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Performance Analysis of Dstatcom for Harmonic Mitigation in Distribution System

Ankur Gour
Dept. of Electrical Engg, Scope College of Engineering, Bhopal (M.P), India

Namrata Sahu
Dept. of Electrical Engg, Scope College of Engineering, Bhopal (M.P), India

Abstract— DSTATCOM is the simplest and widely adopted power conditioner used in Modern Distribution System (MDS) to mitigate harmonics and to improve Power Quality. It isdesigned with voltage source converter (VSC) or a current source converter (CSC).The VSC-based STATCOM (VSTATCOM) has superior technology relative to other members of its family which provide shunt compensation. VSTATCOM is commercially available with high power capacity with simple converter control and robust design. It is comprised of an inverter circuit, inductor, a capacitor acting as dc source, control circuit for reference current Generation. D-STATCOM facilitates in compensation of the load harmonic as it acts as a current source. Further to this it as many greater advantages like source current balancing, suppression of dc offset in the load and it help to maintain unity power factor.The research scope of the paper is to eliminate harmonics which are the outcome of non-linearity in load current and to retrain the sinusoidal system characteristics.

Keywords—; STATCOM, Dynamic voltage Restorer (DVR), active power filter (APF), Unified power quality conditioner (UPQC).

I. INTRODUCTION

As the technology paces with the era, a paradigm shift has been witnessed in the power electronics leading to the concept of multi-functionality. Hingorani [1] has introduced the concept of FACTS controller which were basically a VAR impedance-type controllers, controlled by varying the firing angle. Power Semiconductor Switch Based Converters (PSSCs) are network of power/semiconductor shifts with high degree of reliability and efficiency [2]. At distribution level, widely adopted FACTS devices are; distribution static compensator (DSTATCOM),unified power quality conditioner (UPQC),and dynamic voltage restorer (DVR), with installation location both at load-end and source-end to improve Power Quality (PQ) of the system [3]. One of the commonly used PSSC is Voltage Source Converter (VSC) which is a self-commutating DC-to-AC converter and is known as the backbone of the compensating devices [4]. Since its design feature is capable of absorbing and generating controllable reactive power. The VSC-based STATCOM (VSTATCOM) has superior technology relative to other members of its family which provide shunt compensation. VSTATCOM is commercially available with high power capacity with simple converter control and robust design[7]. In this paper application of DSTATCOM technology at distribution level to improve PQ. The PQ enhancement of STATCOM under critical dynamic reactive power demand under the condition of heavy Non-Linear Load (NL). The control design proposed here has the reference of sine-function in synchronized frame. This helps in obtaining sinusoidal reference-signal as input to Proportional-Integral Controller (PIC) [8,9]

II. STATCOM

Power quality is the term which expresses the characteristics ofsupply voltage and current. Customer at end use demands goodquality of power since the equipments connected are voltagesensitive long lasting fluctuation or any deviation in the supplyvoltage or current waveform may damage the connected load [10,11]. The PQ problems which a grid operator or designer has tolook after are; voltage sag, voltage swell, harmonics, distortion,frequency deviation etc. any of the above issue may cause seriousproblem for the operation of power system and may lead totrouble to the end customer [12]. The best way to solve this PQissues to install FACTS devices.
STATCOM is one of the high-quality FACTS devices amongst all of the FACTS devices designed via VSC with PIC topology [8]. It is used to maintain a good voltage profile and increase the stability. If it is used in the distribution system then it could be referred as D-STATCOM i.e. the distribution STATCOM [9]. It especially includes an inverter circuit, inductor, a capacitor acting as dc source, control circuit for reference current Generation. D-STATCOM facilitates in compensation of the load harmonic as it acts as a current source [10,11]. Further to this it as many greater advantages like source current balancing, suppression of dc offset in the load and it help to maintain unity power factor (PF) [12]. The single line diagram of D-STATCOM is presented in figure 1.
The most suited method of resolving PQ issues is to install PSSCs [13]. With the help of PSSCs, high efficiency in system performances for various conditions of operation can be obtained [14]. The technology of PECs is evolved very fast due to its advantages in power conditioning; hence they are commercially available to be installed at distribution or consumer side for PQ enhancement [15]. D-STATCOM is also a high power PEC installed as PQ compensator precisely for obtaining sinusoidal profile as well as PF. The proposed topology is based on a VSC, which uses only sinusoidal references to control the PWM converters. In this work control of D-STATCOM is designed using conventional PI controller.

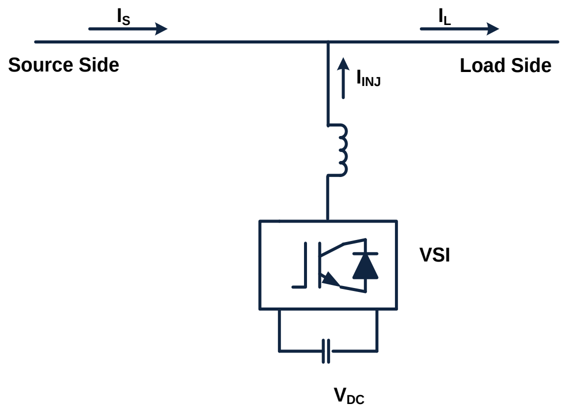

Fig.1 Single-line diagram of STATCOM

The Synchronized Frame of Reference (SFR) is adopted for current-ref generation. The SFR technique is shown in the Figure 2. For simplification of controller 3-Φ-two-phase transformation is done via abc-dq-parks transformation [17]. In the next stage of control architecture, Phase-Locked Loop (PLL) converts the stationary frame into rotating one with sine-cos functionality [18]. This is how synchronization with the source Voltage And Current (V&I) is obtained [19].
The low-pass-filter removes the noise signal from the DC-component of D-Q axis. Proportional-Integral (PI) tunes the signals to rectify static error in the measured quantity in comparison to calculated one.

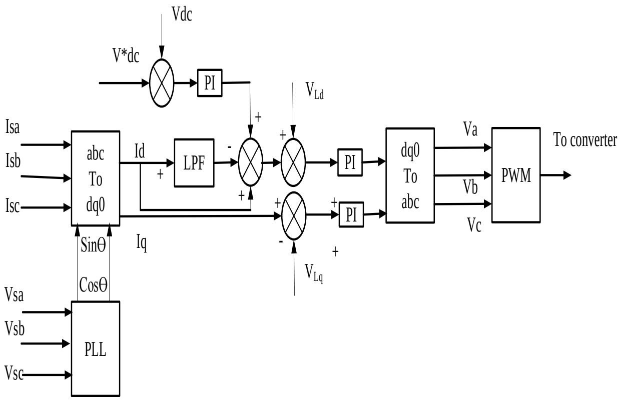

Fig. 2 PI-based DSTATCOM using SFR.

III. SIMULATION RESULTS

Because of large number of non-linear loadings, the occurrence of power quality issue can be reduced but cannot be completely eliminated. In this work PQ-issues elimination is obtained via DSTATCOM.The simulation software is the research tool used to study the performance of DSTATCOM. The MATLAB model of the designed DSTATCOM is presented in Figure 3. The design-parameters for STATCOM connected in MDS is in Table 1. A Simulink block of 3-Φ AC source is considered as grid having 415 V RMS and 50 Hz frequency. The two-level VSI is used to integrate PV with the grid also it acts as a STATCOM which is connected in series with the system using coupling transformer. The performance of the designed DSTATCOM is analyzed for linear loading and non-linear loading.

For linear loading the V&I waveforms have negligible harmonics which are shown in figure 4. Since load is linear hence the V&I waveforms for source as well as load side will be same. Also, waveforms are completely sinusoidal with negligible. For voltage, THD graph is represented in figure 5 and figure 6presents current graph.The effectiveness of designed DSTATCOM to mitigate harmonics is tested by connecting a 3-Φ NL at load bus. The load-current wave-shape containshigh THD as in figure 7. The THD graph for load bus V&I is in figure 8 and the THD for NL load current is presented in figure 9. If any harmonic-compensation is not provided, the high NL current will inject harmonics to the source V&I. The V&I wave forms at source side is presented in figure 10 with DSTATCOM connected. The harmonics in source voltage is presented in figure 11 and the THD for source current is presented in figure 12.

Hence with DSTATCOM shunted at load-bus the NL-current is drained to prohibit to enter the source side and to safeguard the rest of the system connected to the same load-bus.

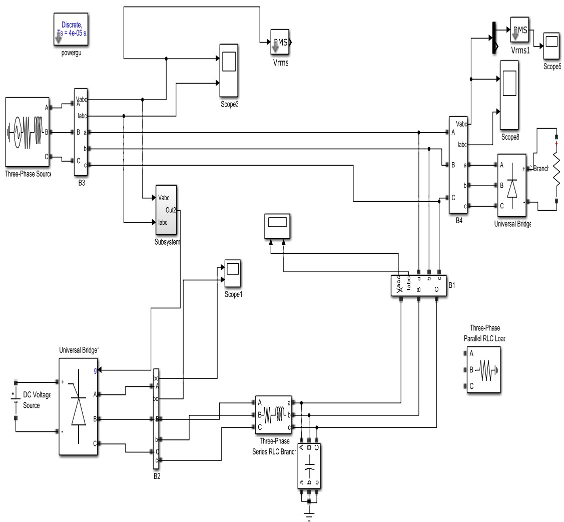

Fig.3 Simulation model of the DSTATCOM

Table 1. Design parameters for DSTATCOM

Parameter	**Values selected**
Voltage, RMS (L-L)	415 V
Impedance of Source	1.58mH
Frequency	50 Hz
V_{DC}	100V
inductance $L_f$of Filter	15mH
resistance R_f of Filter	0.1Ω
capacitor C_f of Filter	800 μF

3-Φ rectifier resistor R_{NLL}	125 Ω
Coupling capacitance	4500 µF
PI-parameter gain	0.04, 500
Linear load	10kW
Non-linear load	8kW

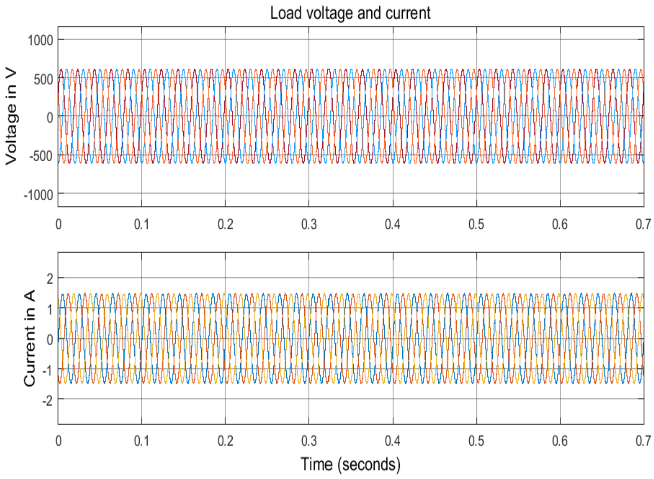

Fig. 4 Voltage and current waveforms for linear loading

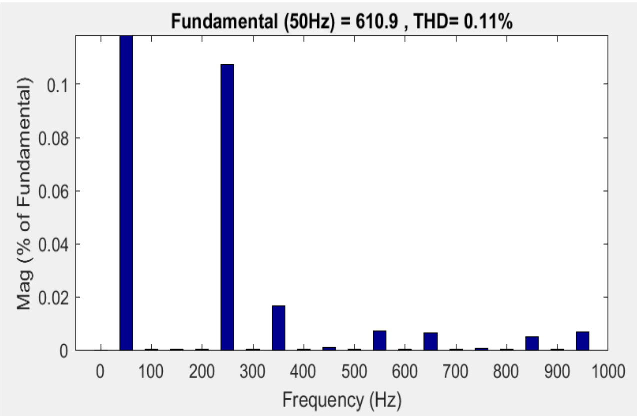

Fig. 5 THD of voltage for linear loading

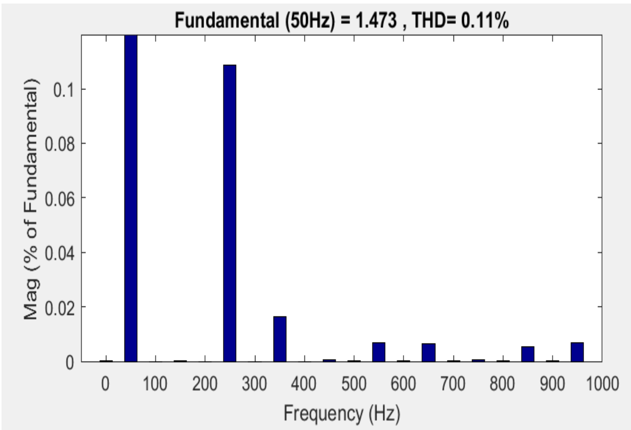

Fig. 6 THD of current for linear loading

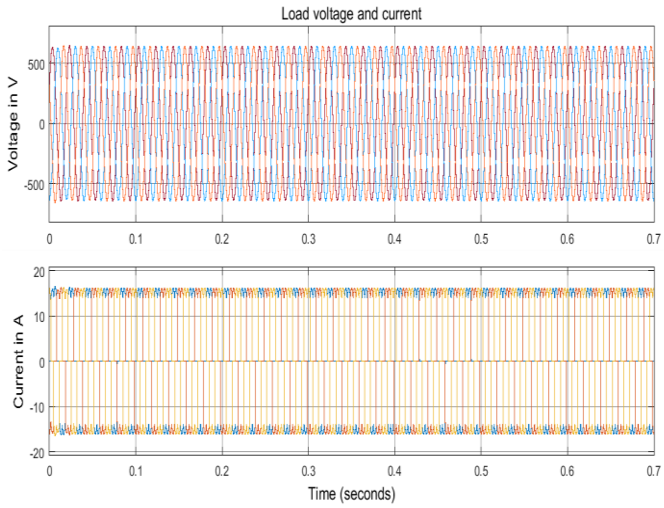

Fig.7 Load voltage and current waveforms for non-linear loading using PI controller

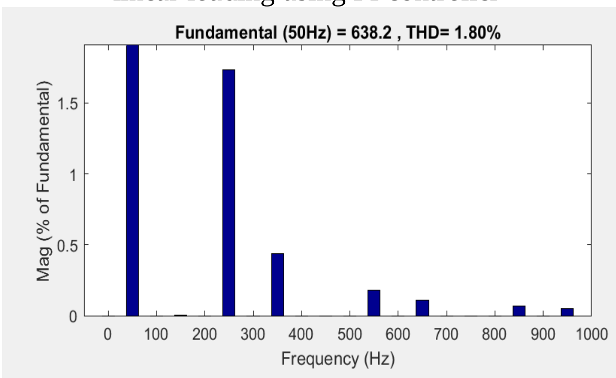

Fig. 8 THD of load voltage for non-linear loading

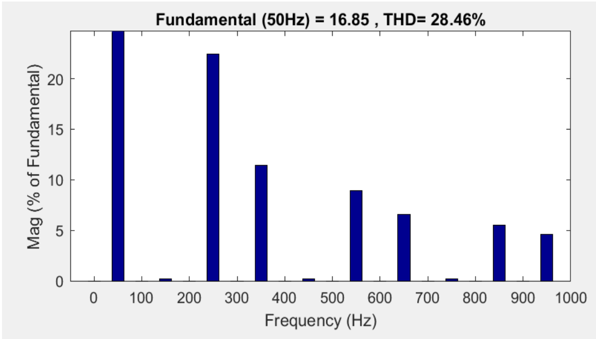

Fig. 9 THD of load current for non-linear loading

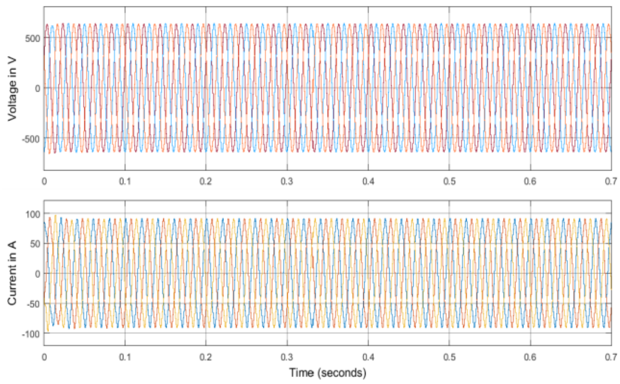

Fig. 10 Source voltage and current waveforms for non-linear loading using Pi controller

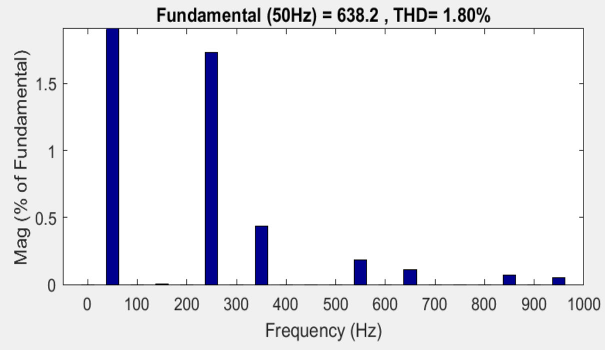

Fig. 11 THD of source voltage for non-linear load

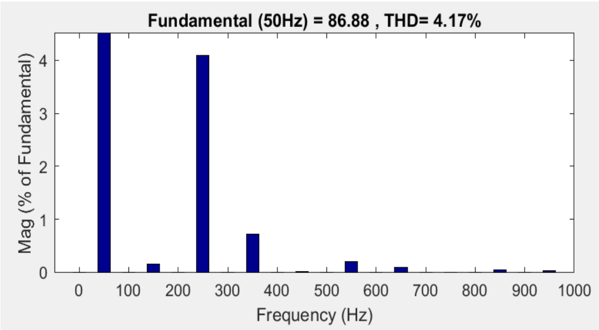

Fig. 12 THD of source current for NL

IV. CONCLUSION

At distribution, there is variety ofunbalancednon-linear connected whichis the threat to the interconnected system as well as may damage partially or completely to various high rating power system equipments and devices connected.Non-linear load (NL) forms the large share of load pattern in MDS. They are basically PSS based controlled load. Theirs popularity is due to low power requirement and versatile attractive product catalogue which is very eye-catching. When NL is connected in the system it injects high harmonics of the order of 28% in load current. If theses harmonics are not mitigated, they will propagate to other busses of the system. When the proposed DSTATCOM is connected at load bus it drains the generated harmonics and the voltage as well as current waveforms are completely sinusoidal with low harmonics of 1.8% and 4.7% respectively. Hence it is widely adopted in MDS to improve PQ of the system.

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