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Analysis of PV Based D-STATCOM

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***Abstract*— With growing environmental concerns, renewable energy** sources are crucial in the production of electric power. Power electronics converters are used to interconnect renewable energy sources in order to enhance power quality at the common coupling point (CCP). Distribution Static synchronous compensators (DSTATCOM) is creatively used in this study, an interface unit between the grid and renewable energy source, and a technique for real power exchange between the dynamic load system, grid, and renewable energy source. This paper, titled "Analysis of PV-Based DSTATCOM" aims to investigate and evaluate the effectiveness of a Solar integrated Distribution Static Compensator (DSTATCOM) using the ICOSϕ method. The study will focus on the performance of the DSTATCOM in reducing problems with power quality such as voltage regulation, reactive power compensation power factor improvement and harmonics while integrating renewable energy sources. Through matlab simulation and analysis, this research will offer insightful information on the practical implementation of DSTATCOM systems with PV integration, contributing to improved power quality and the efficient utilization of renewable energy sources in the distribution network.

Keywords- Photovoltaic Cell (PV),Synchronous reference frame(SRF), PV-DSTATCOM, power quality (PQ), reference dc link voltage, MPPT technique,Voltage Source Converter.

I. Introduction

In this contemporary era of industrialization, due to huge energy demand the issues with electricity quality are receiving a lot of attention. Linear lagging and Non-linear loads like light dimmers, variable speed drives, AC motors, transformer computer and electronic power sources and many more have adverse impact on power quality. That leads to unsatisfactory performance [1]. The primary challenges in the power system are harmonic distortion, low power factor, and high reactive power demand. With increased load demand there is a void between supply and demand of electrical power. One of the best pieces of equipment for distribution systems to minimize this issue at the lowest possible cost is D-STATCOM. By making its output voltage's amplitude larger than the ac supply system's voltage, a VSC-based DSTATCOM can be configured to inject reactive power into the system to increase the power factor and for reactive power compensation in addition to voltage regulation [2]. Plenty of research works have been carried out with device which can provide active power along with compensation of reactive power and improvement in power factor such as PV- DSTATCOM. When there are balanced or unbalanced source and load conditions in a three-phase system, the Icosϕ method can compensate for harmonics, reactive loads, and imbalance. In this proposed work, the Icosϕ algorithm aims to provide actual power exchange from the renewable energy source, reactive power compensation, and power factor adjustment [3]. The proposed system can operate in two modes, namely PV-DSTATCOM and DSTATCOM, with an automatic transition between the two modes depending on PV power availability. The PV-DSTATCOM combines the advantages of a DSTATCOM, addressing current quality issues and reducing the demand on conventional power sources. In times of excess power generation, it allows for bidirectional power flow, supplying power to both the grid and the load. Perturb & Observe MPPT technique is used to improve performance of PV system. However, in the absence of solar PV power, the system seamlessly switches to DSTATCOM mode, drawing power from the grid and the converter system, effectively improving power quality [4]. This paper will provide reactive power compensation, active power support, power factor improvement and constant voltage for linear lagging load with the help of matlab simulation. Figure 1 displays the proposed system's general block diagram.

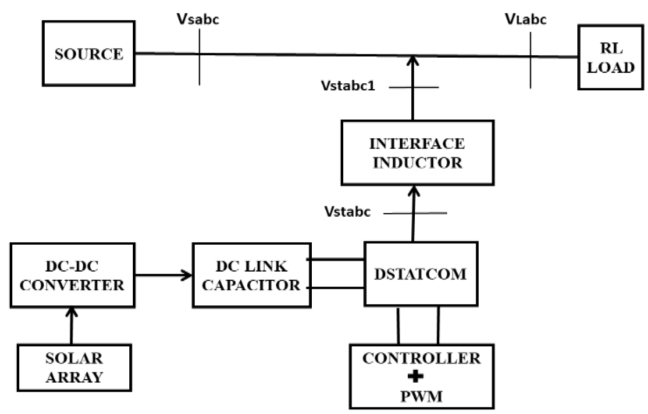

Fig. 1 Block diagram of PV-DSTATCOM

II. 'ICOSϕ' ALGORITHM

The controller circuit receives the detected load current and supply voltage as inputs. The fundamental load current, which has an intrinsic phase shift of 90°, is extracted by feeding the load current into a second-order low pass filter, whose cut-off frequency is 50 Hz. The source phase voltage's zero crossing moment is found using "Detect Negative" logic. The sample and hold circuit receives corresponding response as one of the inputs and the other input comes from the second-order low-pass filter in addition to the phase shift of 90°. The needed Icosϕ magnitude is the output of the sample and hold circuit. To obtain the intended mains current for each phase, multiply the Icosϕ magnitude by the unit amplitude of the associated source phase voltage. The Icosϕ algorithm uses sample and hold circuits and a second-order low-pass filter adjusted to the fundamental frequency to infer the fundamental component of the active part of the load current from the load current in each phase. This indicates the required mains current's amplitude in each phase.

Next, the amplitude "Icosϕ" and the unit sine wave for each phase are multiplied to get the appropriate main currents. The additional power loss in the VSC and/or the interface device is computed using the fluctuations in the capacitor voltage, taking into account the necessity of an independent DC bus for the VSC. In each phase, the active component of the fundamental load current is increased by the corresponding current amplitude, which has been computed. The difference between the actual load currents and the intended mains currents for each of the three phases is consequently used to calculate the reference compensation currents for the shunt active filter. Unit amplitude sine waves in phase with the main voltages are produced by using the three-phase mains voltages as templates. The required waveform of source current in each phase is obtained by multiplying of the two, that is, the amplitude Icosϕ of the reference source current and the unit sine wave. We can produce the gate pulses for DSTATCOM using this waveform [1]. Figure 2 shows the Block diagram of "Icosϕ" algorithm.

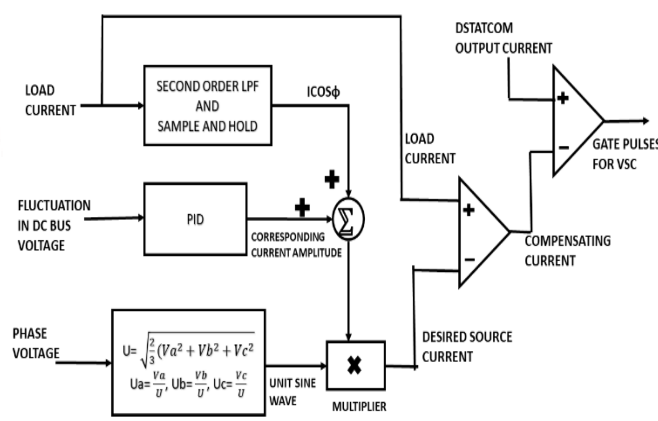

Fig.2 Block diagram of "Icos φ" Algorithm

III SYNCHRONOUS REFERENCE FRAME THEORY

Of all the controlling schemes, SRF is a traditional control scheme. SRF is used to balance the current harmonics of loads that are linked to distribution lines. The gate pulses for thyristors are produced by this technique, which computes reference current signals and compares them to source currents. Parks transformation is being used for the transformation from abc to dq0 frame. The inverse parks transformation is used to transform abc from dq0 once the direct and quadrature axis parameters have been adjusted. The three leg inverter circuit's gate pulse is then obtained using the received abc signal.

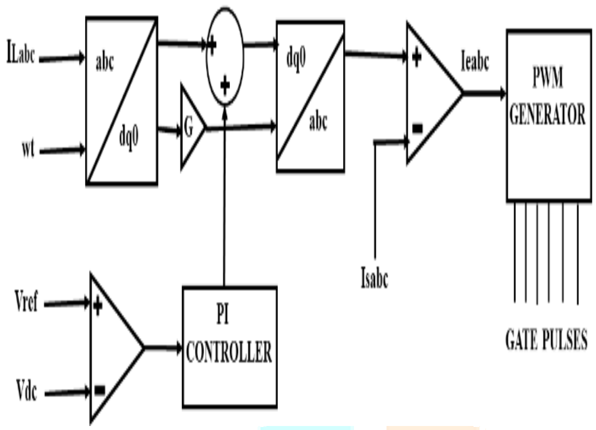

Fig. 3 Controlling of D-STATCOM by generation of gate pulses

Figure 3 indicates the controlling of DSTSTCOM with the help of SRF theory. The load current is first changed by parks transformation from abc to dq0 in order to control. To keep the system's necessary active power, the d-axis current is further used. Active power flow requires the error voltage (Vref-Vdc) to be passed to the PI controller in order to maintain the capacitor voltage to Vref. The current error signal is created from the voltage error signal after it has passed through the PI controller and is added to the Id.

Reactive power to the system is further controlled by the q-axis current. By altering the controller's gain, the Iq travels through it and modifies the reactive power supply provided to the system. Gain adjustments are made with the requirements for reactive power supply in mind, which regulates the reactive power coming from the DSTATCOM.

IV SIMULATION MODEL OF PV-DSTATCOM

Figure. 4 shows the MATLAB Simulink model of the entire PV based DSTATCOM. In this model three phase source is used of 415 volts, 50Hz and solar irradiation is considered as 1000 W/m2. The linear lagging load having 100KW and 50KVAR is connected at PCC. DSTATCOM is connected at Point Of Common Coupling(PCC) at 0.5 second. The parameters of system are indicated in Table. 1

Table.1 Various parameters of the system

SYSTEM PARAMETERS	VALUE
AC line voltage	415
Coupling inductor	3mH
DC bus Capacitance of DSTATCOM	10000µF
DC bus voltage of DSTATCOM	700V
PI controller	Kp= 1.4 and Kd=
Linear lagging load	P= 100KW Q= 50KVAR

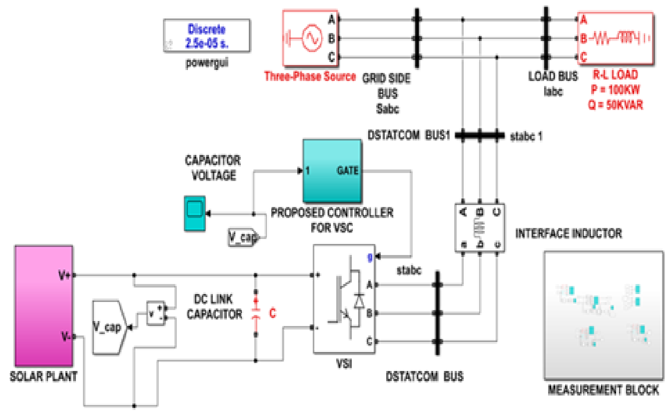

Fig.4 Simulation Model of PV- DSTATCOM

The Photovoltaic cell comprises of many configurations (modules) connected to a series and parallel to generate voltage and current that are essential to the system (DC-link). The DC-link voltage is maintained at 700 V. The output of solar plant is raised using boost converter. Perturb and Observe MPPT technique is implemented. The output voltage, current and power of PV system is shown in Figure 5.

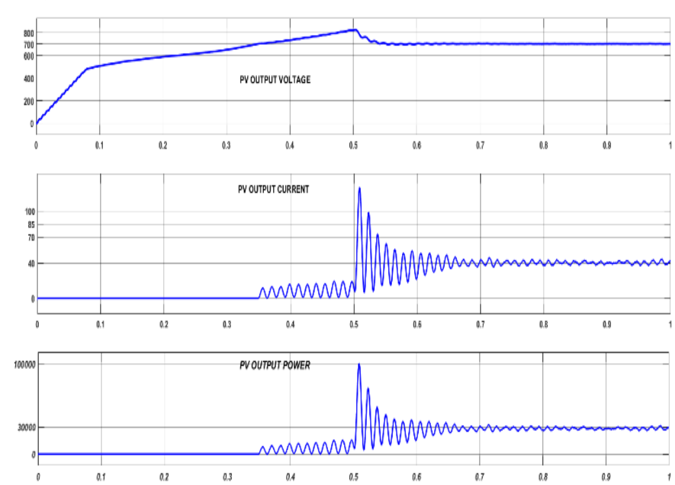

Fig.5 Output of PV system

The DC-link capacitor is set to initial charged and DC-link voltage is maintained at 700V using PI controller which have been shown in Figure 6.

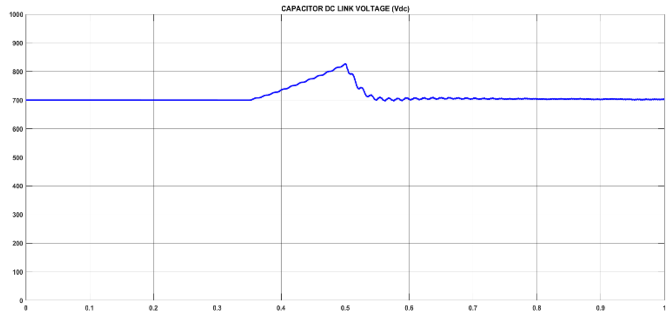

Fig.6 DC-link Voltage

Figure 7 indicates the waveforms of three phase source side voltage and current before and after DSTATCOM operation. From waveforms it is observed that the value of current supplied by source is reduced after DSTATCOM operation and power factor becomes unity as well. DSTATCOM becomes enable at 0.5 sec and result of power factor is shown in figure 8.

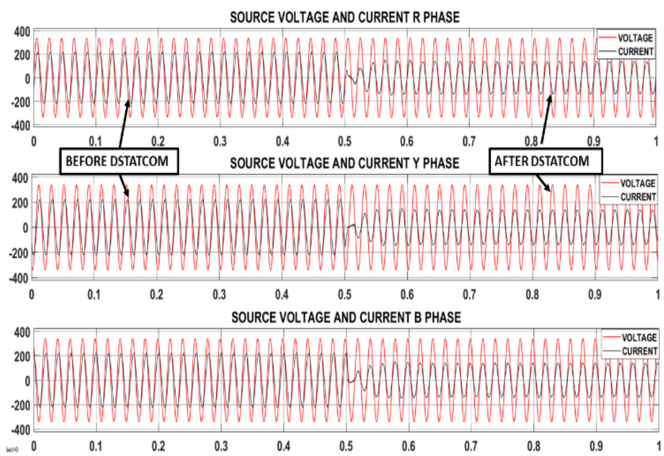

Fig.7 Waveforms of Source side voltages and currents

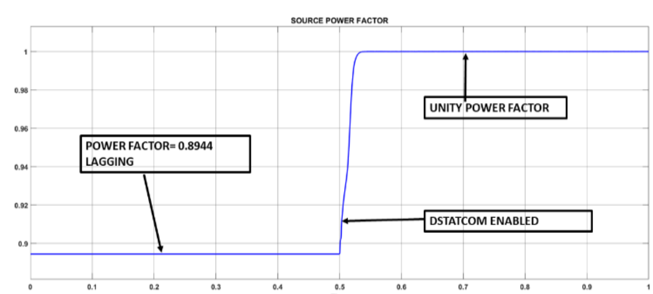

Fig.8 Simulation result for power factor

During PV-DSTATCOM phase, PV array is interfaced with DSTATCOM to inject active power to the grid and or to the load along with the reactive power injection depending upon the load requirement. When solar power is not available at that time DSTATCOM works as a shunt active filter and provides reactive power support, power factor improvement and maintain source side voltages at constant value. The simulation results provide better insight about performance of PV based DSTATCOM. The figure 7 describes firmly that source voltage remains constant throughout operation.

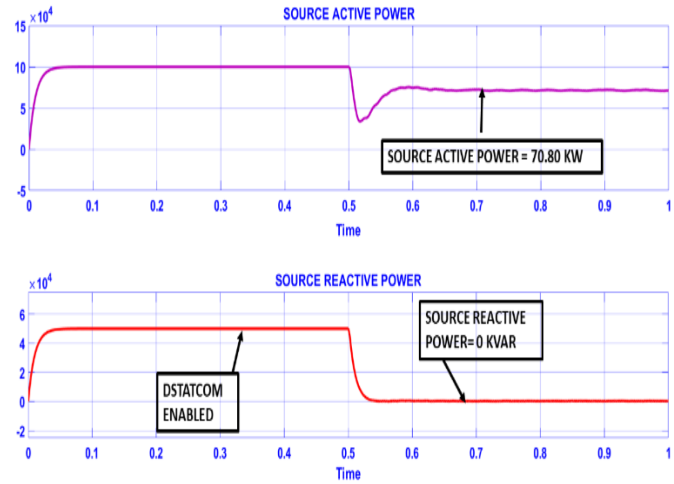

Fig.9 Active and Reactive power supplied by Source

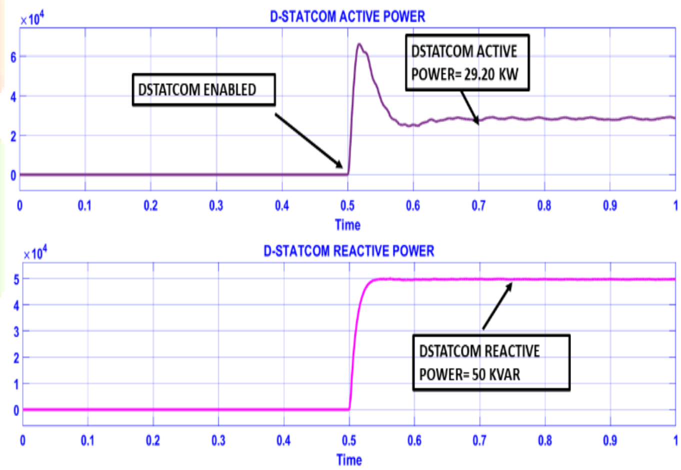

Fig.10 Active and Reactive power supplied by DSTATCOM

From the figures 9 and 10, it is evident that up to simulation duration 0.5 sec the source(grid) is in charge of meeting the load's whole actual and reactive power requirements which are 100KW and 50KVAR. After simulation period 0.5 sec the DSTATCOM becomes enable and the source is delivered 70.80KW of active power and remaining active power is handled by PV system. In addition to it, the source provides 50KVAR reactive power as much as simulation period 0.5 sec and after 0.5 sec whole reactive power demand of load is handled by DSTATCOM which operates using the gating pulses produced by the controller circuit based on a Icosϕ algorithm.

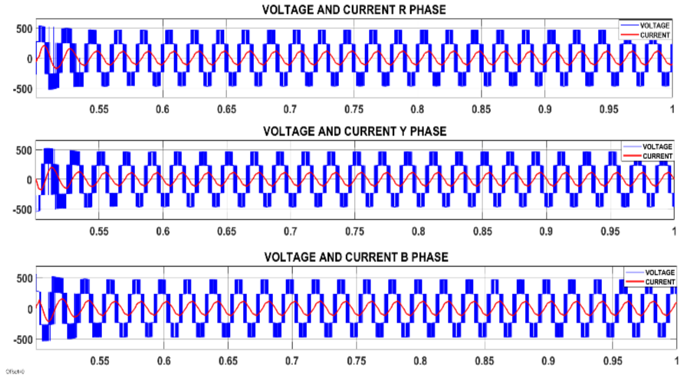

Fig.11 Compensating Voltage and Current supplied by DSTATCOM before interfacing Inductor

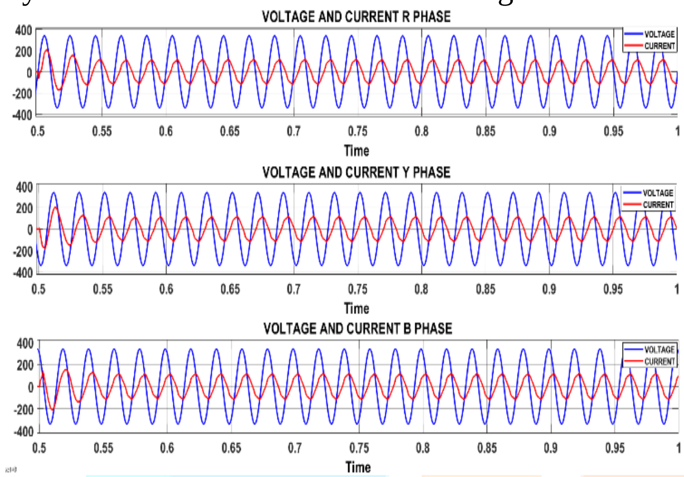

Fig.12 Compensating Voltage and Current supplied by DSTATCOM after interfacing Inductor

Figures 11 and 12 depict the waveforms of compensating voltages and currents before and after interfacing inductor respectively. The reactive power flow can be controlled by inserting control gain to control Iq component of sensed load current which is transformed into dq component from abc using park transformation.

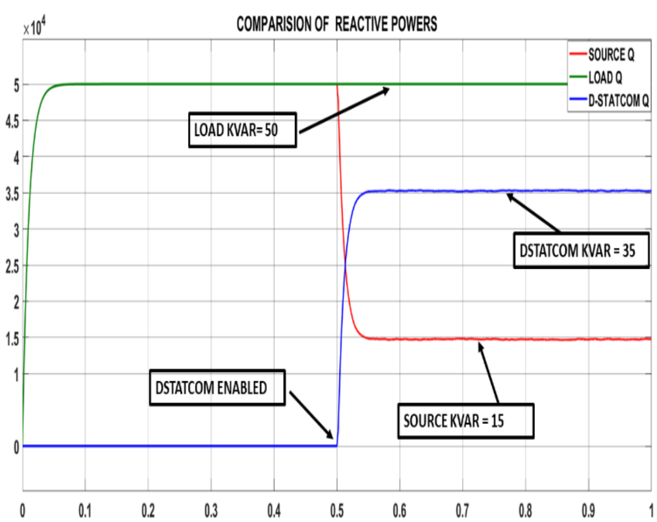

Fig.13 70% Reactive power compensation by DSTATCOM

Figure 13 demonstrates that the DSTATCOM provides 70% reactive power demand and remaining 30% supplies by the source.

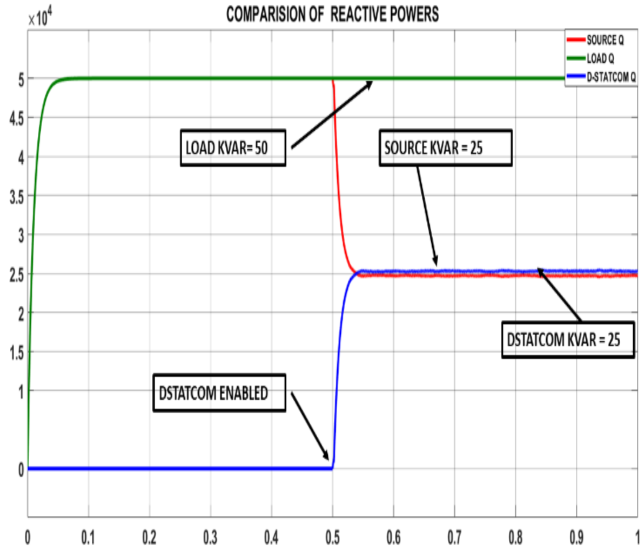

Fig.14 50% Reactive power compensation by DSTATCOM

As seen in Figure 14, the DSTATCOM compensates for 50% of the reactive power and supplies the remaining 30% by the grid.

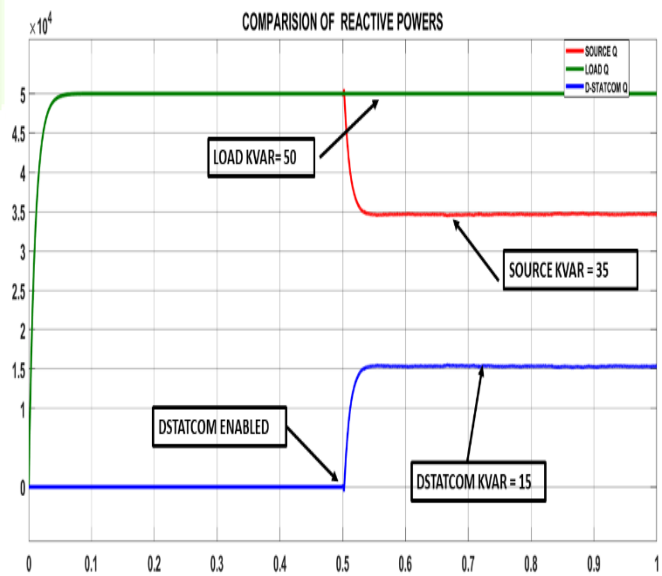

Fig.15 30% Reactive power compensation by DSTATCOM

Figure 15 shows that 70% of the reactive power is supplied by the source and 30% is provided by the DSTATCOM. The change in power factor is tabulated in Table 2.

Table 2 Change in Power Factor due to DSTATCOM OPERATION

TIME	CASE	POWER SHARING			POWER FACTOR
		LOAD DEMAND	SOURCE POWER	D-STATCOM POWER	
0 to 0.5 sec	D-STATCOM off	Q= 50KVAR	Q= 50KVAR	Q= 0 KVAR	0.894
0.5 to 1 sec	**Degree of reactive power Compensation**				
	100% by D-STATCOM	Q= 50KVAR	Q= 0KVAR	Q= 50 KVAR	1
	70% by D-STATCOM	Q= 50KVAR	Q= 15 KVAR	Q= 35 KVAR	0.9796
	50% by D-STATCOM	Q= 50KVAR	Q= 25 KVAR	Q= 25 KVAR	0.9454
	30% by D-STATCOM	Q= 50KVAR	Q= 35 KVAR	Q= 15 KVAR	0.9007

Table 2 makes it evident that we can adjust the quantity of reactive power compensation and power factor in accordance with variations in controller gain. DSTATCOM is turned off for 0 to 0.5 seconds, during which the source is solely responsible for supplying the entire reactive power needed by the load. As the degree of KVAR adjustment by DSTATCOM changed, the power factor of the system goes decline.

V. CONCLUSION

This paper uses MATLAB/SIMULINK to construct a full simulation model of PV-based DSTATCOM. Control theories based on Icosϕ is used to analyse the performance of the proposed system in power quality enhancement and grid integration. In every instance, DC bus voltage control is also accomplished. DC bus voltage management, reactive power compensation, and power factor enhancement are the three ways that power quality improvement is accomplished. PV provides the necessary compensation by charging the DSTATCOM DC link capacitor and supplying electricity to the load. When solar radiation is unavailable, it functions similarly to a traditional DSTATCOM, requiring only reactive power consumption to reduce a range of PQ problem .

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BIOGRAPHIES

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