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Enhancing the Power Quality Improvement of QBC Fed Trans ZSI-UPFC for Grid-Connected RES Systems

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Abstract : This paper presents the MATLAB simulation model of a UPFC for open loop controlled as a voltage sag mitigation device in electrical power distribution networks. The comparison is done in term of time domain response parameters like steady state error, Total Harmonic Distortion & settling time. UPFC is a popular device to improve voltage of weak buses in multi bus system. This work deals with modeling and simulation of open loop controlled quadratic boost converter boost converter with TZSI based UPFC in wind, and PV system. Various issues such as voltage sag/ harmonics and distortion degrade the power quality and leads to system failure. This work deals with modeling and simulation of open loop controlled Three Phase voltage Trans Z-source inverter based UPFC and statcom in two bus system.

***Index Terms* – UPFC-Unified power flow controller, Dynamic voltage restorer, Static compensator**

I. INTRODUCTION

The ongoing expansion and growth of the electric utility industry continuously introduce changes to a once predictable business. Electricity is increasingly being considered and handled as a commodity. Thus transmission systems are being pushed closer to their stability and thermal limits with the focus on the quality of power delivered. In the evolving utility environment, financial and market forces will continue to demand a more optimal and profitable operation of the power system with respect to generation, transmission, and distribution. Advanced technologies are paramount for the reliable and secure operation of power systems. To achieve both operational reliability and financial profitability it is clear that more efficient utilization and control of the existing transmission system infrastructure is required.

Improved utilization of the existing power system is provided through the application of advanced control technologies. Power electronics based equipment or Flexible AC Transmission systems (FACTS) provide proven technical solutions to address these new operating challenges being presented today. FACTS technologies allow for improved transmission system operation with minimal infrastructure investment, environmental impact and implementation time compared to the construction of new transmission lines. FACTS technologies provide advanced solutions as a cost-effective alternative to new transmission line construction. FACTS provide the needed corrections of transmission functions in order to efficiently utilize existing transmission systems and therefore, minimize the gap between the stability and the thermal level. The ongoing expansion and growth of the electric utility industry continuously introduce changes to a once predictable business. Electricity is increasingly being considered and handled as a commodity. Thus transmission systems are being pushed closer to their stability and thermal limits with the focus on the quality of power delivered. In the evolving utility environment, financial and market forces will continue to demand a more optimal and profitable operation of the power system with respect to generation, transmission, and distribution. Advanced technologies are paramount for the reliable and secure operation of power systems. To achieve both operational reliability and financial profitability it is clear that more efficient utilization and control of the existing transmission system infrastructure is required.

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II. UPFC PRINCIPLE

The continuous growth of the electric utility industry brings ongoing changes to what was once a predictable business. Electricity is now seen as a commodity, leading to transmission systems being pushed closer to their limits to ensure high-quality power delivery. Financial and market forces in the evolving utility landscape drive the need for more efficient and profitable power system operation. Advanced technologies play a crucial role in ensuring reliable power system operation while maximizing financial gains. Improved utilization of the existing power system is achieved through advanced control technologies such as Flexible AC Transmission systems (FACTS). FACTS technologies offer effective solutions to current operating challenges, enhancing transmission system operation without the need for extensive infrastructure investments or long implementation times associated with building new transmission lines. By addressing transmission functions, FACTS technologies enable the efficient use of existing systems, bridging the gap between stability and the thermal level. The electric utility industry's constant development causes continuing adjustments to what was previously a dependable business. Electricity is today viewed as a commodity, pushing transmission networks to their limitations in order to provide high-quality power supply. Financial and commercial dynamics in the changing utility environment are driving the demand for more efficient and profitable power system operation. Advanced technologies are critical to ensure dependable power system functioning while optimizing financial rewards. Advanced control technologies, such as Flexible AC Transmission Systems (FACTS), enable better usage of the current power system. FACTS technologies provide effective answers to present operational difficulties by improving transmission system operation without the requirement for substantial infrastructure expenditures or extended implementation delays associated with building new lines.

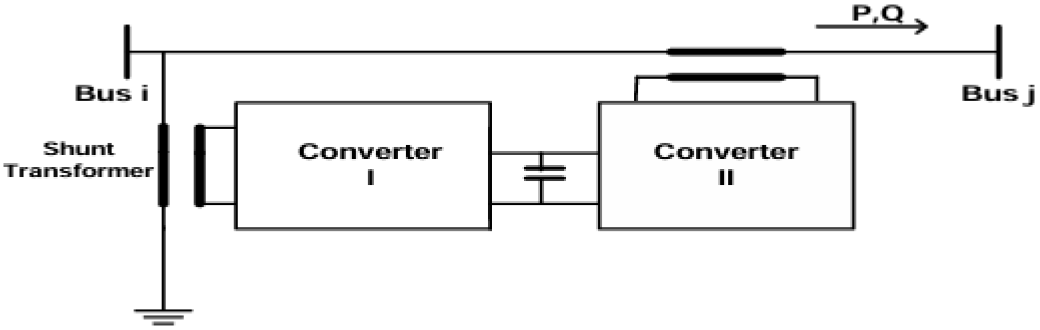

Figure 1 Configuration of UPFC

III. PROPOSED DIAGRAM

UPFC, which is made up of a series and a shunt converter coupled by a common dc link capacitor, can manage both transmission line real/reactive power flow and UPFC bus voltage/shunt reactive power. The UPFC's shunt converter regulates the UPFC bus voltage/shunt reactive power, as well as the voltage of the DC link capacitor. The UPFC's series converter regulates the transmission line's real/reactive power flows by injecting a series voltage with configurable magnitude and phase angle. The interplay of the series injected voltage and the transmission line current causes actual and reactive power exchange between the series converter and the power system. Under steady-state conditions, the shunt supplies the true power requirement of the series converter. Figure 2 shows proposed diagram of UPFC.

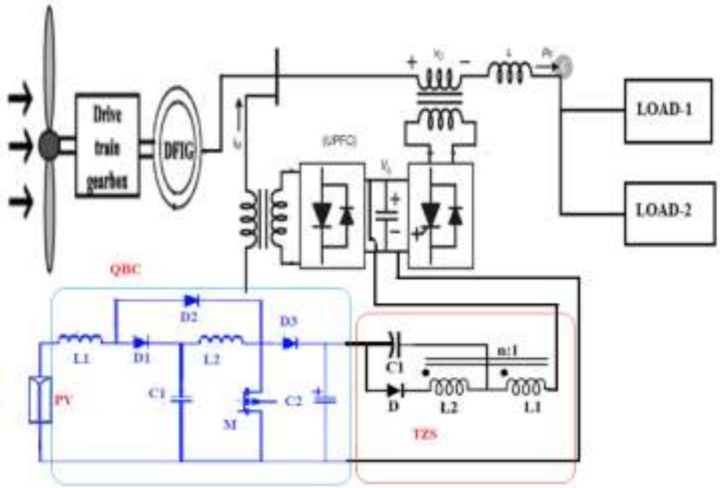

Figure 2 Proposed circuit diagram of UPFC

IV. ZSI SOURCE INVERTER

The main purpose of a static power converter is to generate an AC output waveform from a DC source. An impedance source inverter is an inverter that uses a unique impedance network coupled to the inverter main circuit and the power source. This inverter has unique features in terms of voltage (both step-up and step-down voltages) compared to conventional inverters. A two-port network consisting of split inductors and capacitors connected in an X-shape is used to provide an impedance source (Z-source) that connects the inverter to a DC source or other converters. The DC source/load can be either a voltage or a current source/load. Thus, the DC source may be a battery, a diode rectifier, a thyristor converter, a fuel cell, a PV cell, an inductor, a capacitor, or a combination of them. The switch used in the converter is a combination of a switching device and an anti-parallel diode, as shown in Figure 4.3. There are six switches used in the circuit. Each is traditionally composed of a power transistor and an anti-parallel (or freewheeling) diode, providing bidirectional current flow and unidirectional voltage blocking function. Commonly used switches include metal-oxide-semiconductor field-effect transistors (MOSFETs), insulated-gate bipolar transistors (IGBTs), bipolar transistors (BJTs), silicon-controlled rectifiers (SCRs), and gate-turn-off thyristors (GTOs). used IGBTs as switches, which combine the advantages of BJTs and MOSFETs.

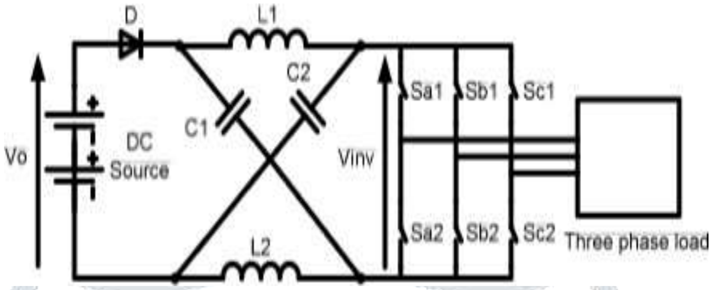

Figure 3 ZSI Inverter

Advantages of ZSI

This technology enables the management of voltage fluctuations within one energy processing stage. It functions as a buck-boost inverter and the central circuit of the ZSI can be a traditional VSI or CSI. It offers enhanced resistance to switching errors and EMI interference, making it user-friendly. It offers voltage bridging without requiring extra circuitry during voltage drops. Additionally, it enhances power efficiency, lowers harmonic currents, and minimizes common mode voltages. This system provides a cost-effective, reliable, and efficient solution for both stepping down and stepping up power conversion in a single stage. The ZSC can support various loads including inductive, capacitive, or another Z source network.

IV. RESULTS AND DISCUSSION

Circuit diagram of without facts device is delineated in Figure 4. Voltage across RL load is delineated in Figure 5 & its value is 1500V. Output voltage THD is delineated in Figure 6 & its value is 9.91%. Output current through RL load is delineated in Figure 7 & its value is 13A. Output current THD is delineated in Figure 8 & its value is 10.97%. Real power is delineated in Figure 9 & its value is0.0235MW. Reactive Power is delineated in Figure 10 & its value is0.0378MVAR.

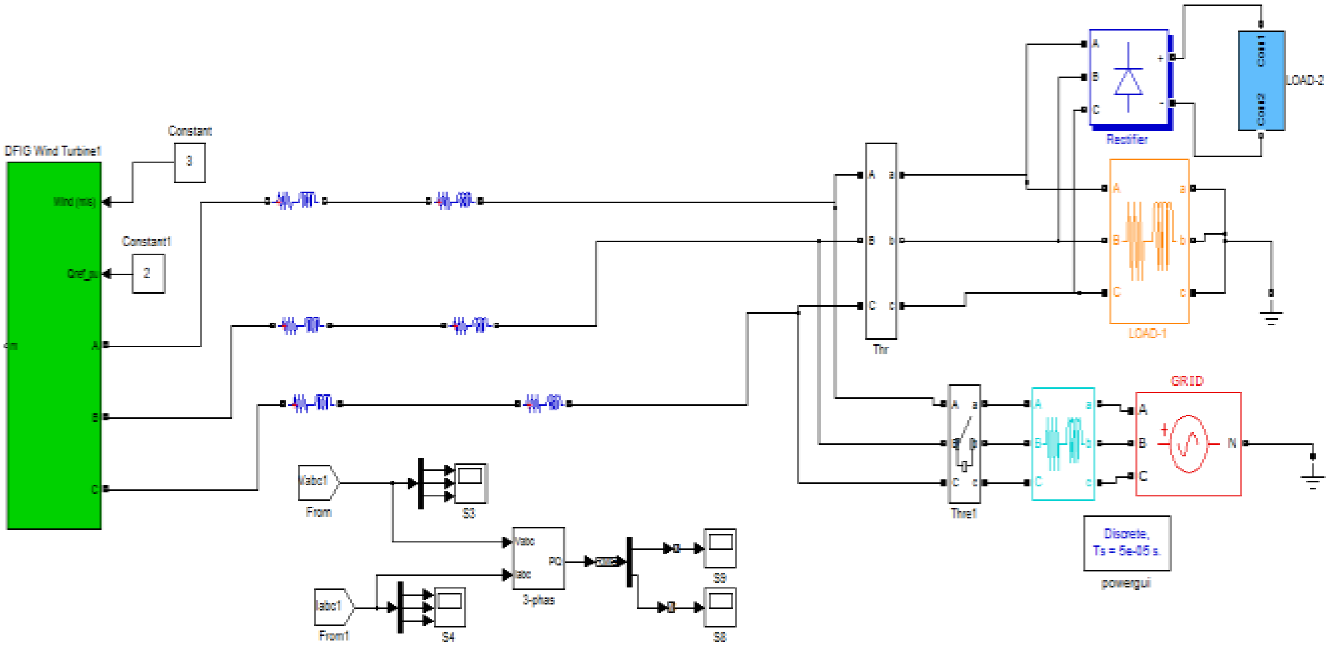

Figure 4 Circuit diagram of without facts device

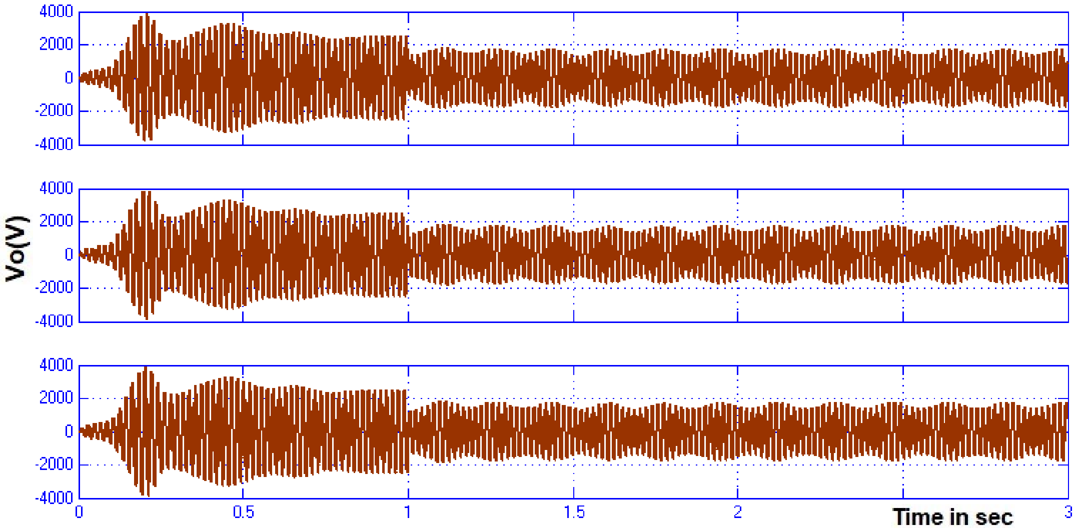

Figure 5 Voltage across RL load

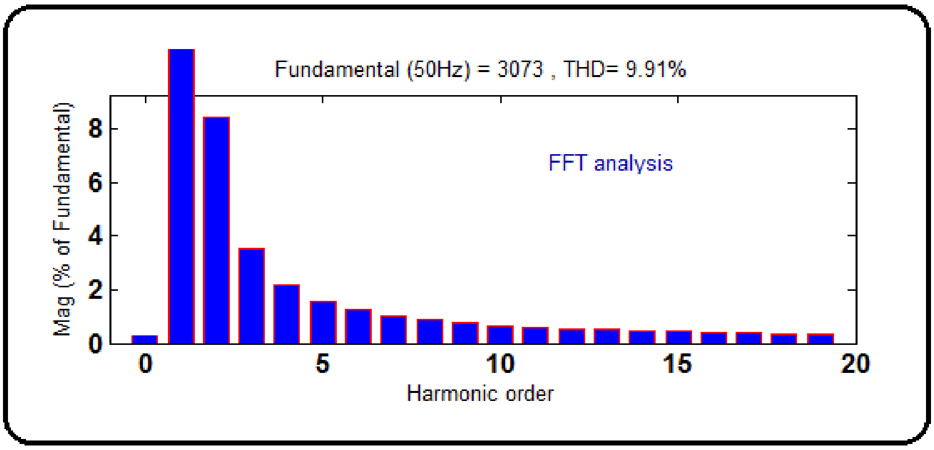

Figure 6 Output voltage THD

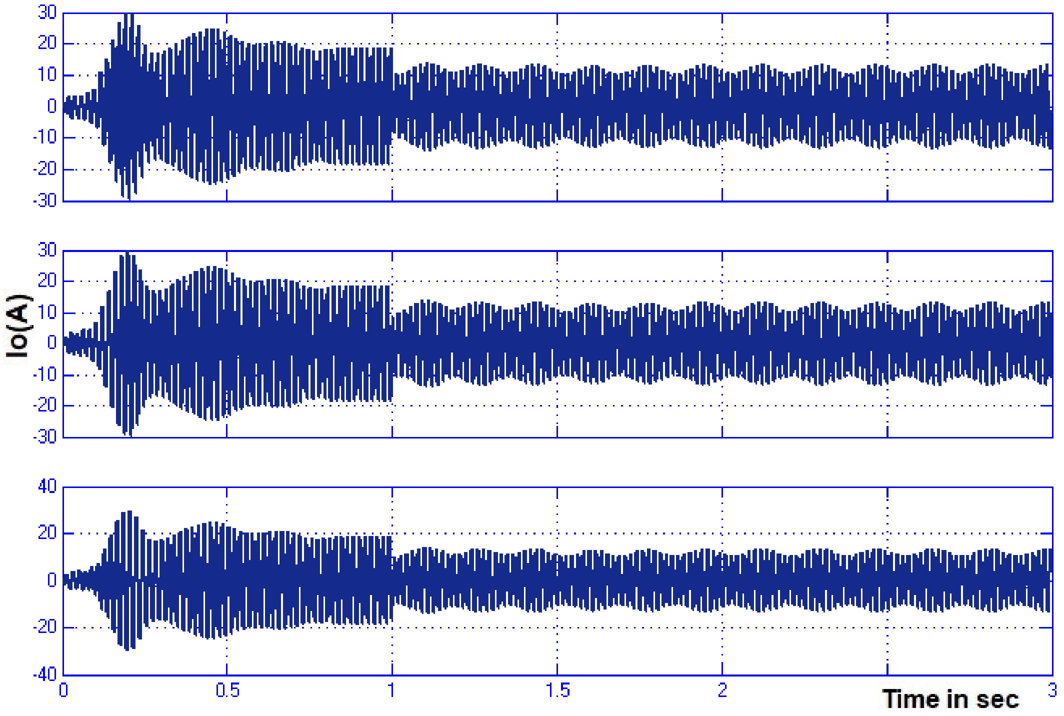

Figure 7 Current through RL load

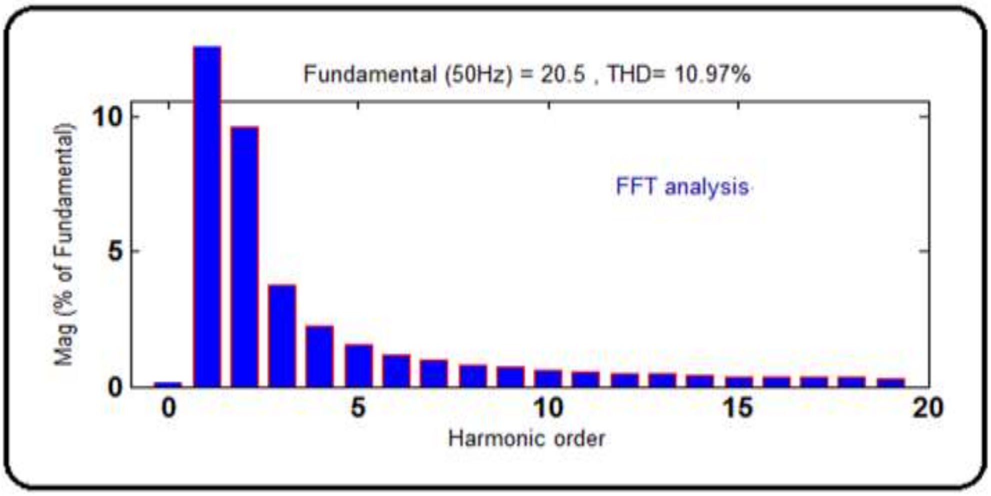

Figure 8 Output current THD

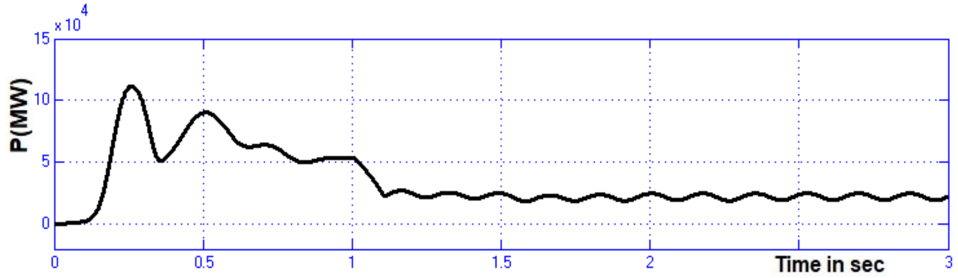

Figure 9 Real power

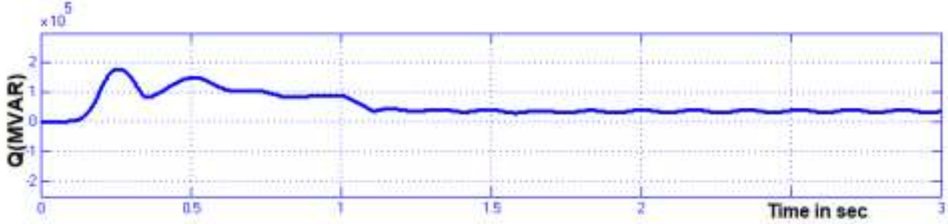

Figure 10 Reactive Power

Circuit diagram of two bus with DVR device is delineated in Figure 11. Voltage across RL load is delineated in Figure 12 & its value is 1850V. Output voltage THD is delineated in Figure 13 & its value is 7.96 %. Output current through RL load is delineated in Figure 14 & its value is 13A. Output current THD is delineated in Figure 15 & its value is 7.48%. Real power is delineated in Figure 16& its value is 0.0463MW. Reactive Power is delineated in Figure 17 & its value is 0.0726MVAR.

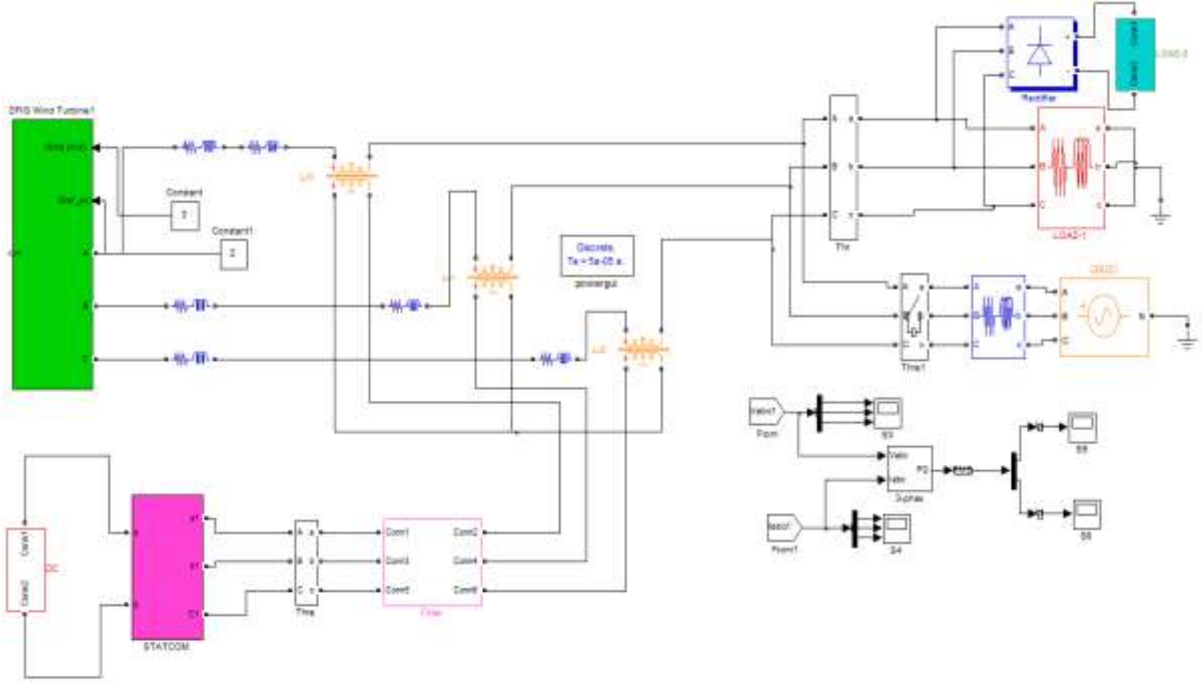

Figure 11 Circuit diagram of two bus with DVR device

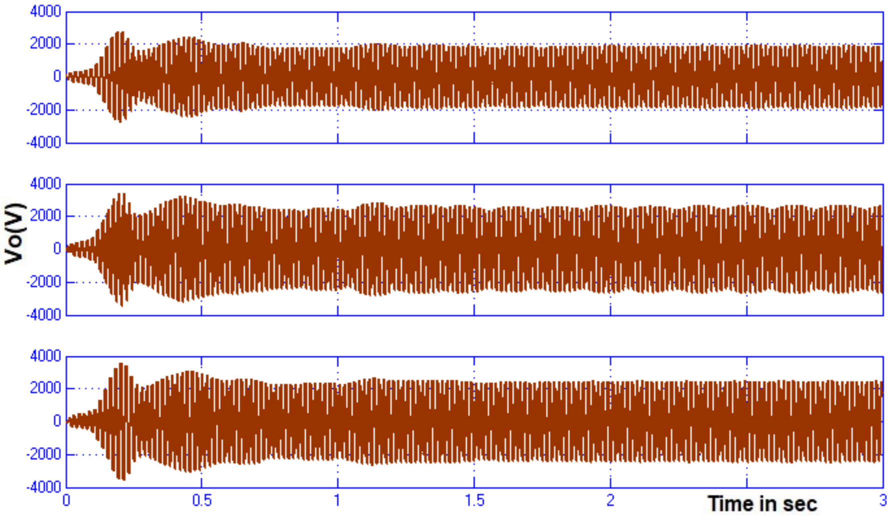

Figure 12 Voltage across RL load

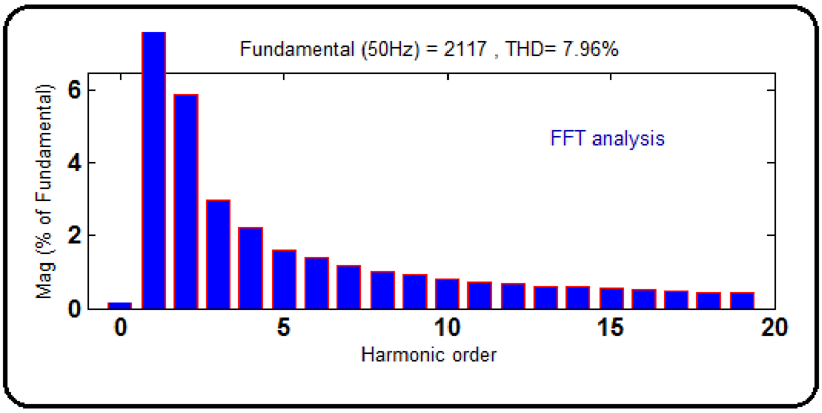

Figure 13 Voltage THD

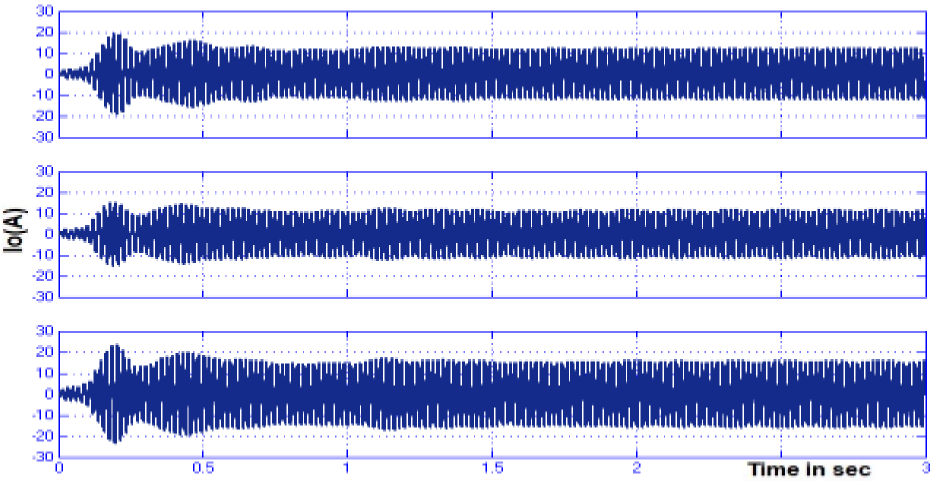

Figure 14 Current through RL load

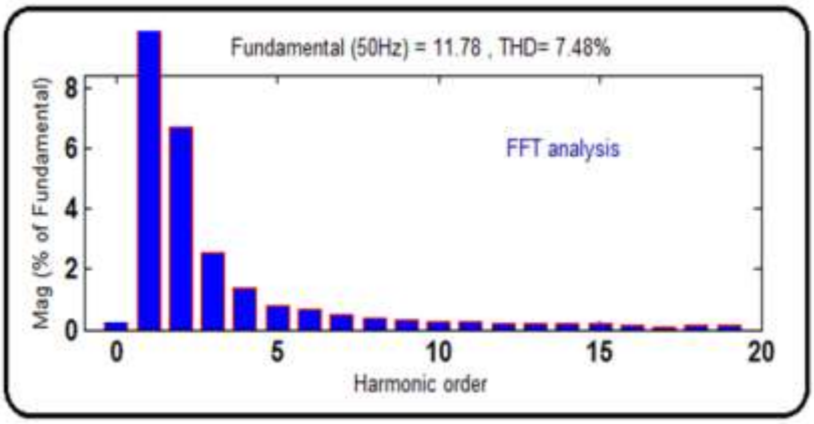

Figure 15 Current THD

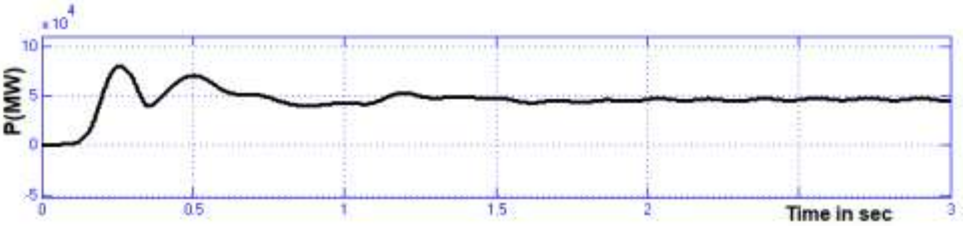

Figure 16 Real power

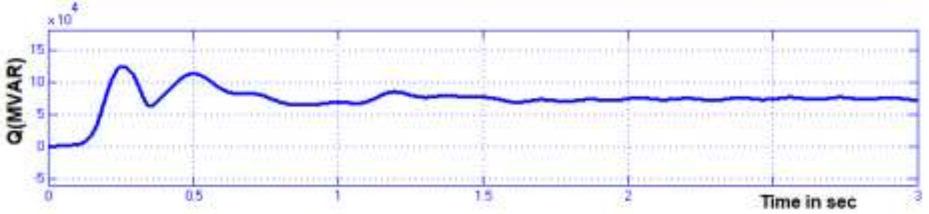

Figure 17 Reactive Power

Circuit diagram of with UPFC is delineated in Figure 18. Voltage across RL load is delineated in Figure 19 & its value is 2500V. Output voltage THD is delineated in Figure 20 & its value is 5.00 %. Output current through RL load is delineated in Figure 21 & its value is 13A. Output current THD is delineated in Figure 22 & its value is 5.84%. Real power is delineated in Figure 23 & its value is 0.0600MW. Reactive Power is delineated in Figure 24 & its value is 0.0987MVAR.

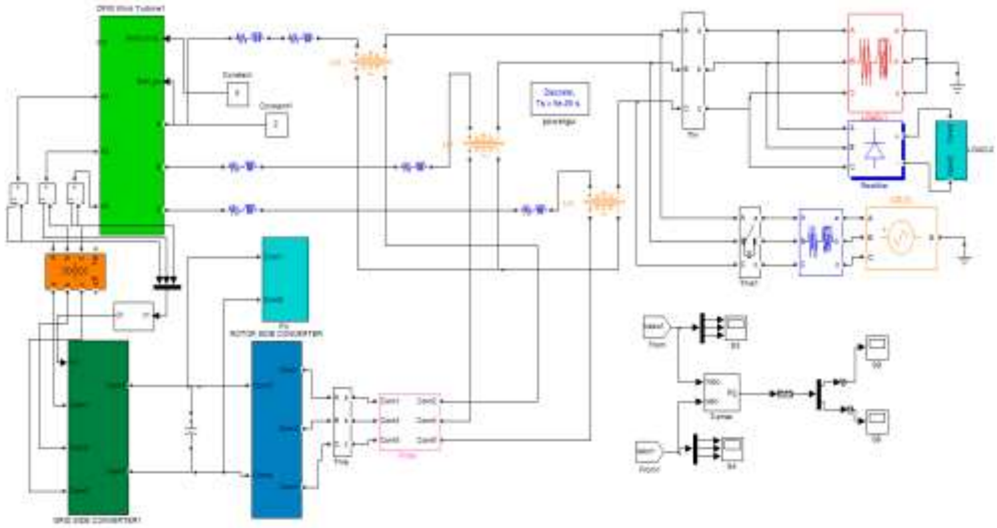

Figure 18 Circuit diagram of with UPFC

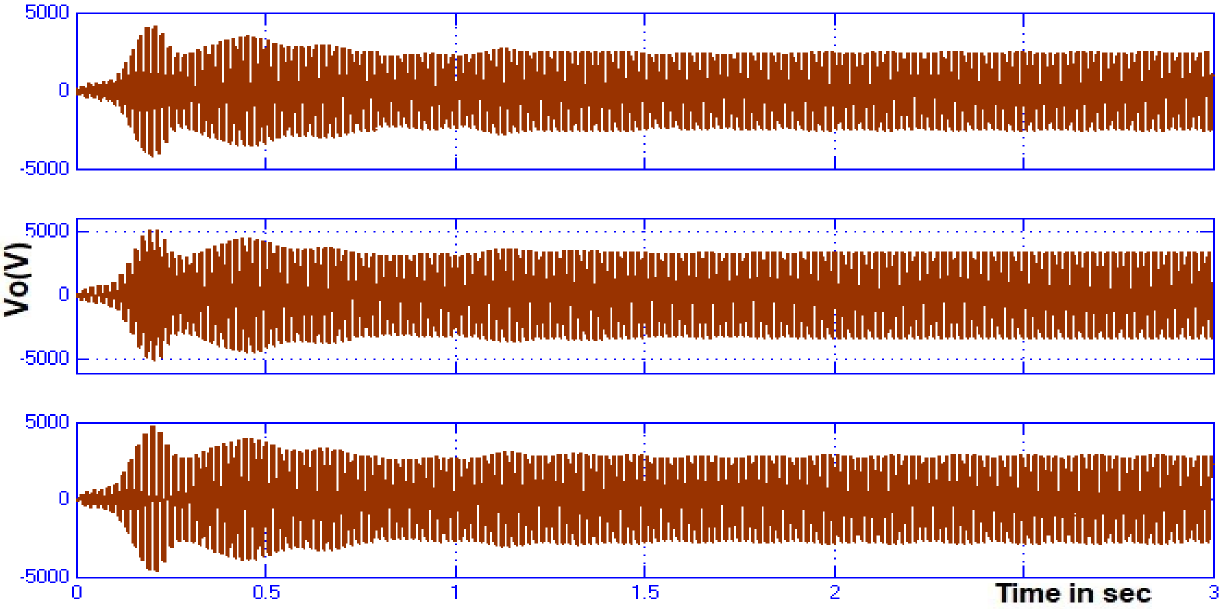

Figure 19 Voltage across RL load

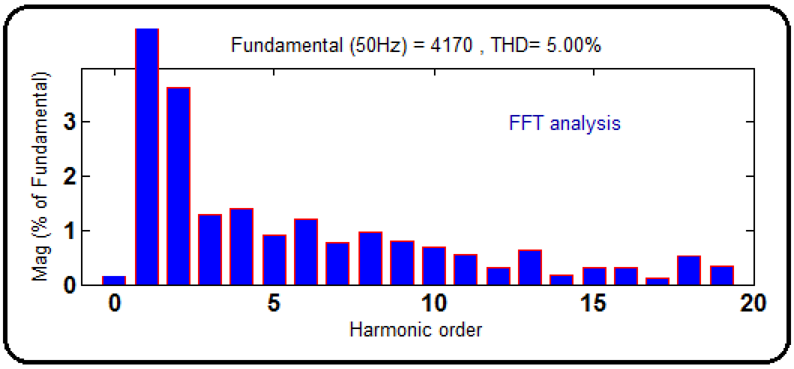

Figure 20 Output voltage THD

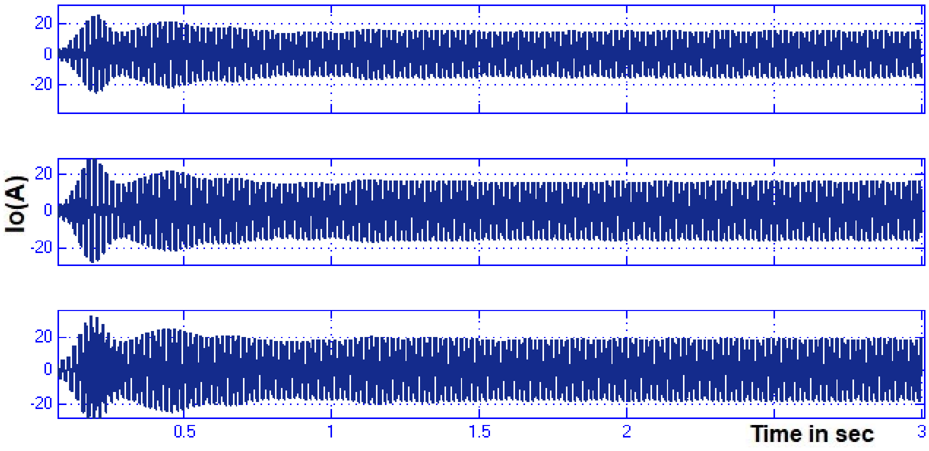

Figure 21 Current through RL load

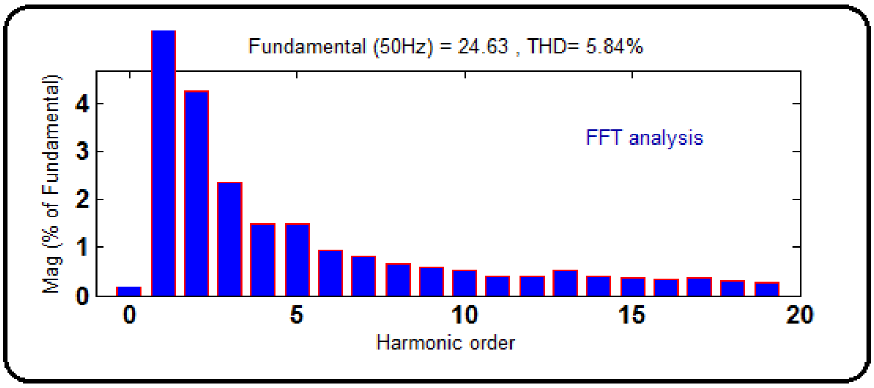

Figure 22 Output current THD

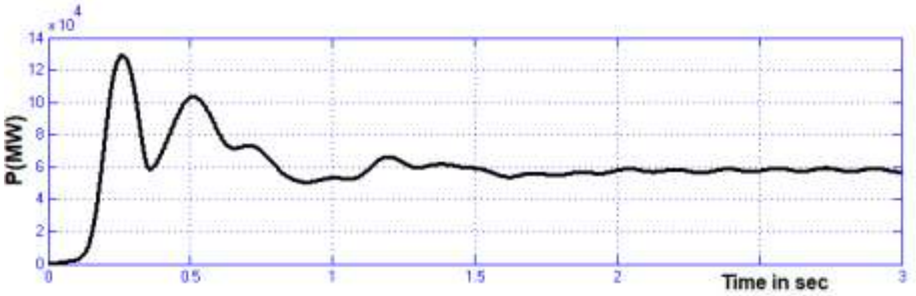

Figure 23 Real power

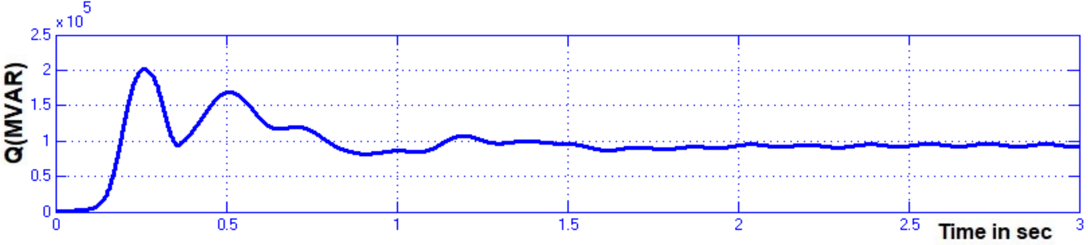

Figure 24 Reactive Power

Table-1Comparison of voltage, Real & Reactive Power

Facts	P(MW)	Q(MVAR)	Vo(V)
Without Facts	0.0235	0.0378	1550
With DVR	0.0463	0.0726	1850
With UPFC	0.0600	0.0987	2500

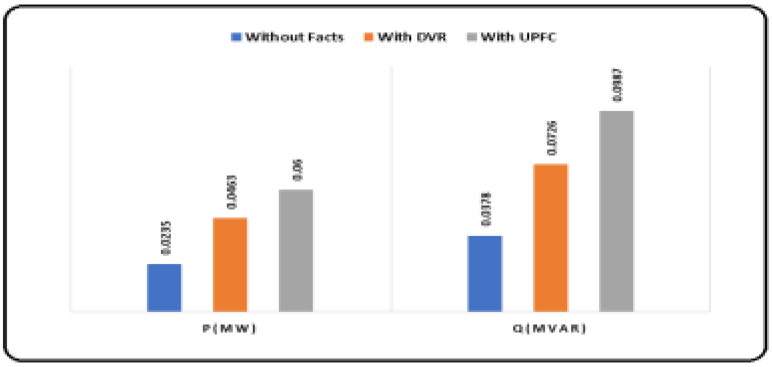

Figure 25 Bar chart of Real & Reactive Power

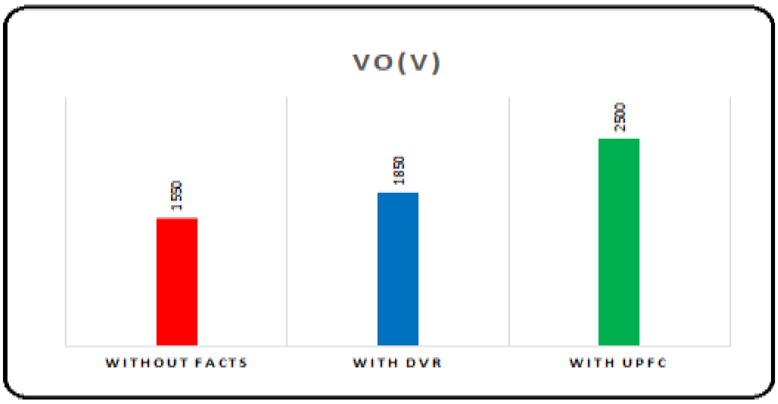

Figure 26 Bar chart of output voltage.

The table 1 shows the Comparison of voltage, Real & Reactive Power for without facts system, with DVR system and with UPFC system. The Figure 25 shows the Bar chart of Real & Reactive Power for without facts system, with DVR system and with UPFC system. The Figure 26 shows the Bar chart of output voltage for without facts system, with DVR system and with UPFC system.

Table-2 Comparison of output voltage and current THD

Facts	Voltage THD (%)	Current THD (%)
Without Facts	9.91	10.97
With STATCOM	7.96	7.48
With UPFC	5.00	5.84

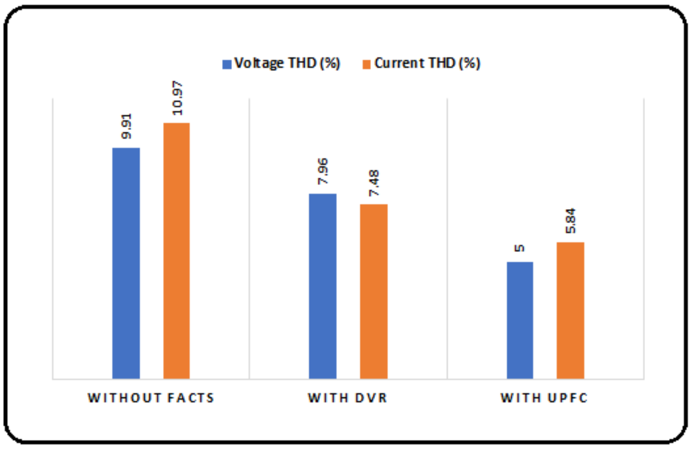

Figure 27 Bar chart of voltage and current THD.

The table 2 shows the Comparison of voltage and current THD for without facts system, with DVR system and with UPFC system. The Figure 27 shows the Bar chart of voltage and current THD for without facts system, with DVR system and with UPFC system.

V. CONCLUSION

Two bus system without Facts system is simulated. Existing Two bus system with DVR system is simulated.Proposed Two bus system with UPFC system is simulated. Above systems are compared. Voltage and current THD was improved by using UPFC.

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