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PERFORMANCE ANALYSIS OF DSTATCOM BASED ON PV SOLAR SYSTEM

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Abstract :

The Green Energy sources (solar, wind) are performing an active role to reach the electric power demand. thanks to the presence of non-linear loads, reactive loads within the distribution system and therefore the injection of wind generation into

the grid integrated system results power quality issues like current harmonics, voltage fluctuations, reactive power demand etc__ Using the MATLAB environment, this study explores the design and satisfactory performance assessment of a solar farm as a PV-STATCOM (Static Synchronous Compensator) for improving power quality in grid tie systems (Simulink). For the mitigation of quality related difficulties in the proposed test system, the proportional and integral (PI) Controller and Hysteresis Current Controller (HCC) were successfully used to inject the necessary current from a voltage source converter (VSC) based PV-STATCOM at PCC

I. INTRODUCTION

The primary activities (Industrial, Commercial, Domestic, and Traction activities) in nature have been intertwined with electrical energy for several decades. As a result, the demand for electricity is always greater than the supply. For power engineers, it is also an important study topic. To fulfil the demand for capital power The Grid integrated system actively participates in green energy sources (wind, solar) [5]. The existence of non-linear or sensitive loads in the power system, as well as the infusion of renewable energy into an already existing Grid system, increases the technical problems associated with power quality (poor PF, current harmonics, voltage fluctuations, and so on). Poor electrical power quality can result in significant power losses, as well as negative consequences for the nation's economy, customer service, productivity, system efficiency, and so on. Because of the rapid and active forward steps in their research efforts on Custom Power Devices, most power quality related technical difficulties are neutralised by Custom Power Devices (CPD) (FACTS devices). The shunt active filter (Statcom) will eliminate all current related power quality concerns among all Custom power devices [2], [3]. The generation of reference or gate signals for the shunt active power filter (PV-Statcom) is critical for the proposed system's active contribution to the mitigation of power quality concerns [21]. For the improvement of power quality and active electricity into the grid system, the Statcom is supplied by a photovoltaic system. For the mitigation of quality-related difficulties in the proposed test system, the PI Controller and Hysteresis Current Controller (HCC) were successfully used to inject the desired current from PV-STATCOM at PCC.This article is organised as follows: Design Aspects of a Voltage Source Converter based on STATCOM is covered in part II, while sections III, IV, and V show how to generate a reference signal, analyse the results, and draw conclusions, respectively.

2. DESIGN ASPECTS OF A STATCOM FOR POWER QUALITY

This segment primarily shows the design of a shunt connected active power filter (Statcom) for addressing the aforementioned power quality-related technical problems as well as reactive power management in the grid-assimilated proposed system. The schematic diagram of the grid-assimilated suggested system for improving power quality is shown in Figure 1. Non-linear three-phase demands were fed by three-phase AC mains and wind-power systems.

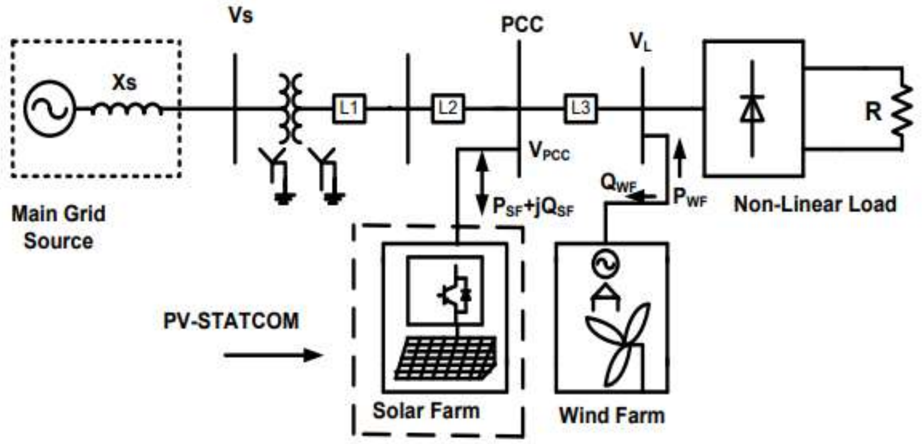

Figure 1. Representation of proposed system for power Quality Enhancement in Micro grid applications

As illustrated in Figure 2, a shunt connected PV-Statcom comprises of many components such as an interface inductor (Lf), a DC bus capacitor (Cdc), ripple filter components, and so on (a). For control and design of shunt connected Statcom to deliver an acceptable performance in a grid tie system, the selection and fixing of ratings for these components is critical. The following are the ratings fixing or design specifications for various components of shunt connected Statcom.

2.1. DC Bus Voltage

The DC bus voltage (Vdc) is calculated with the help of following expression

$$V_{dc} = \frac{2\sqrt{2}.V_{LL}}{\sqrt{3}.m} \tag{1}$$

Where VLL is AC line output voltage, "m" is modulation index and it is treated as '1'. Vdc must be greater than AC mains voltage for successful PWM control of Shunt Active Power Filter (SAPF) [2]. By using Equation 1 for VLLof 415V, Vdc is 677.69V and is fixed as 750V.

2.2. DC Bus Capacitor

The designing of Cdc depends on the nominal DC voltage (Vdc), minimum voltage level of dc bus (Vdc1), Over Loading Factor (a), the phase voltage (Vph), phase currents (Iph) and on time (t) for which DC bus voltage is recovered [2]. DC bus capacitor is designed based on depression in its voltage due to application of loads and rise in dc bus voltage by removal of loads by using law of conservation of energy. The Cdc is calculated as

$$\frac{1}{2}C_{dc}\{(V_{dc}^2 - V_{dc1}^2\} = K\{3V_{ph}(aI_{ph})t\} \tag{2}$$

Where “K” is constant varying from 0.05 to 0.15 as [2] for Vdc =750V, Vdc1=677.69V, Vph=239.60V, Iph=38.95A, t=0.04sec, a =1.2 the value of Cdc is calculated as Cdc =3.905222mF and is selected as 5 mF.

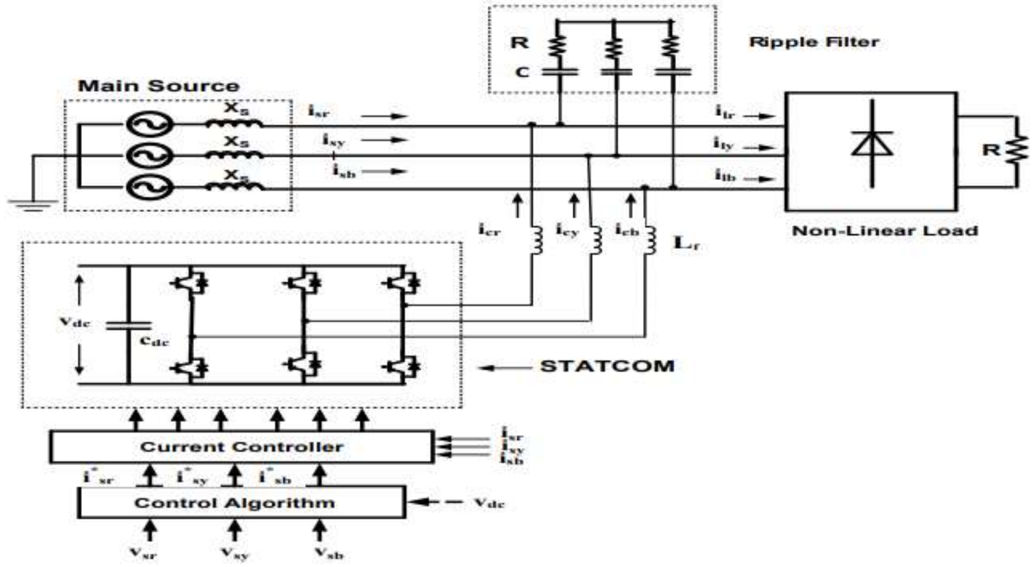

Figure 2 (a). Control of PV-Statcom for Enhancement of Power Quality in Micro Grid System.

3. GENERATION OF GATE SIGNALS FOR A PV-STATCOM

It is critical to create switching signals for PV-Statcom operation activation in order to improve power quality. To generate switching signals for PV-Statcom, various control strategies such as P-Q control theory (Instantaneous Reactive Power Theory), Id-Iq control theory (Synchronous reference frame theory), hysteresis current control strategy, perfect harmonic cancellation (PHC), Fuzzy logic controller, and unity PF (UPF) methods exist. As stated in [1], [3], and [9], a hysteresis current regulated method is developed in this article with the use of a unit vector template model. Each phase's unit vector voltage templates are computed as

$$u_{sr} = \frac{V_{sr}}{V_{sm}}, u_{sy} = \frac{V_{sy}}{V_{sm}}, u_{sb} = \frac{V_{sb}}{V_{sm}}. \quad \textbf{(3)}$$

The sampled peak voltage (Vsm) is computed with help sinusoidal phase voltages Vsr ,Vsy , Vsb as follows

$$V_{sm} = \{\frac{2}{3}(V_{sr}^2 + V_{sy}^2 + V_{sb}^2)\}^{\frac{1}{2}}$$

Where

$$V_{sr} = V_m \sin(wt) \; V_{sy} = V_m \sin(wt - 120) \; V_{sb} = V_m \sin(wt - 240) \quad (4) \,\&\, (5)$$

As stated in Equation 6, the reference current signals for Statcom are calculated using the unit vector templates and active current component for each phase.

$$i_{sr}^* = I_m u_{sr}, i_{sy}^* = I_m u_{sy}, i_{sb}^* = I_m u_{sb} \quad \textbf{(6)}$$

The active current component (I_m) is computed as

$$I_{m(k)} = I_{m(k-1)} + K_P V_{dc(k)}(V_{err(k)} - V_{err(k-1)}) + K_I V_{dc(k)} V_{err(k)} \quad \textbf{(7)}$$

Where "k" is sampling instant and Verr is dc-link error voltage. is proportional gain and is Integral gain. The Dc-Link error voltage at k th sampling instant is computed as

$$V_{err(k)} = V_{dcref(k)} - V_{dc(k)} \quad \textbf{(8)}$$

The control method and suggested current controller are used to create reference signals for PV-STATCOM operation activation. In the controlled method depicted in Figure 2, the reference currents ($i^*_{sr}, i^*_{sy}, i^*_{sb}$) are produced with the aid of real and reference voltages [13] [17]. (a). The reference signals for PV-Statcom were generated using the proportional and integral (PI) controller and the Hysteresis Current Controller (HCC) by properly using current error from reference currents ($i^*_{sr}, i^*_{sy}, i^*_{sb}$) and real currents [20]. The block diagram in Figure 2 (b) depicts the production of reference or gate signals for activating PV- Statcom operation in micro grids to improve power quality.

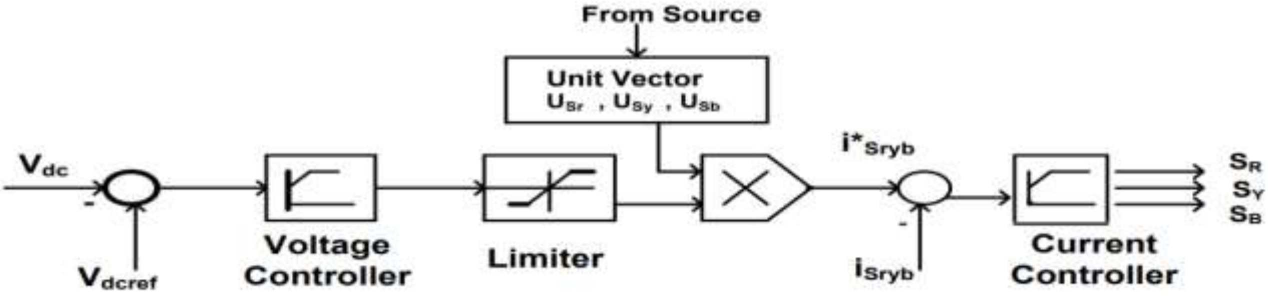

Figure 2 (b). Block diagram representation for reference current signals generation

Figure 3 shows the switching functions (Sr, Sy, Sb) of the Voltage Source Converter (VSC) in PV-Statcom using the suggested current control method. HB stands for hysteresis band. The needed parameters and their specifications for active operation and power quality enhancement in the Micro Grid system are listed in Table 1.

Table 1. Proposed system parameters and their specification S.No. Parameter Specifications

1.	Source Voltage 415 V, 50 Hz
2.	IGBT Ratings Collector Voltage=1200 V, I=50 A, Gate Voltage=20 V
3.	Solar plant 3.75 kVA
4.	Wind Generator 3.35 kVA,415V,50Hz,N=1500 rpm ,P=4,Rr=20 Ω, Lr=0.06 H
5.	DC Bus Capacitor Vdc=750 V, Vdc1=677.69 V, Vph=239.60 V,Iph=38.95 A, Cdc =5mF
6.	Distorting Load 25kW

SWITCHES

S_R can take either of two values

1	$i_{sr} > (i^*_{sr} - HB) \rightarrow S_R$
0	$i_{sr} < (i^*_{sr} - HB) \rightarrow S_R$

S_y can take either of two values

1	$i_{sy} > (i^*_{sy} - HB) \rightarrow S_y$
0	$i_{sy} < (i^*_{sy} - HB) \rightarrow S_y$

S_b can take either of two values

1	$i_{sb} > (i^*_{sb} - HB) \rightarrow S_b$
0	$i_{sb} < (i^*_{sb} - HB) \rightarrow S_b$

Where 1 = ON ; 0 = OFF

Figure 3. Switching Status for IGBT of PV-Statcom

Increase in Stable Power Transfer Limit (MW) for Study System I with Different PV-STATCOM Controls

PV STATCOM CONTROL	NIGHT	DAY	
		Solar Power Output 19 MW	Solar Power Output 91 MW
Voltage Control	102	85	7
Damping Control	119	**121**	**142**
Voltage Control with Damping Control	**168**	93	36

4. RESULT ANALYSIS

Based on the MATLAB/Simulated results, the active performance of a solar farm as a static synchronous compensator (PV-STATCOM) in the suggested test system is investigated as follows. The PV-Statcom is connected to the grid system in shunt for improved analysis. Similarly, the system has a wind energy source and a three-phase non-linear load from a diode rectifier. For the production of reference current signals to activate the functioning of PV-Statcom, the proportional (kp) and integral (ki) gain values are 2.5 and 1.25, respectively. The PV-Statcom may function in the 0.1s to 0.2s range. The overall simulation time in Matlab is 0.25s.
The reactive, nonlinear loads, and induction generator are all part of the proposed micro grid system in this study. As shown in Figure 5, the system has a reactive power requirement of almost 4 kVAr before 0.1 sec and after 0.2 sec (PVStatcom OFF), and reactive power is compensated by PV-Statcom between 0.1 sec and 0.2 sec (PV-Statcom ON) (a). Figure 5 (a) shows that the primary grid source is delivering less than 15 kW actual power to the load, and that the PV-Statcom injects the needed amount of real power (almost 1kW) into the grid system to keep the load power constant (b).

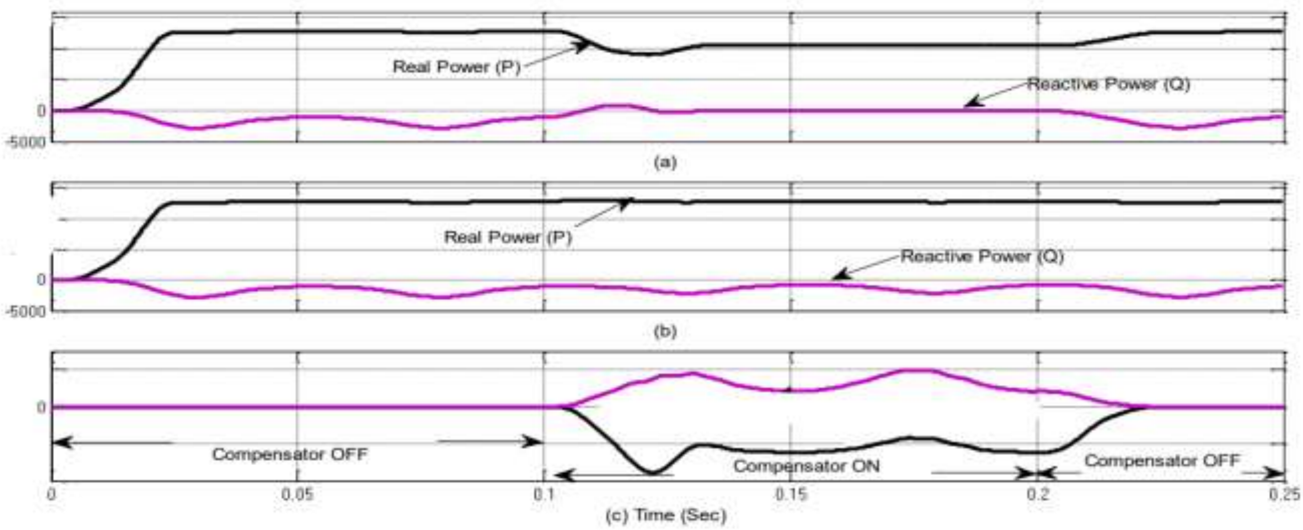

Figure 5. Representation of Active and Reactive power for (a) Source powers (P&Q), (b) Load Powers (P&Q), (c) PV-Statcom Powers (P&Q)

5. CONCLUSION

This study summarizes the efficient and effective performance of a Solar Farm as a static compensator (PV-STATCOM) in a grid-tie system to mitigate power quality concerns caused by non-linear loads. It also reminds users of the design features of a PV-STATCOM and the creation of switching signals using a current control method for active involvement of a Voltage Source Converter based shunt active filter for power quality magnification in the MATLAB/Simulink platform. Harmonics in the source current were reduced, and reactive power was balanced, thanks to the active operation of PV-Statcom. The power factor and Total Harmonic Distortions were enhanced with the aid of the suggested compensator, which regulates the voltage at the PCC by keeping the capacitor voltage constant. The sophisticated control method had the highest chance of increasing the grid integrated system's utilisation factor.

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