necessary magnitude into the line to counteract voltage fluctuations. In Eq.(1), Vs represents the voltage at the source, $V_L$ the voltage at the load, and Vin the voltage at the injector which is depicted in Figure. 2. This new digital video recorder (DVR) makes use of phase compensating methods. The suggested model alone compensates for voltage magnitude. Both the reference and load voltages are inputs to the controller. The proposed FOPID controller uses the voltage differential to drive pulses to the inverter through a pulse width modulation method. The inverter injects the necessary voltage into the line through an injection transformer. The boosting factor determines the amount of voltage that is injected. In the next part, the suggested controller is discussed.

From Eq. (1) where $V_{in}$ is the injected voltage, the source is voltage $V_s$, load voltage is $V_L$ represented in Figure. 2.

$$V_{in} = V_L - V_S \tag{1}$$

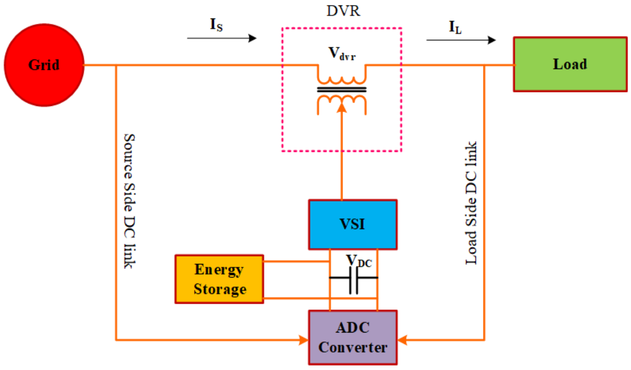


**Figure 1.** DVR Architecture

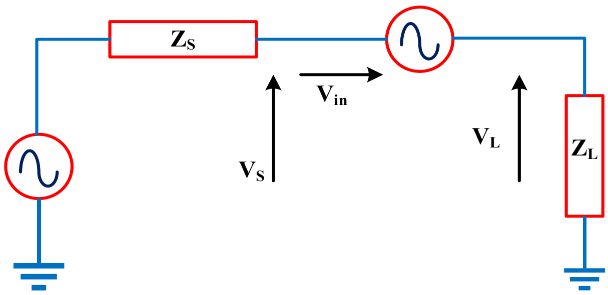


**Figure 2.** Voltage Compensation

## 3. BWO Technique

BWO based FOPID controller to improve the performance of a DVR. Figure. 3 represents flow chart of the BWO technique [10-11]. The BWO algorithm simulates the behaviour of black widow spiders searching for prey and can be used to optimize the control gains of the FOPID controller. The FOPID controller uses fractional calculus to improve control performance, and by combining it with the BWO algorithm, it is possible to improve the DVR's ability to mitigate voltage sags and swells in power systems. This can lead to better PQ and increased power system reliability. Eq. (2) represents the objective function. Figure.3 represents the BWO Flow Chart.

$$\text{Error } E(s) = V_{dc(ref)} - V_{dc} \tag{2}$$

## 4. FOPID Controller

FOPID controller is a type of advanced controller that uses fractional calculus to achieve better performance in systems with complex dynamics and uncertainties. In the case of Dynamic Voltage Restorer (DVR) applications, the

FOPID controller can regulate the voltage of the distribution network and enhance the system's PQ and reliability.
However, the optimal performance of the FOPID controller is highly dependent on the accurate tuning of its parameters, which can be a challenging task in practice. To overcome this issue, the BWO optimization technique can be used to automatically adjust the FOPID controller's parameters and obtain the best possible control performance. Eq. (3) represents the FOPID controller modelling. Figure.4 represent FOPID controller structure [12-13].

The PI controller is used to inject the required voltage into the line using DVR. Figure. 5 depicts voltage sag is observed during 0.5 to 0.7s. and depicts the voltage injection during this period. From this the abnormalities in the voltages are compensated. The proposed DVR based TID controller model is simulated in MATLAB/SIMULINK.

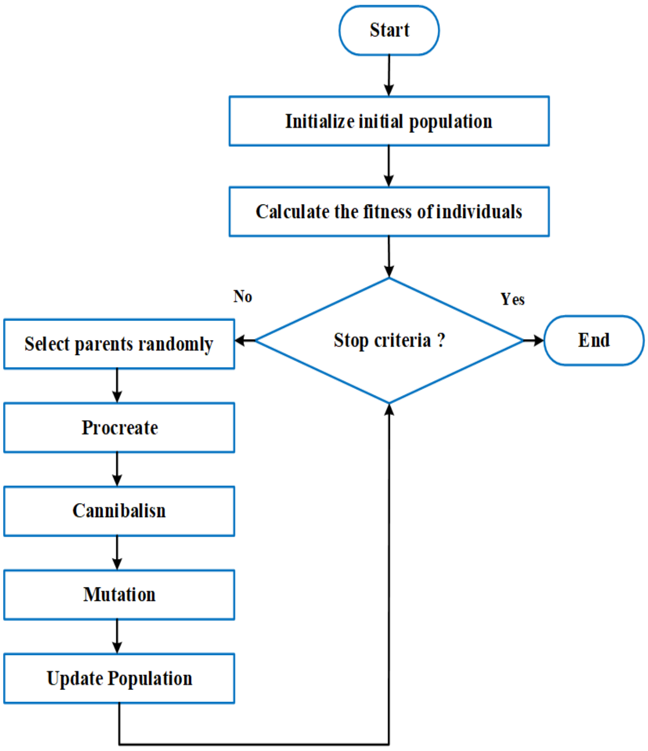


**Figure 3.** Flow Chart of BWO

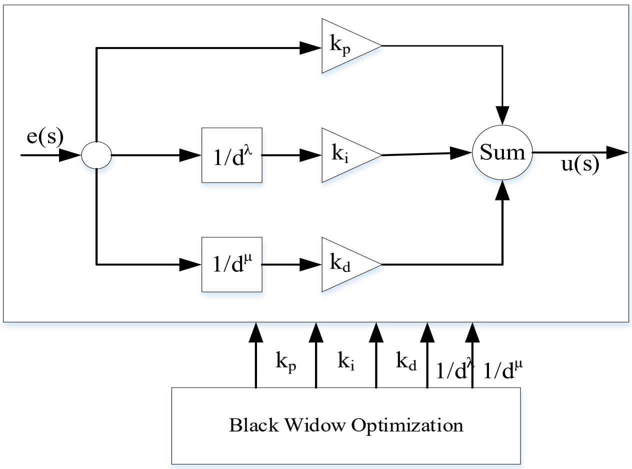


**Figure 4.** BWO-FOPID Controller

## 5. Results and Discussions

### 5.1. Case-I: Analysis of Voltage Sag

Figure 5 depicts voltage sag is observed during 0.75 to 0.85s due to three phase fault on the line. During the sag condition the proposed controllers is injecting the required compensated voltage. The THD during this condition is being observed to be 7.48% when PI controllers is used which is depicted in Figure. 6. Table. 1 represents the system parameters for the designed model.

### 5.2. Case-II: Analysis of Voltage Swell

Figure.7 depicts the observation of swell during 0.75 to 0.85s. which depicts the voltage swell is observed due to three phase faults on the line. This swell voltage is being reduced to its normal value by using this BWO-FOPID controller. Finally, one of the important factor for PQ improvement is THD which is being reduced to 1.58% depicted in Figure.8 with the proposed controller. BWO parameters are represented in Table. 2.

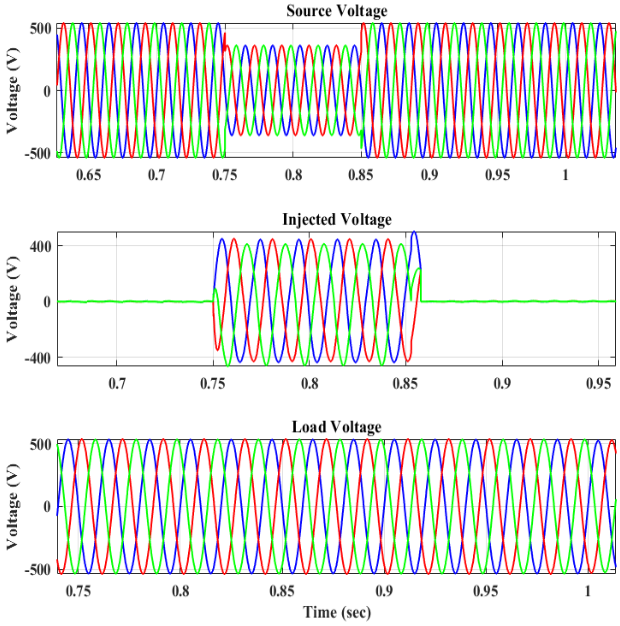


**Figure 5.** Analysis of Voltage Sag

## 6. Conclusion

The proposed DVR model with TID controller effectively mitigated the PQ issues such as voltage sag/swell. The comparison with the traditional PI controller proves the proposed controller is much effective and the THD is improved from 7.48% to 1.58% which fall within IEEE 519 standards. The proposed design proves it is very much cost effective. The comparative results prove that the abnormalities in voltage and THD.

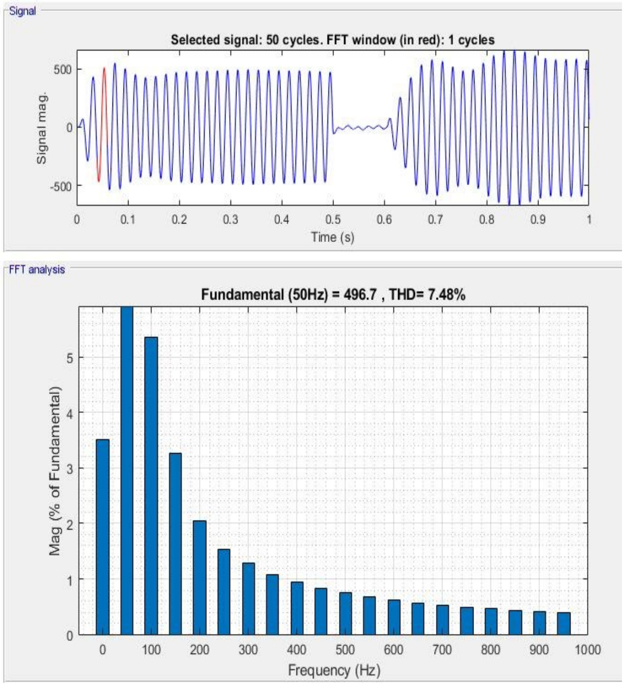


**Figure 6.** Analysis of THD using PI controller

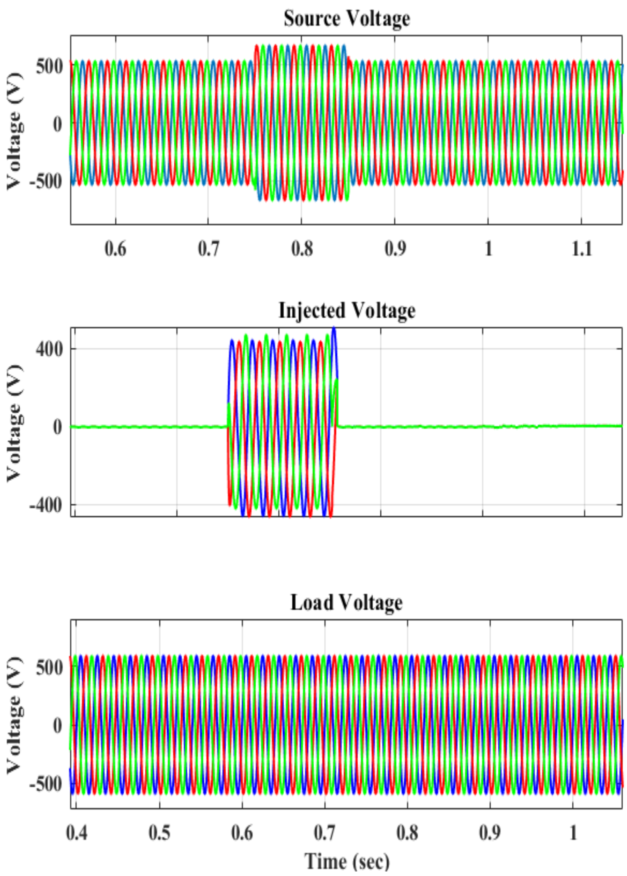


**Figure 7.** Analysis of Voltage Swell

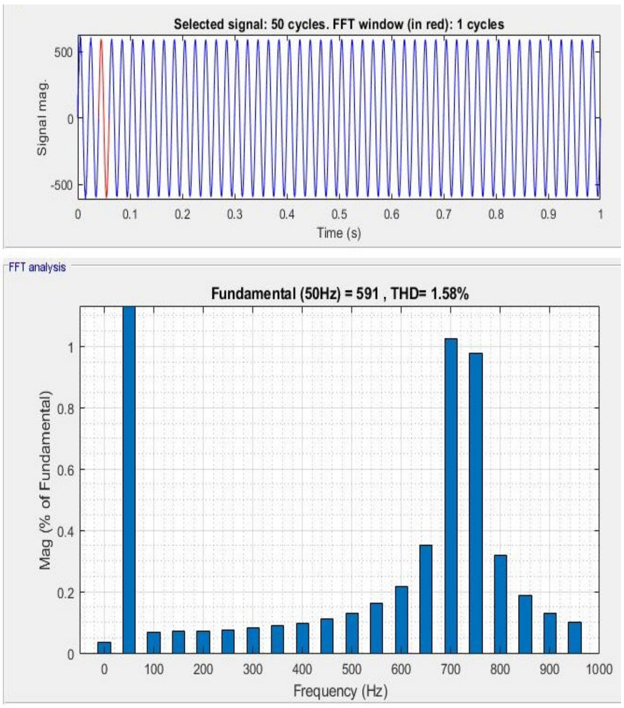


**Figure 8.** Analysis of THF using BWO-FOPID Controller

**TABLE I.** SYSTEM PARAMETERS

| Parameter | Value |
|---|---|
| Source Voltage | 550V |
| Frequency | 50Hz |
| DC Link | 600V |
| Resistance | 1Ω |
| Capacitance | 20μF |

**TABLE II.** BWO-FOPID CONTROLLER OPTIMAL GAINS

| Parameters | Value |
|---|---|
| $K_P$ | 49.4264 |
| $K_I$ | 29.750 |
| $K_D$ | 0.3953 |
| Lam | 1 |
| Del | 0.82 |

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