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Power Quality Improvement Using TID based DVR Controller

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Abstract

The effectiveness of power utilized by electronic devices is crucial for various reasons. Firstly, high-quality power results in better efficiency, allowing devices to operate at optimal energy levels. This article aims to clarify the significance of Power Quality by highlighting the benefits of using a Dynamic Voltage Restorer (DVR) to improve power quality for electricity consumers. The proposed method employs a hysteresis voltage control system that operates with variable switching frequency to enhance DVR reliability and ease of operation. Using a Tilt Integral Derivative (TID) controller, a type of fractional order controller similar to the PID controller, voltage compensation under disturbances is achieved with satisfactory results demonstrated via simulation. The primary objective of this project is to mitigate power quality issues such as voltage swell and sag in a distribution power system by enhancing power quality with a TID controller and comparing the results with those obtained from a previously implemented PID controller, using MATLAB software. Keywords: Dynamic Voltage Restorer (DVR), Tilt Integral Derivative controller (TID), Total Harmonic Distortion, MATLAB software.

Keywords: DVR, PI controller, TID controller, Total harmonic distortion

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1. Introduction

The modern power system is complex, consisting of numerous generating units and loads, which presents challenges in terms of optimality and quality power supply. The main concern of load centers is to have a reliable and quality power source for their machines to function efficiently [1]. However, despite advances in the power sector, the delivery of quality power remains a challenge due to distribution-side abnormalities caused by non-linear loads, motor starting, load changes, faults, and load switching [2].

Most of the PQ issues are commonly voltage sag/swells that significantly causes many losses and also affects the system malfunctions. To mitigate all these problems DVR is introduced during failures to avoid tripping and improve Fault Ride Through (FRT) performance [3]. Voltage injection capability and the amount of energy available are two main responsible factors which determines DVR compensating capability. Controller measures the compensating voltage required

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and injects using transformer [4]. Due to several factors such as smaller size, low cost and dynamic response to disturbances are quick DVR is mostly used to mitigate such issues. [5]

In this paper to mitigate PQ issues such as voltage sag/swell DVR fed with DC link capacitor and feed forward compensation technique is used [6]. The study covers MATLAB/Simulink-based modeling, analysis, and simulation of a DVR employing feed-forward vector control, including performance comparisons during fault occurrences. DVR with TID controller is proposed to recover the Low Voltage Ride Through (LVRT), a TID controller with DVR is proposed [7]. A zero active power methodology for improving DVR performance that produced better results than the usual In-Phase Compensation with DVR was also proposed [8].

Furthermore, some countries have addressed transmission and distribution system problems using Flexible AC Transmission Systems (FACTS) and Distribution FACTS (D-FACTS) devices. According to IEEE standards, FACTS are AC transmission systems containing static and power electronics-based controllers to increase power transfer capability and more measurable controllability [9]. With the rise in electricity demand, the production of generation and distribution systems has become critical.

Figure. 1 represents the DVR which mainly comprises of a Tilt integral controller, filters, transformer and VSI. The output of the filter is connected to the system via injection transformer. To generate reference voltage required by the DVR is calculated with use of reference voltage subtracted from the actual source voltage. TID controller is used to processes the resulting error obtained from reference voltage and actual injected DVR voltage [10-12].Alenezi et al. (2021) developed a novel Convolutional Neural Network (CNN) integrated with a block-greedy algorithm to enhance underwater image dehazing. The method addresses color channel attenuation and optimizes local and global pixel values. By employing a unique Markov random field, the approach refines image edges. Performance evaluations, using metrics like UCIQE and UIQM, demonstrated the superiority of this method over existing techniques, resulting in sharper, clearer, and more colorful underwater images [13]. In their study presented at the 13th International Conference on Computing Communication and Networking Technologies, Vikas et al. (2022) examined the classification of agricultural land using machine learning algorithms. The research, illustrated using Zhashui County as an example, established a Rating Factor System through methods like the Delphi method and straight-line method. They assessed various factors related to the land, calculating a classification index and achieving preliminary land classification. Furthermore, the study emphasized the role of weather and soil characteristics in agricultural decision-making, highlighting the potential for more accurate and cost-effective land classification through satellite images and machine learning algorithms [14].

The VSI is then given the output of the TID controller for switching purposes. The Sliding mode controller has the advantages of being robust, providing stable conditions for large supply, good dynamic response, and simple implementation. Total harmonic distortion (THD) quantifies the degree to which a signal is distorted due to harmonics. According to the literature it is calculated as the ratio of the total power of all harmonic components to the power of the fundamental frequency.

2. DVR Controller

DVR is used to improve the voltage quality and is maintained by modifying the amplitude, shape and phase of the voltage DVR is used. To overcome the disturbances in voltage with voltage restoration by injecting the required magnitude into the line.

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.

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

Phase compensation techniques is used by the proposed DVR. Only voltage magnitude is compensated with the proposed model. The controller is fed with the reference voltage and load voltage. TID controller generates the optimal pulses to the converter using PWM technique using the difference error of the voltages. Inverter injects the amount of magnitude of the voltage required into the line. This injected voltage depends on the boosting factor. Next section deals with the proposed controller.

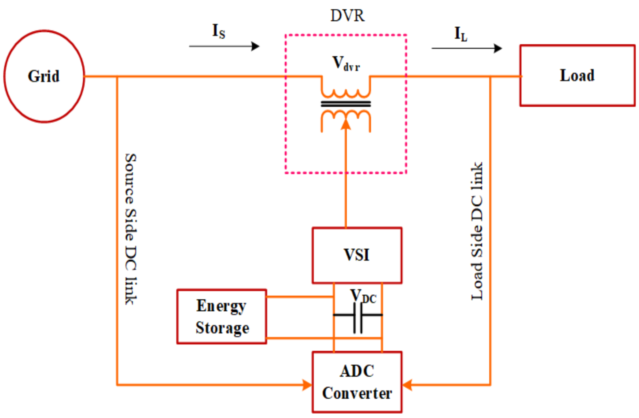

Figure 1. Architecture of the Proposed System

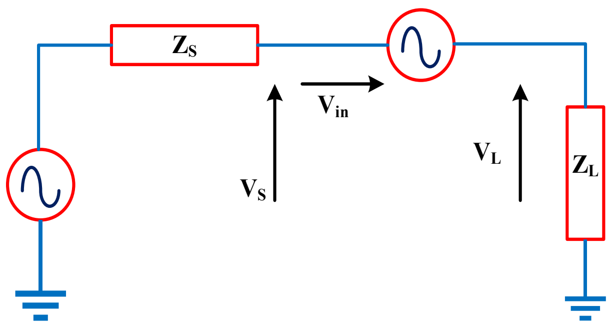

Figure 2. Voltage Compensation

3. TID Controller and Objective Function

3.1 Control Method

In popular practice, a PI controller is a hybrid of proportional and integral controllers. The output signal in a PI controller is proportional to both the error signal and its integral. The integral term cancels out steady-state error, whereas the proportional term gives an instantaneous reaction to any fault. This integration yields a controller with quick reaction and reliable performance. Motor control, temperature control, and process control are just a few of the many control applications that make use of the PI controller. Figure.3 represents the PI controller structure. Eq. (2) represents the objective function.

$$M(t) = K_p e(t) + K_i \int e(t) \qquad (2)$$

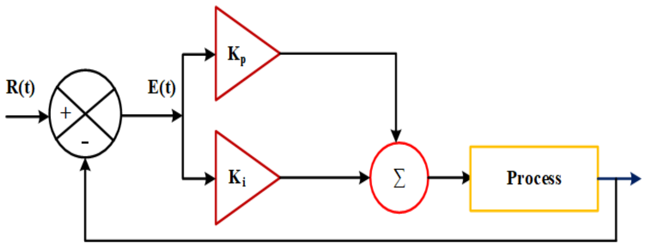

Figure 3. PI controller

3.2 TID Controller and Objective Function

The Tilt Integral-Derivative (TID) compensator depicted in Figure.4 is a controller that modifies the gain frequency of a standard compensation device based on the feedback gain. Integral and derivative operations are combined with a tilting factor to enhance the system's steadiness. Improved set-point tracking and disturbance rejection are two popular applications of the cascade controller in multi-loop control systems. It has two loops: the main loop, which may be thought of as either the inner slave loop or the outer master loop. The inner loop's quicker reaction time allows it to dampen disturbances before they spread to the rest of the system. It is widely established that a cascade controller is superior than a single-loop controller represented in Eq. (3). Table.1 represents the system parameters.

$$K_T \frac{1}{\frac{1}{sn}} + I\frac{1}{s} + KDS \qquad (3)$$

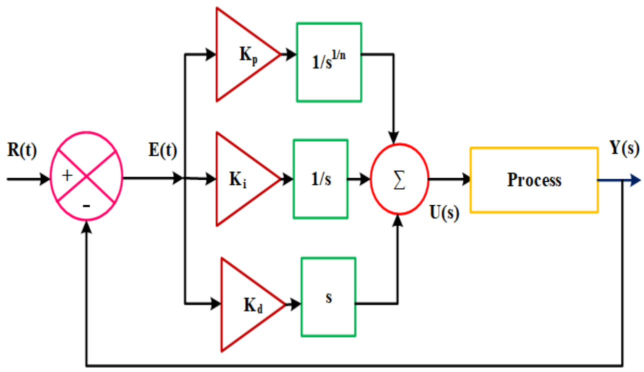

Figure 4. TID controller

4. Results and Discussions

4.1. Case-I: Analysis of Voltage Sag using PI Controller

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.

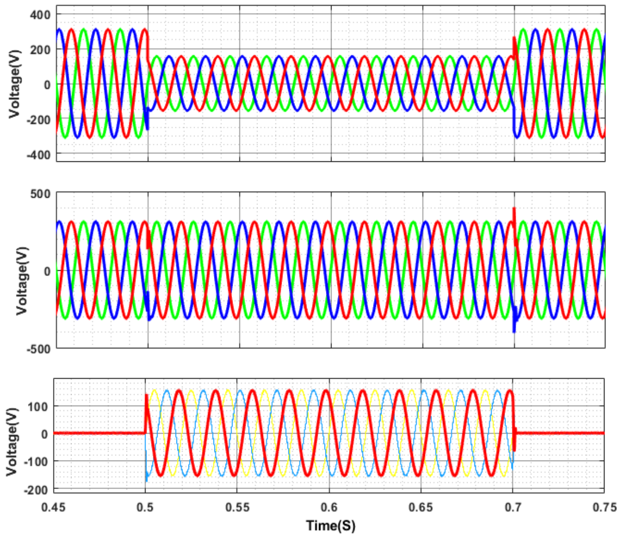

Figure 5. Voltage Sag using PI Controller

4.2. Case-II: Analysis of Voltage Swell using PI Controller

The PI controller is used to inject the required voltage into the line using DVR. Figure. 6 depicts voltage swell is observed during 0.2 to 0.4s. and also depicts the voltage injection during this period. From this the abnormalities in the voltages are compensated. Figure.7 depicts 6.16% THD using PI controller which is need to compensated using the proposed controller.

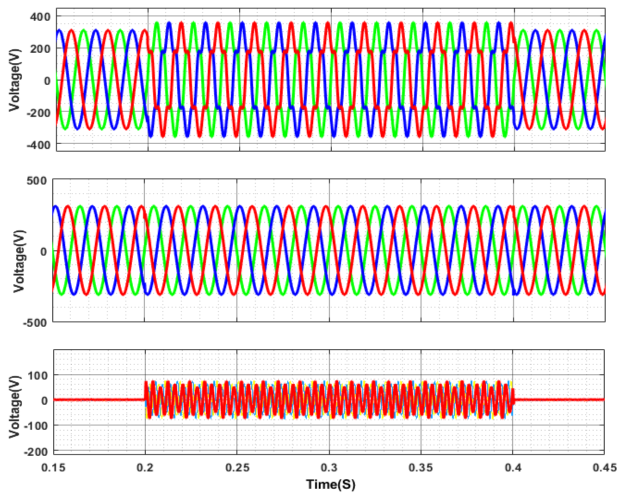

Figure 6. Voltage Swell using PI Controller

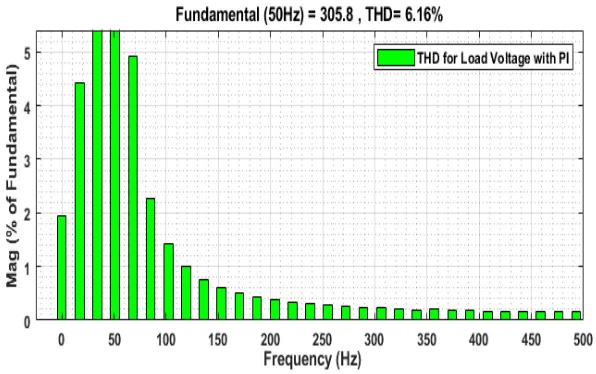

Figure 7. THD analysis using PI Controller

4.3. Case. III. Analysis of Voltage Sag Using TID Controller

The designed TID controller is used to inject the required voltage into the line using DVR. Figure. 8 depicts voltage sag is observed during 0.5 to 0.6 s. and also depicts the voltage injection during this period. From this the abnormalities in the voltages are compensated.

4.4. Case IV. Analysis of Voltage Swell using TID Controller

The designed TID controller is used to inject the required voltage into the line using DVR. Figure .9 depicts voltage swell is observed during 0.2 to 0.4s. and also depicts the voltage injection during this period. From this the abnormalities in the voltages are compensated. Figure.10 depicts with the reduced THD with 4.16% which falls under IEEE 519 standards.

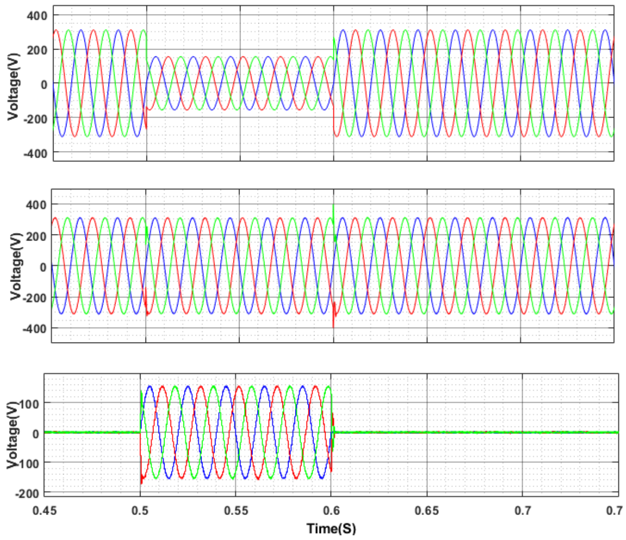

Figure 8. Voltage Sag analysis using TID Controller

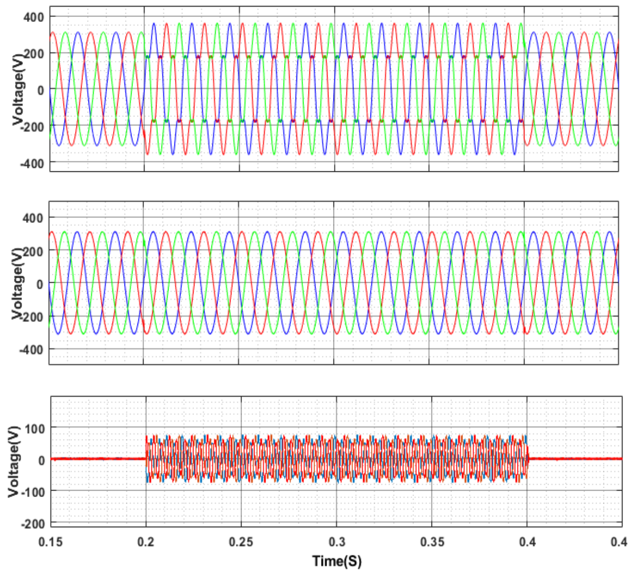

Figure 9. Voltage Swell Using TID Controller

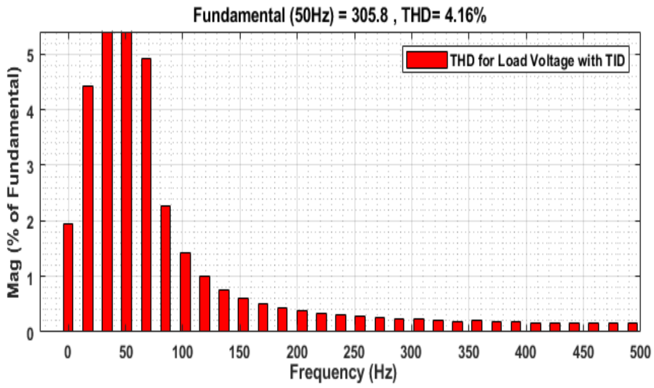

Figure 10. THD analysis using TID controller

Table. I SYSTEM PARAMETERS

Parameter	Notation	Values
Supply voltages	$V_{s,\,abc}$ L-L	380 V; 50Hz
DC-link voltage	V_{dc}	750V
Load	R_L, L_L	20Ω, 15mH
Series active power filter parameters	Notation	Values
AC filter	R_f, C_f	5Ω, 3μF
Series transformer	Rated	1/3
AC inductance	L_c	3.5mH

5 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 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.

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