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Voltage Sag Compensation in Multiline Distribution System using Closed Loop Controlled IDVR

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Abstract
This paper deals with the modelling and an the simulation of voltage sag compensation using Interline Dynamic Voltage Restorer (IDVR). Voltage sag is created by connecting an additional load in parallel with the existing load. The closed loop PI , PID and FL controlled systems are modelled and simulated using Simulink and the results are presented. The Responses of closed loop systems with PI , PID and FLC are compared.The results of comparision show the improvement in dynamic response in terms of setteling time and steady state error.

Keywords: IDVR,Voltage Sag,Fuzzy Logic Controller

List of abbreviations

PI- Proportional Integral

PID- Proportional-Integral-Derivative

DVR- Dynamic Voltage Restorer

IPFC- Interline Power Flow Controller

FACTS- Flexible Alternating Current Transmission System

RMS- Root Mean Square

THD- Total Harmonic Distortion

PWM- Pulse Width Modulation

IDVR- Interline Dynamic Voltage Restorer

INTRODUCTION

With the widespread use of electronic equipment, loads are becoming more sensitive and less tolerant to short-term voltage disturbances in the form of voltage sags. Custom power is a technology-driven product and service solution which embraces a family of devices to provide power-quality enhancement functions. Among the several novel custom-power devices, the dynamic voltage restorer (DVR) [1], [2] is the most technically advanced and economical device for voltage-sag mitigation in distribution systems. The conventional DVR [2] functions by injecting AC voltages in series with the incoming three-phase network, the purpose of which is to improve voltage quality by adjustment in voltage magnitude wave shape, and phase shift. These attributes of the load voltage are very important as they can affect the performance of the protected load. The voltage-sag compensation involves injection of real and reactive power to the distribution system, and this determines the capacity of the energy storage device required in the restoration scheme. The reactive power requirement can be generated electronically within the voltage source inverter of the DVR. An external energy storage is necessary to meet the real-power requirement. Thus, the maximum amount of real power that can be supplied to the load during voltage-sag compensation is a deciding factor of the capability of a DVR, especially for mitigating long-duration voltage sags. Voltage injection with an appropriate phase advance with respect to source side voltage can reduce the energy consumption [2]. However, the energy requirement cannot be met by the application of such phase-advance technique alone for mitigating deep sag of long duration, as it is merely a way of optimizing existing energy storage. If the DC link of the DVR can be replenished dynamically by some means, the DVR will be capable of mitigating deep sags with long durations. The interline IDVR proposed in this paper provides a way to replenish the energy in the common DC-link energy storage dynamically. The IDVR system consists of several DVRs protecting sensitive loads in different distribution feeders emanating from different grid substations, and these DVRs share a common DC link. The interline power-flow controller (IPFC) proposed in [3] addresses the problem of compensating a number of transmission lines at a given substation. The IPFC scheme provides a capability to transfer real power directly between the compensated lines, while the reactive power is controllable within each individual line. The IDVR scheme provides a way to transfer real power between sensitive loads in individual line through the common DC link of the DVRs, as it does in the IPFC. However, the lines in the IPFC originate from a single grid substation while the lines in the IDVR system originate from different grid substations. When one of the DVRs in IDVR system compensates for voltage sag by importing real power from the DC link, the other DVRs replenish the DC-link energy to maintain the DC-link voltage at a specific level. An example of a potential location for such a scheme is an industrial park where power is fed from different feeders connected to different grid substations, those that are electrically far apart. The sensitive loads in this park may be protected by DVRs connected to respective loads. The DC links of these DVRs can be connected to a common terminal, thereby forming an IDVR system. This would cut down the cost of the custom-power device, as sharing common DC link reduces the size of the DC-link storage capacity substantially, compared to that of a system in which loads are protected by clusters of DVRs with separate energy storage systems. The control system of a DVR plays an important role, with the requirements of fast response in the face of voltage sags and variations in the connected load. Generally, there are two control schemes, open loop [4] and closed loop [5], which is used in the DVR applications. The above literature does not compare responses pf PI,PID and FL controlled IDVR systems.This work compares the responses of the above mentioned systems.The objective of this work is to propose suitable controller for closed loop controlled IDVR system.

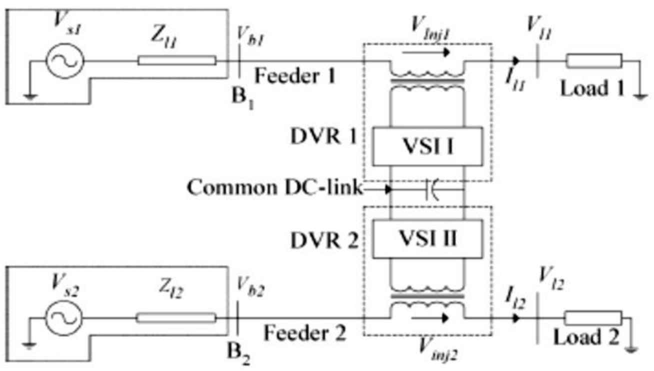

Figure 1. Schematic diagram of an IDVR in a two-feeder system.

OPERATION OF IDVR

The IDVR system consists of several DVRs in different feeders, sharing a common DC link. A two-line IDVR system shown in Fig. 1 employs two DVRs connected to two different feeders originating from two grid substations. These two feeders could be of the same or different voltage level. When one of the DVRs compensates for voltage sag, the other DVR in IDVR system operates in power-flow control mode to replenish dc-link energy storage which is depleted due to the real power taken by the DVR working in the voltage-sag compensation mode. Propagation of voltage sags due to fault in the power system depends on many factors, such as voltage level, fault current, transformer in the propagation path and their connection arrangement, etc. Voltage sags in a transmission system are likely to propagate to larger electrical distance than that in a distribution system. Due to these factors and as the two feeders of the IDVR system in Fig. 1 are connected to two different grid substations, it is reasonable to assume that the voltage sag in Feeder 1 would have a lesser impact on Feeder 2. Therefore, the upstream generation-transmission system to the two feeders can be considered as two independent sources. These two sources are represented by the Thevenin's equivalent voltage sources Vs_1 and Vs_2 in series with Thevenin's equivalent impedances Z_{l1} and Z_{l2} connected to the buses B_1 and B_2 as in Fig. 1. Z_{l1} and Z_{l2} are calculated based on the fault level at B_1 and B_2.

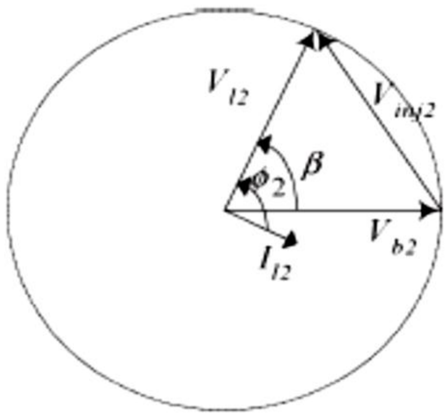

Figure 2. Phasor diagram of DVR2 for real-power transfer.

SIMULATION RESULTS

The Simulink diagram of the closed loop controlled IDVR system with the PI controller is shown in the Fig 3.1.The AC output voltage of the CT is rectified using a controlled rectifier. The DC is converted into AC using a PWM inverter, and the output voltage of the inverter is injected using a transformer. The load voltage is sensed and it is rectified and compared with a reference voltage .The error signal is applied to the PI controller .The output of the PI controller is used to produce the required pulse width for the switches of the inverter. The voltage across the load 1 and the load 2 are shown in Fig 3.2.The peak value is 3500V.The RMS voltage is shown in Fig 3.2 and its value is 2500V.The new load is connected at 0.3 seconds and the voltage is compensated at 0.5 seconds. The THD value is 5% .Closed loop system with the PID controller is shown in Fig 4.1. The voltage across the load 1 and the load 2 are shown in Fig 4.2.The RMS voltage across the load is shown in Fig 4.3 and its value is 2500V. The frequency spectrum is shown in Fig 4.4.It can be seen that the THD contact is reduced to 2.5%. Simulink model of closed loop system with FLC is shown in Fig 5.1. The PID controller is replaced by FLC voltage across load 1 and load 2 are shown in Fig 5.2. The RMS voltage across the load is shown in Fig 5.3.FFT analysis for the output voltage is done and the THD contact is 0.45%. This value is much less than that of PI,PID controllerd systems

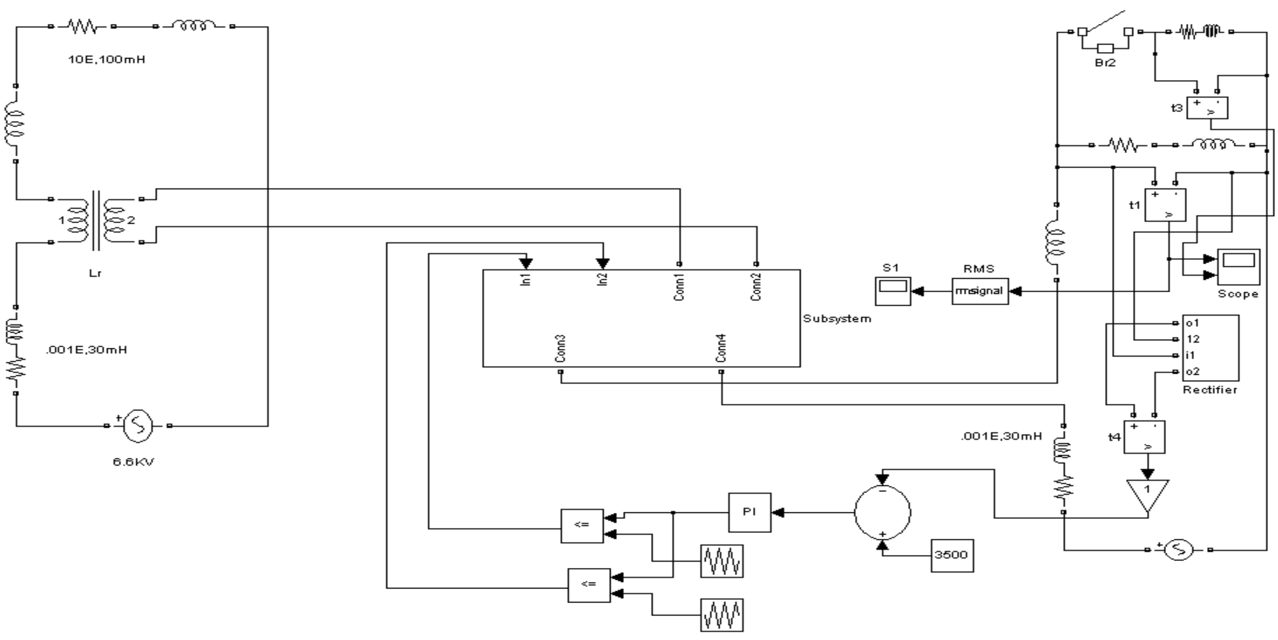

Figure 3.1. Closed loop controlled IDVR system with PI controller

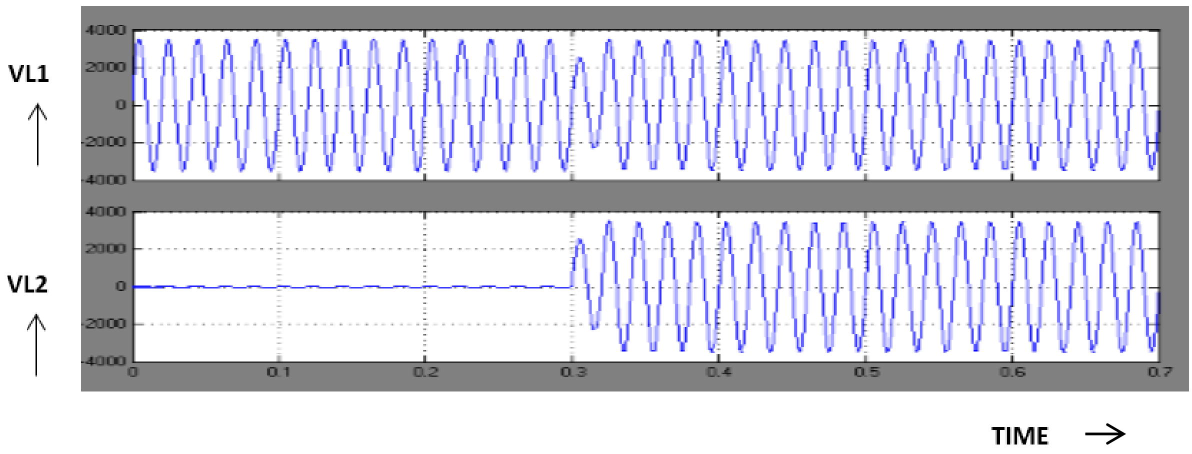

Figure 3.2. Voltage across load 1 and load 2

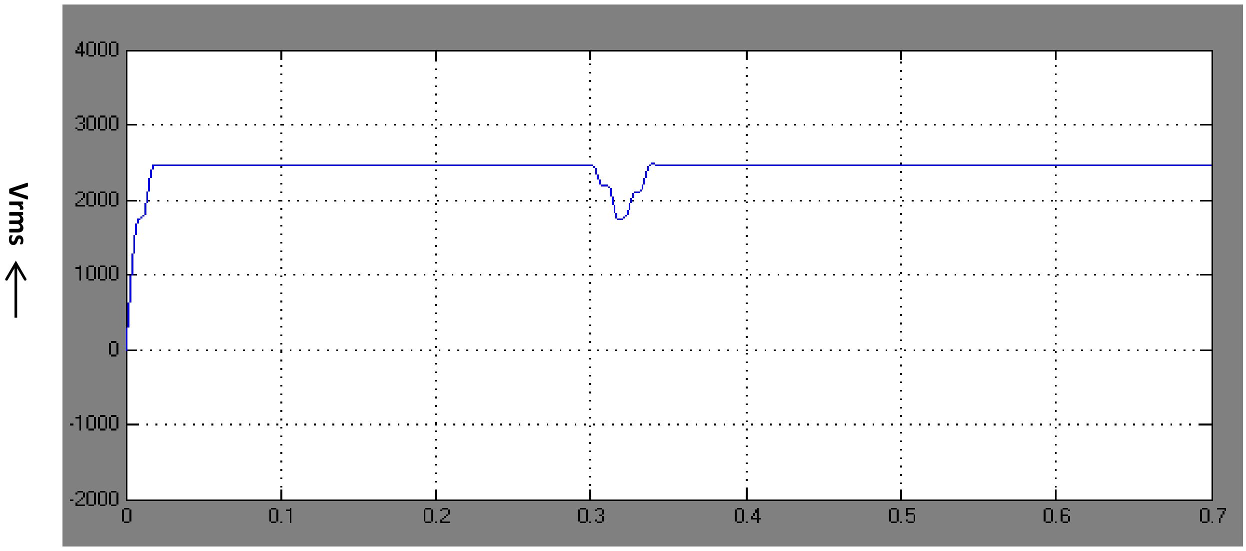

Figure 3.3. RMS voltage across load

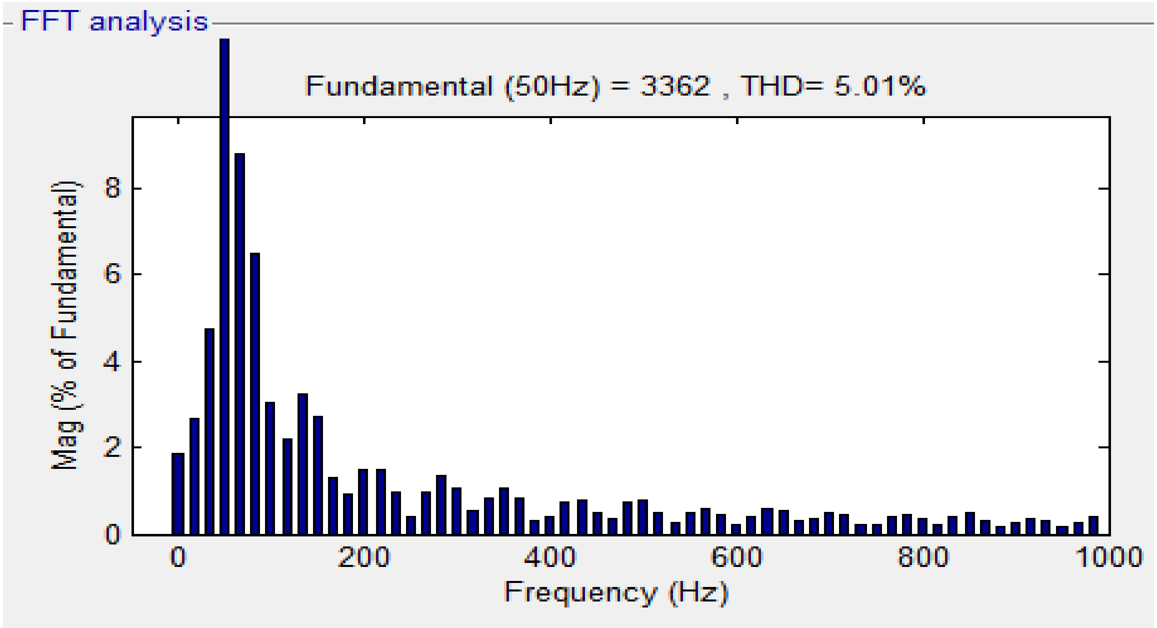

Figure 3.4. Frequency spectrum for load voltage

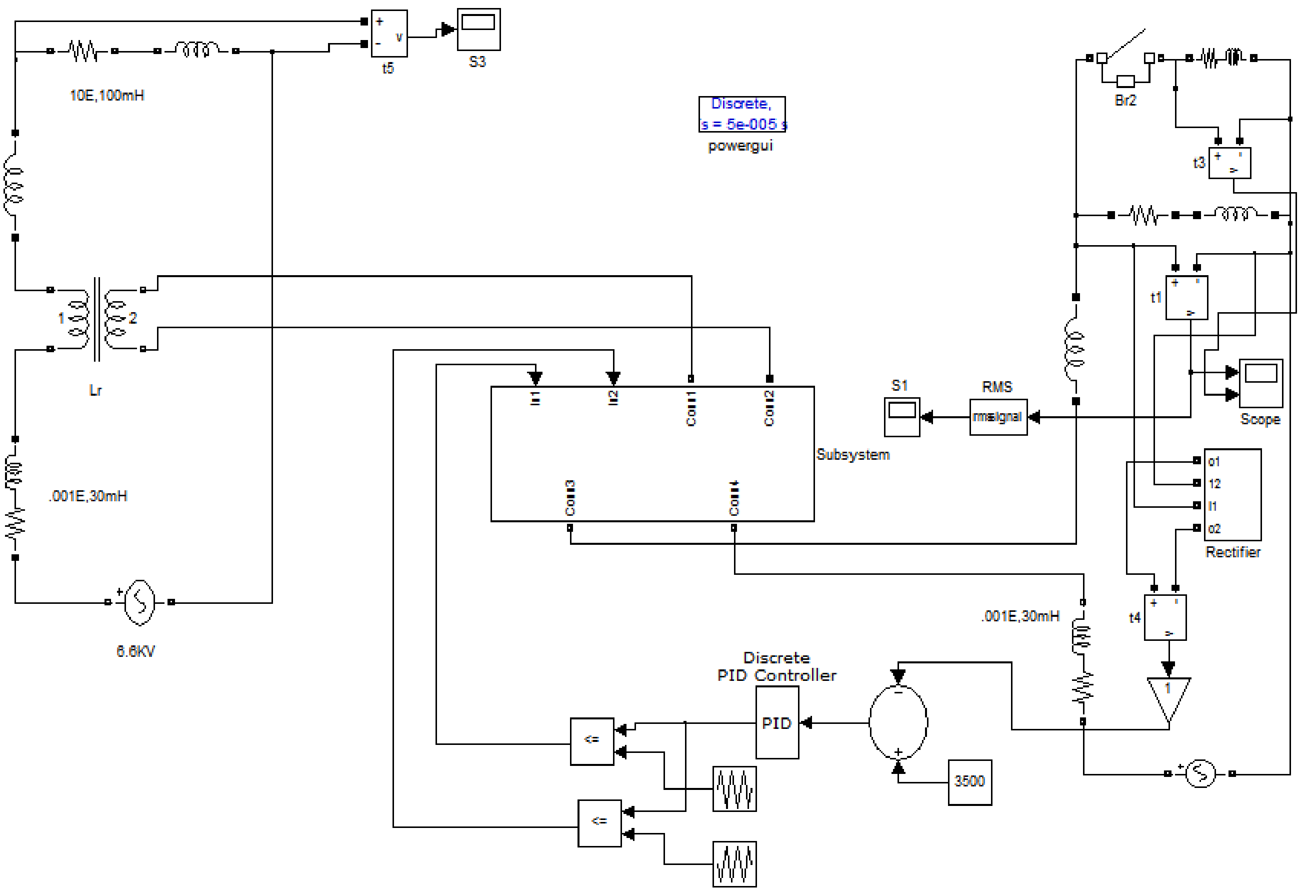

Figure 4.1. Closed loop system with PID controller

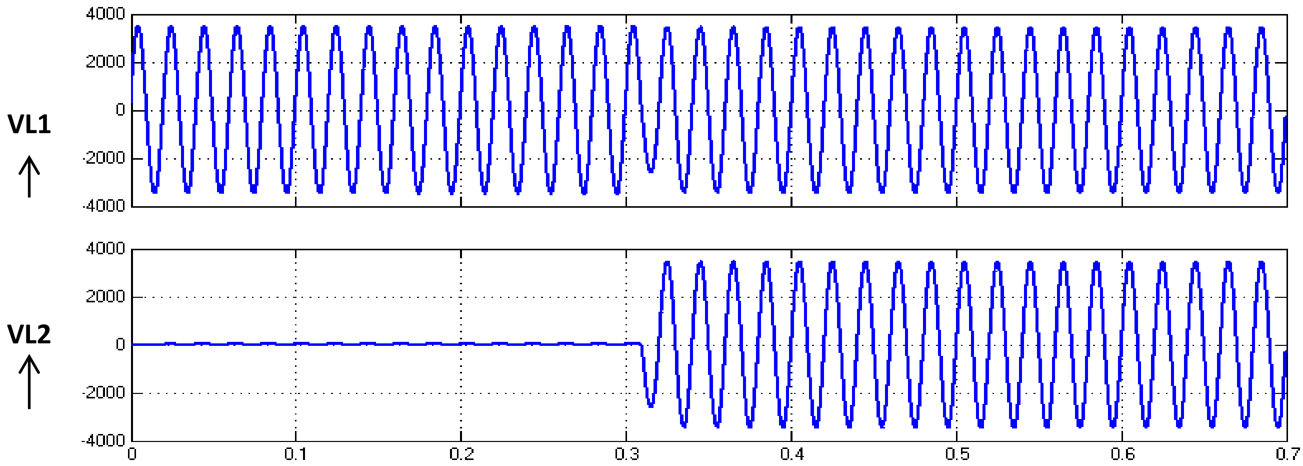

Figure 4.2. Voltage across load-1 and load-2

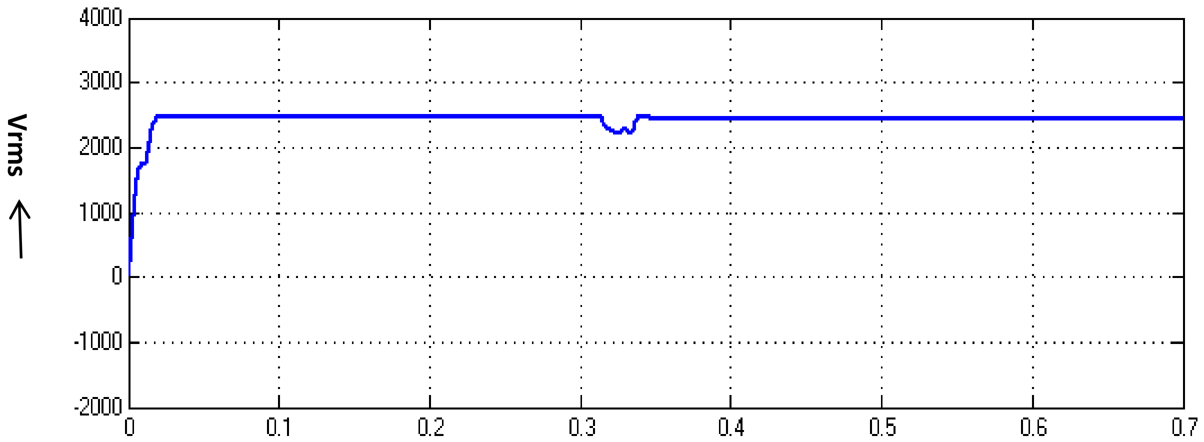

Figure 4.3. RMS voltage across load

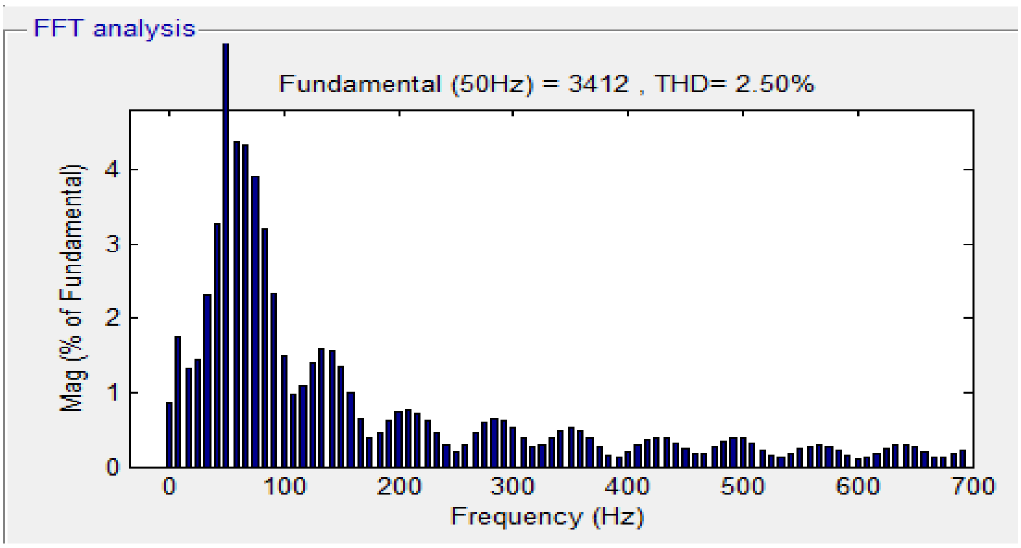

Figure 4.4. Frequency spectrum for output voltage

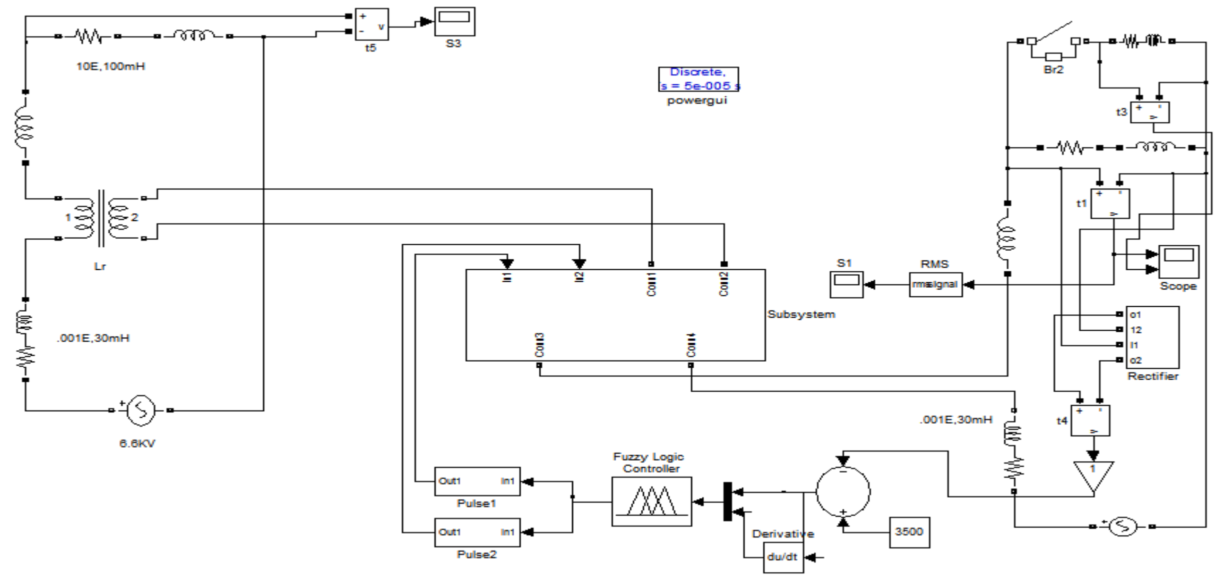

Figure 5.1. Closed loop system with FUZZY controller

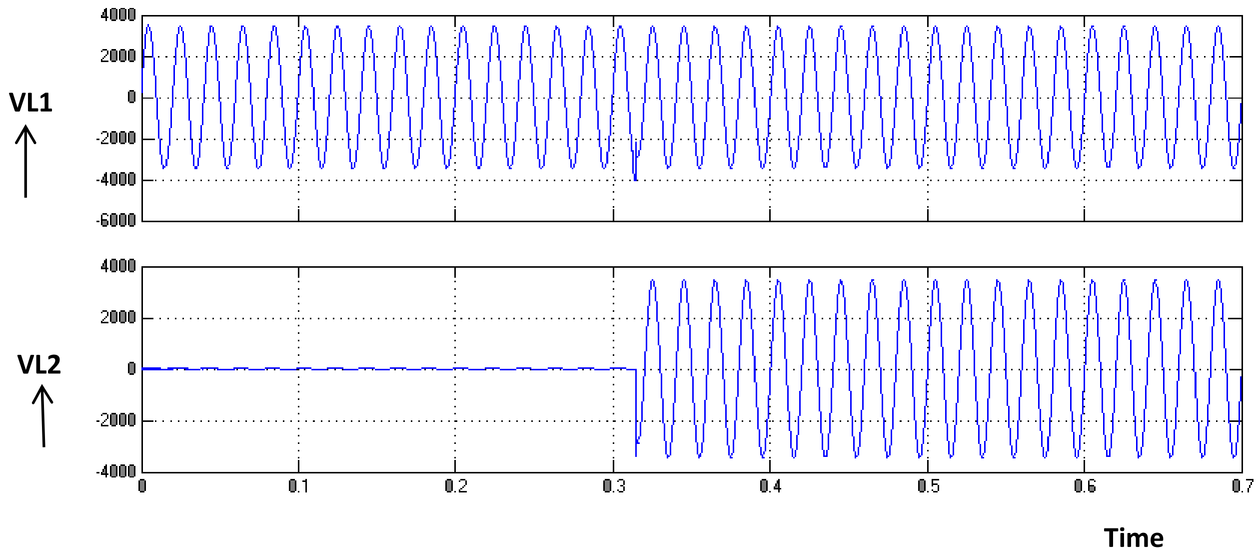

Figure 5.2. Voltage across load-1 and load-2

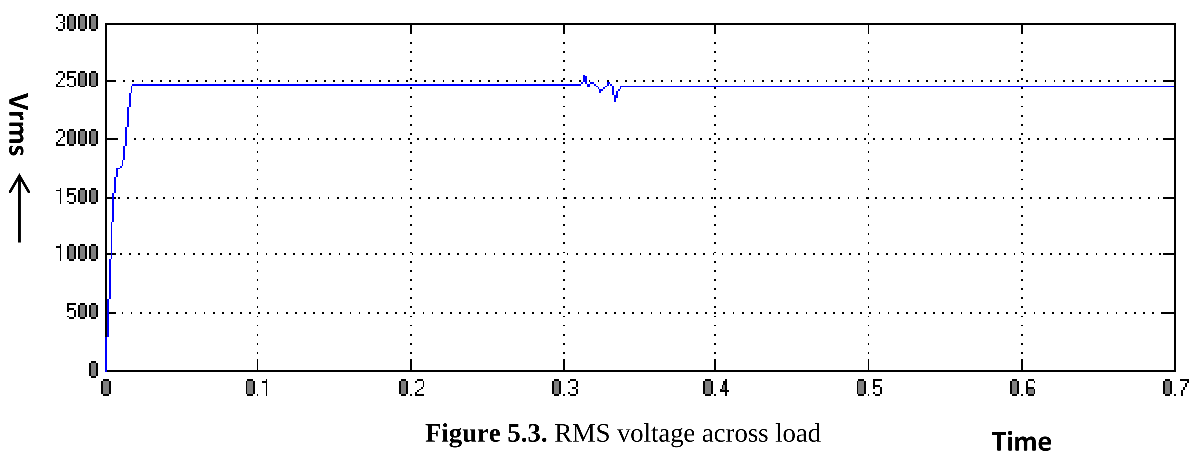

Figure 5.3. RMS voltage across load

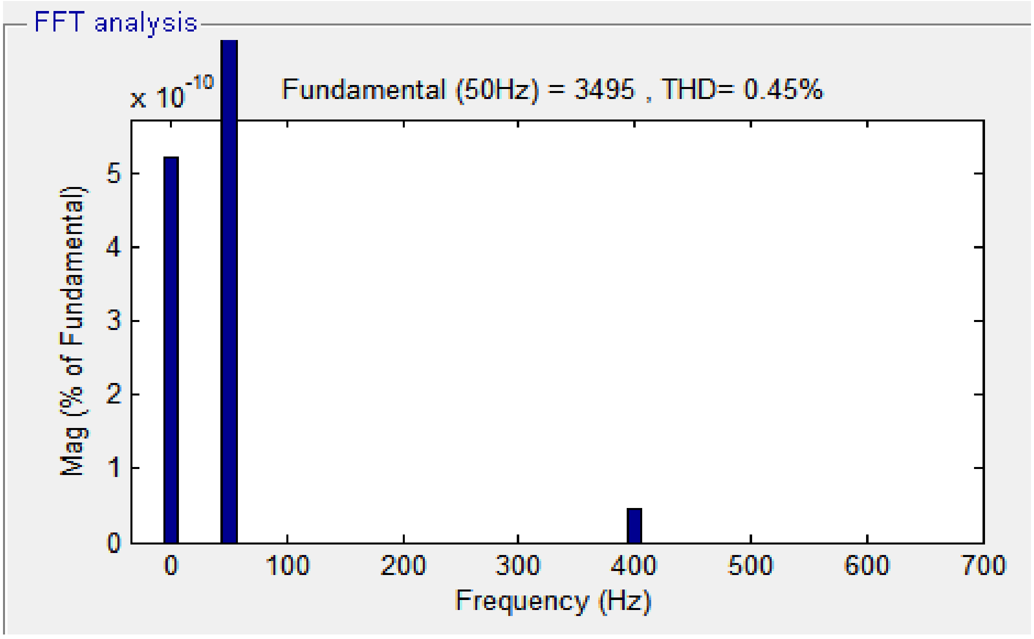

Figure 5.4. Frequency spectrum for output voltage

Table 1: Comparision of responses with PI,PID and FLC

CONTROLLERS	RISE TIME (S)	PEAK TIME (S)	SETTLING TIME(S)	STEADY STATE ERROR(V)
PI	0.019	0.32	0.36	0.8
PID	0.015	0.31	0.33	0.6
FLC	0.005	0.006	0.31	0.01

CONCLUSION

The closed loop controlled compensation in four bus system was achieved using PI,PID and FLC controllers. The comparison of the responses indicates that the FLC produces better dynamic response then PI and PID controlled systems.The THD content is reduced to 0.45% using fuzzy logic controlled system.The IDVR has the ability to compensate the voltage in one of the lines. The disadvantage of IDVR is that voltage injected is limited by the voltage rating of the transformer and the inverter.

The present work deals with comparison of the PI,PID and FL controlled IDVR systems. The comparison with ANN controller will be done in future.Prototype hardware may be done in future to validate the simulation results

REFERENCES

[1] A. Ghosh and G. Ledwich, "Compensation of distribution system voltage using DVR," *IEEE Trans. Power Del.*, vol. 17, no. 4, pp. 1030–1036, Oct. 2002.

[2] S. S. Choi, B. H. Li, and D. M. Vilathgamuwa, "Dynamic voltage restoration with minimum energy injection," *IEEE Trans. Power Syst.*, vol. 15, no. 1, pp. 51–57, Feb. 2000.

[3] L. Gyugyi, K. K. Sen, and C. D. Schaude, "The interline power flow controller concept: A new approach to power flow management in transmission system," *IEEE Trans. Power Del.*, vol. 14, no. 3, pp. 1115–1123, Jul. 1999.

[4] J. G. Niesen, F. Blaabjerg, and N. Mohan, "Control strategies for dynamic voltage restorer compensating voltage sags with phase jump," in *Proc. 16th Annu. IEEE APEC*, 2001, vol. 2, pp. 1267–1273.

[5] M. Vilathgamuwa, A. A. D. R. Perera, and S. S. Choi, "Performance improvement of the dynamic voltage restorer with closed-loop load voltage and current-mode control," *IEEE Trans. Power Electron.*, vol. 17, no. 5, pp. 824–834, Sep. 2002.

[6]. Zhuhai Yuan, Sjoerd W.H. de Haan. "A New Concept of Exchanging Active Power without Common DC Link for Interline Power Flow Controller (S-IPFC)" *IEEE Transactions on Power Delivery, Vol. 23, No. 4*, March 2008

[7]. Sayed-mahdi and Moghadasi, "Composite System Reliability Assessment Incorporating An Interline Power-flow Controller" *IEEE Transactions On Power Delivery, Vol. 23, No. 2*, April 2008

[8]. Xia Jiang and Liana Hopkins."A Novel Approach for Modelling Voltage-Sourced Converter-Based FACTS Controllers"*IEEE Transactions on Power Delivery, Vol. 23*, NO. 4, October 2008

[9]. Valentin Azbe and Rafael Mihalic"The Control Strategy for an IPFC Based on the Energy Function" *IEEE Transactions On Power Systems*, VOL. 23, NO. 4, November 2008

[10]. Nemat Talebi "Automatic Generation Control Using Interline Power Flow Controller" *2009 2nd International Conference on Power Electronics and Intelligent Transportation System*

[11]. Ahmed Elserougi Ahmed Hossam-Eldin "Investigation of Inter-Line Dynamic Voltage Restorer with Virtual Impedance Injection" 978-1-4244-5226-2/10/$26.00 ©2010 IEEE

[12]. Khalid. H. Mohamed* and K. S. Rama Rao** "Intelligent Optimization Techniques for Optimal Power Flow using Interline Power Flow Controller" *IEEE International Conference on Power and Energy , Nov 29 - Dec 1, 2010*, Kuala Lumpur, Malaysia

[13]. Sandeep, R. K. Tripathi, and Rishabh Dev Shukla"Voltage Stability Improvement in Power Systems using Facts Controllers: State-of-the- Art Review" 978-1-4244-8542-0/10/$26.00 ©2010 IEEE

[14]. Majid Moradlou, and Hamid R. Karshenas. "Design Strategy for Optimum Rating Selection of Interline DVR" *IEEE Transactions on Power Delivery*, Vol. 26, No. 1, January 2011

[15]. Shan Jiang Ani M. Gole, Udaya D. Annakkage and D. A. Jacobson. "Damping Performance Analysis of IPFC and UPFC Controllers Using Validated Small-Signal Models" *IEEE Transactions On Power Delivery*, Vol. 26, No. 1, January 2011

[16] Vinod Khadkikar James and L. Kirtley. "Interline Photovoltaic (I-PV) Power System A Novel Concept of Power Flow Control and Management" *IEEE* 978-1-4577-1002-5/11/$26.00 ©2011

[17]. Ahmed Moawwad, *Student Member, IEEE* "Photovoltaic Power Plant as FACTS Devices in Multi-Feeder Systems" 978-1-61284-972-0/11/$26.00 ©2011 IEEE

[18]. Bach Q. Khanh, J. Lian, B. Ramachandran, S. Srivastava, D. Cartes"Mitigating Voltage Sags Due to DOL Starting of Three Phase Asynchronous Motors Using Dynamic Voltage Restorer (DVR)" 978-1-4673-1935-5/12/$31.00 ©2012 IEEE

[19]. Jose M. Lozano, Miguel A. Hernandez-Figueroa"An Operative Comparison of Two DVR Topologies based on a Matrix Converter without Energy Storage

[20]. Amin Kargarian, *Student Member, IEEE*, Bamdad Falahati, *Student Member, IEEE*, Yong Fu,"Multi objective Optimal Power Flow Algorithm to Enhance Multi-Microgrids Performance Incorporating IPFC" 978-1-4673-2729-9/12/$31.00 ©2012 IEEE

[21]. Hyunsik Jo1, Ilyong Lee1, Byung-Moon Han2 & Hanju Cha1"A Dynamic Voltage Restorer with a selective Harmonic Mitigation and Robust Peak Detection:978-1-4673-4355-8/13/$31.00 ©2013 IEEE

[22]. Esmaeil Ebrahimzadeh, Shahrokh Farhangi "Improved Phasor Estimation Method for Dynamic Voltage Restorer Applications" 0885-8977 (c) 2013 IEEE

[23]. Xiaoqing Han, Ruifen Cheng, Peng Wang, Yanbing Jia"Advanced Dynamic Voltage Restorer to Improve Power Quality in Microgrid" 978-1-4799-1303-9/13/$31.00 ©20 13 IEEE

[24]. Arash Tavighi1 , Hamed Abdollahzadeh2 , José Martí1'Fast Response DVR Control Strategy Design to Compensate Unbalanced Voltage Sags and Swells in Distribution Systems

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