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Matlab Simulink Model of D-STATCOM for Power Quality under Various Operating Modes

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Abstract: The objective of this paper is to design external inductor which satisfies several practical constraints, allow DSTATCOM to regulate load voltage in stiff as well as resistive feeder, reduce the current requirement for mitigation of sag, and reduce the system losses. With coordinated control of the load fundamental current, terminal voltage, and voltage across the external inductor, a dynamic reference load voltage generation scheme is presented. This scheme ensures unity power factor (UPF) operation during normal operation and maintains load voltage constant during voltage disturbances. Detailed simulations to support the same have been carried out in MATLAB, and the results are presented.

Keywords: DSTATCOM, Voltage Sag, External Inductor

I. Introduction

In recent years, the main concern of consumers of electricity was the reliability of supply. The reliability is defined as the continuity of the electric supply. Even though the power generation in most developed countries is fairly reliable, the distribution is not always so. It is not only reliability that the consumers require in these days, bus also power quality is very important to them. For example, the consumers that are connected to the same bus that supplies a large motor load may have to face a severe voltage sags or dips in their supply. In some extreme cases, they may have to tolerate with blackouts. This is unacceptable to most customers. There are also very sensitive loads such as hospitals (life support, operation theatre and patient database system), processing plants (semiconductor, food, rayon and fabrics), air traffic control, financial institutions and many other data processing and service providers that require clean and uninterrupted power. In several processes such as semiconductor manufacturing or food processing plants, the products can be destroyed by voltage sag of very short duration. Such customers are very wary of such voltage sags since each such interruption cost them a substantial amount of money. Thus in this changed scenario in which the customers increasingly demand quality power, the term power quality (PQ) attains increased significance.

Faults in a widespread power system as well as switching of large loads create voltage disturbances such as sag and swell in a distribution system [1]. These power quality (PQ) problems significantly degrade the performance of sensitive loads like process-control industry, electronics equipment, adjustable drives, etc. Conventionally, static var compensator (SVC) is used to regulate load voltage, compensate reactive current, and improve transient stability. However, the SVC causes problems like harmonic current injection in the system, harmonic amplification, and possible resonance with the source impedance [2]. Distribution static compensator (DSTATCOM) has been proposed to overcome the limitations of SVC [3]–[9]. A DSTATCOM is one of the most effective solutions to regulate the load voltage.

It provides load voltage regulation by supplying fundamental reactive current into source [5], [10]–[15]. However, most of the conventional DSTATCOMs used for voltage regulation consider highly inductive and/or significantly large feeder impedance [11], [13]. This is usually not true in a distribution system where feeder impedance used to be resistive in nature [16], [17]. In this scenario, the DSTATCOM will have small voltage regulation capability. Another important issue is the generation of reference load voltage. In conventional DSTATCOM application for voltage regulation, reference load voltage is set at 1.0 per unit (p.u.) [13]. At this load voltage, voltage-source inverter (VSI) always exchanges reactive power with the source with leading power factor. This causes continuous power losses in the feeder and VSI. Also, a conventional DSTATCOM requires high-current rating VSI to provide voltage support [11]. This high-current requirement increases the power rating of the VSI and produces more losses in the switches as well as in the feeder.

Based on the distance between source and load, a source is termed as stiff or nonstiff. If the distance is long, then source is termed as nonstiff and has high feeder impedance, whereas if the distance is very small, then source is termed as stiff and has negligible feeder impedance. Generally, a source (stiff or nonstiff) supplies a permissible range of voltage, which is sufficient for satisfactory performance of load [14]. In this situation, DSTATCOM should operate in CCM. However, due to grid faults, the source voltage (stiff or nonstiff) can change at any time, and then, the VCM operation is required. DSTATCOM regulates the load voltage by indirectly regulating the voltage across the feeder impedance. When a load is connected to nearly a stiff source, feeder impedance will be negligible [1] – [4], [15], [16].

The voltage regulation performance of DSTATCOM mainly depends upon the feeder impedance and its nature (resistive, inductive, stiff, and nonstiff). For voltage control mode (VCM) operation of DSTATCOM and/or grid-connected inverters, the idea of inserting an external inductor in line has been reported [18], [19]. However, in these schemes, only the concept has been introduced leaving ample scope for further investigation and insight into the design details.

II. D-STATCOM

The heart of the D-STACOM used for compensation of the power system is its control system that the D-STATCOM control strategies will be presented in this chapter. In addition, the example of the applications and installations of the D-STATCOM for compensation of the distribution system are presented.
The schematic diagram for load compensation using the D-STATCOM is shown in Figure 1.

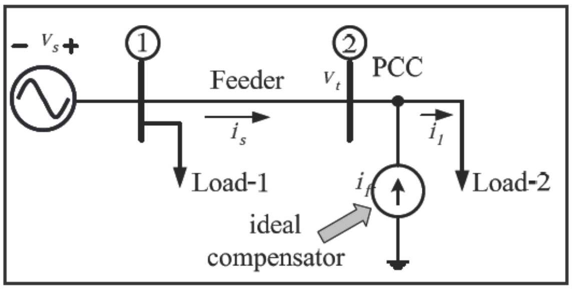


Figure1: Distribution systems with the installed D-STATCOM

III. DSTATCOM Control Methods

The control methodologies used for generation of the compensating commands generally involve frequency domain and time domain control techniques. The D-STATCOM using the time-domain methodologies senses the time-domain signals of instantaneous voltage and / or current vectors and synthesizes the dq signals using the popular dq synchronous rotating axis transformation.

Control techniques like PI or PID are then used to process the transformed signals to derive the compensating signals. In addition to this symmetrical component transformation and unit vector control are some of the other popular control schemes to extract the reference signals in time domain. In the PWM mode of control two popular control techniques, voltage control (VC) and current control (CC) are adopted. The schematic diagram for the carrier based PWM control is shown in Figure 2. A fixed frequency carrier based sinusoidal PWM is used for generating the switching pulses for the switch of the VSC. This algorithm is based on the instantaneous reactive power theory. The instantaneous voltage and current of the system and the load are measured.

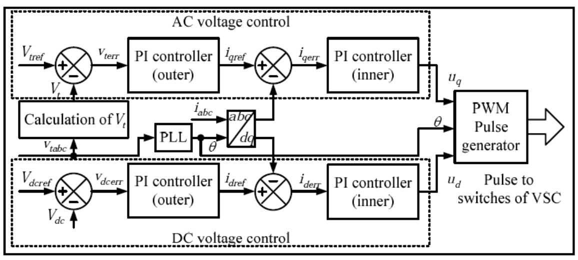


Figure 2: Schematic diagram for the carrier based PWM control

IV. Simulation Result Analysis

This section presents detailed simulation results of the proposed control system. The simulated system is shown in Figure 3.

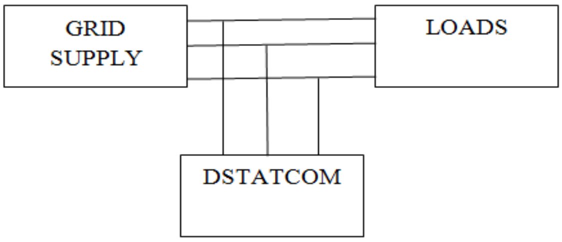


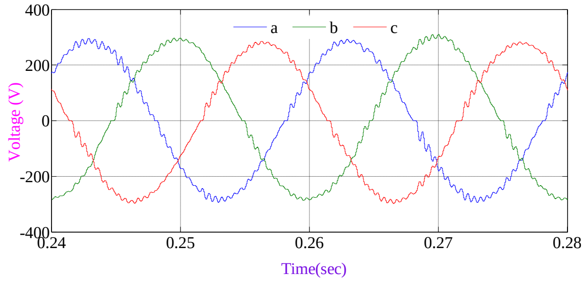
Fig.3: Block diagram of DSTATCOM topology in the distribution system

An external inductance L_{ext} is included in series between load and source points. This inductor helps DSTATCOM to achieve load voltage regulation capability even in worst grid conditions, i.e., resistive or stiff grid.

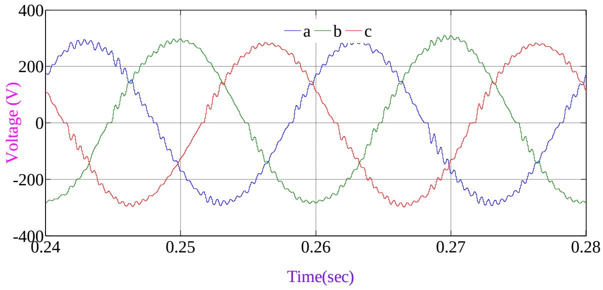
Table 5.1: Parameters of simulation

Parameters	Values
Source Voltage	230 V rms, 50 Hz
DC voltage	240V
LC filter	3mH, 33µF
Non Linear Load	Three Phase Rectifier

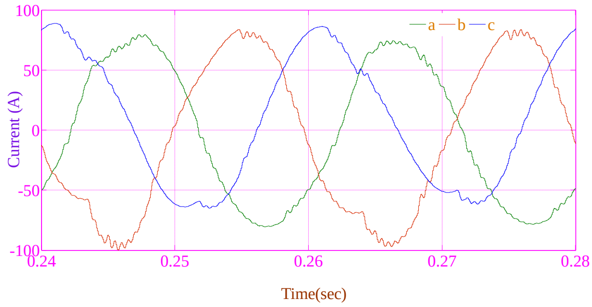
The steady-state waveforms of three-phase PCC voltages, load voltages, source currents, filter currents, and load currents are shown in Figure 4 (a)–(e), respectively. Figure 5 (a)–(b) is the steady-state waveforms with the designed external inductance and flexible control strategy. This scheme simultaneously controls load voltages and source currents.



(a) Source Voltage



(b) Load Voltage



(c) Source Currents

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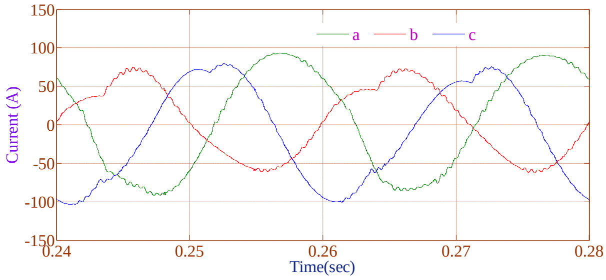
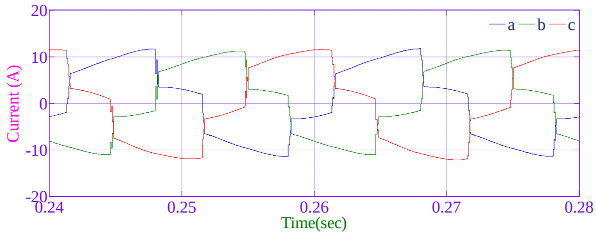
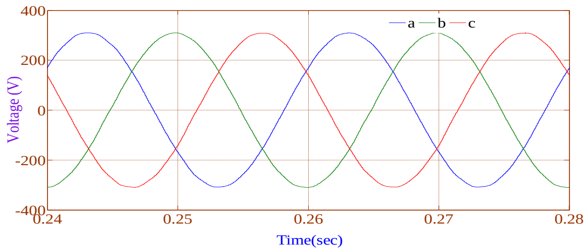


(d) Filter Currents

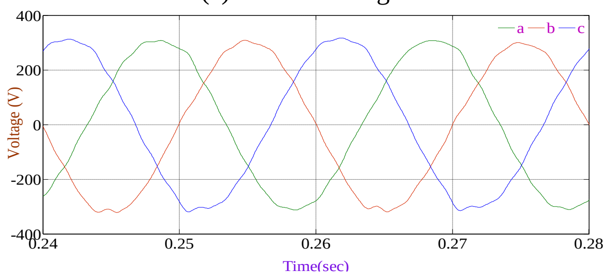


(e) Load Currents

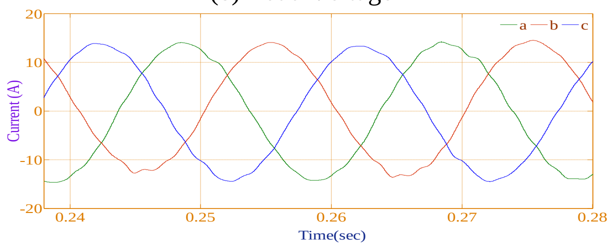
Figure 4 (a)–(e), the steady-state waveforms



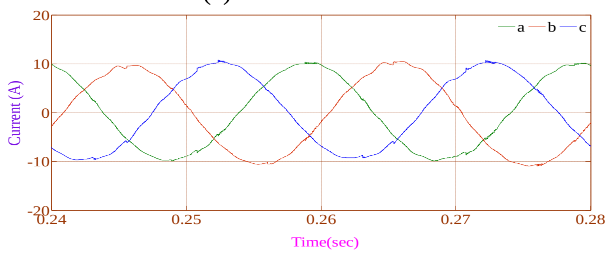
(a) Source Voltage



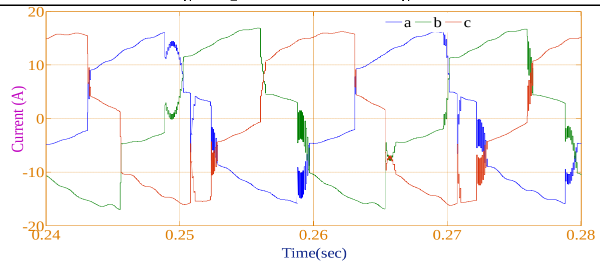
(b) Load Voltage



(c) Source Current

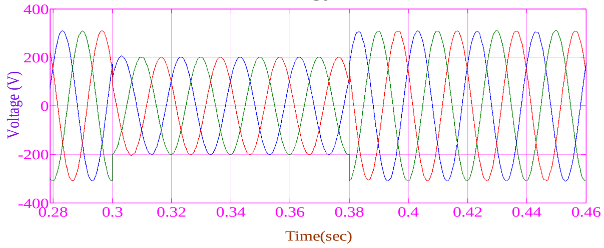


(d) Filter Currents

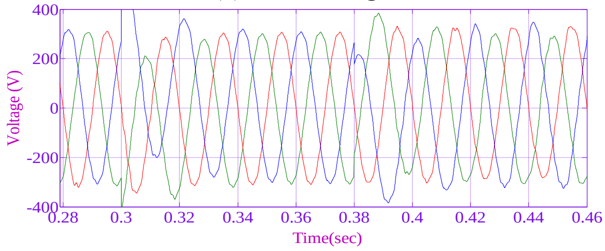


(e) Load currents

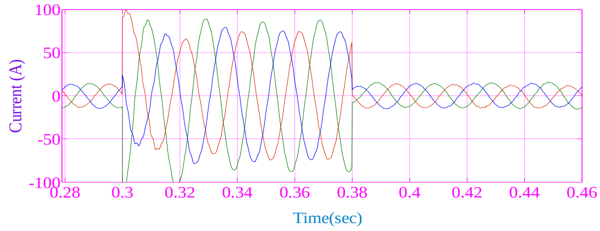
Figure 5 (a)–(b) is the steady-state waveforms with the designed external inductance and flexible control strategy.



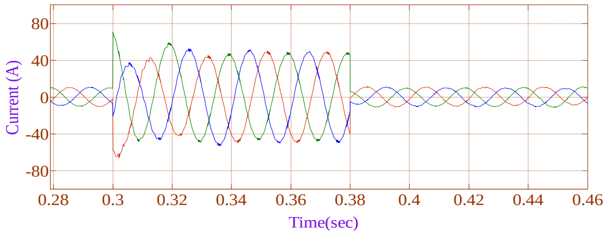
(a) PCC Voltage



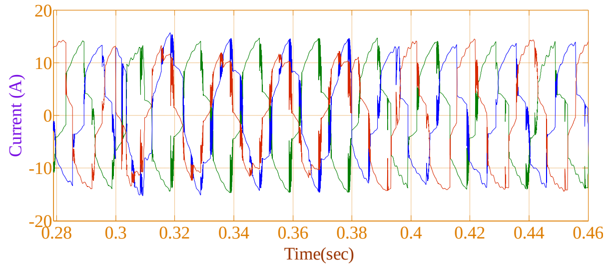
(b) Load Voltage



(c) Source Current

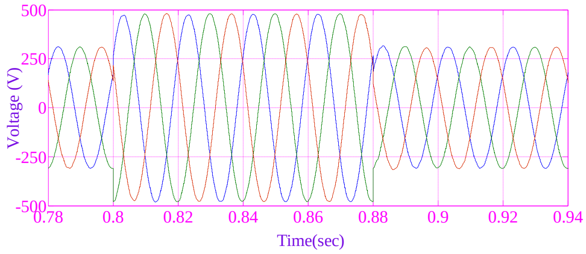


(d) Filter Current

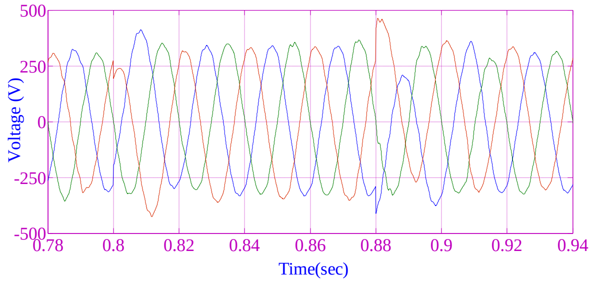


(e) Load Current

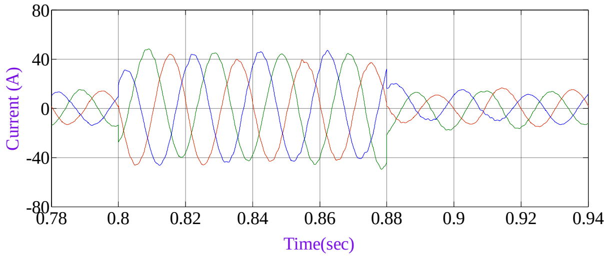
Figure 6: D-STATCOM simulation results during voltage sag



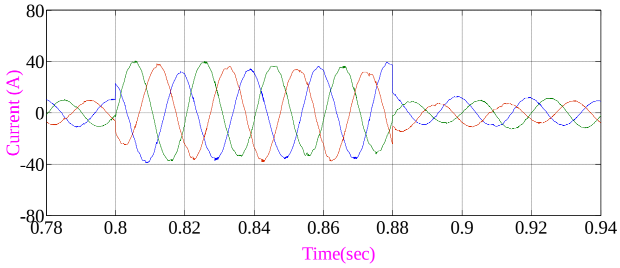
(a) PCC Voltage



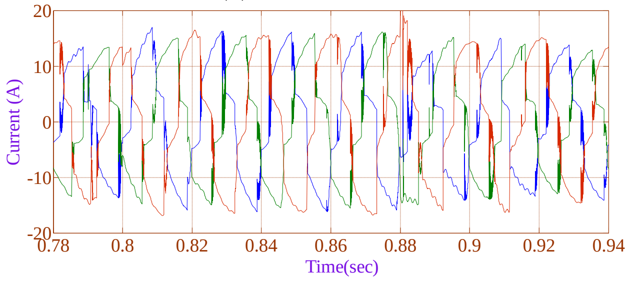
(b) Load Voltage



(c) Source Current



(d) Filter Current



(e) Load Current

Figure 7: D-STATCOM simulation results during voltage swell

Voltage sag is created by reducing the source voltage at t = 0.3 s for four cycles as shown Figure 6. Source voltage is increased to 1.4 p.u. at t = 0.8 s to create swell. The PCC voltages are shown in Figure 7(a).

V. Conclusion

In this paper, algorithm is formulated for dynamic reference load voltage magnitude generation. Dynamic reference load voltage generation scheme allows DSTATCOM to set different constant reference voltage during voltage disturbances. Simulation results validate the effectiveness of the proposed solution under different operating modes.

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