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Analysis of Photovoltaic based DSTATCOM Performance using SRF and IRP Control Theory

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ABSTRACT: Automation needs and advancements in our power system has shown drastic success rate. Increasing the advancements in controller's technologies there behind need for basic formulations. This paper mainly proposes the importance of P-Q & D-Q theories. In the Other END power delivery to end consumers still showing a big challenge to Indian electricity board. Now the advancement in Automation has completely changed the load conditions including pre analysing, due to widespread use of power electronic based drives such as adjustable speed drives, Energy efficient lighting, PC's, office accessories etc. In this mainly the power electronic based sensitive equipment's are the causing major fatalities of power quality problems such as voltage Sag, Swell, Waveform distortion, Poor power factor etc. In this paper, a three phase three wire Distribution Static Compensator (DSTATCOM) which is fed by Photovoltaic (PV) array is proposed for power quality improvement. The DSTATCOM is a three leg voltage source Inverter (VSI) with a DC link capacitor. Photovoltaic module is used to keep regulate the desired voltage at DC link. The Power quality improvement is achieved in terms of reactive power compensation, Power factor correction, Harmonic reduction, DC voltage control. In this paper, the performance of DSTATCOM is shown for Power factor correction (PFC) and Zero voltage regulation (ZVR) modes using d-q and p-q theories of control. The effectiveness of the PV based DSTATCOM is verified with simulation results. The simulation is carried out on MATLAB software using Simulink and PSB toolboxes.

KEYWORDS: Keywords-Photovoltaic Cell; DSTATCOM; SRF; IRPT

I. INTRODUCTION

Due to the wide use of power electronic based equipment's in the electricity consumer community, power quality has become the key challenge to the researchers. Because all automatic equipment's draw reactive power and inject harmonics into the distribution system so responsible to the poor power quality [3, 4, 6]. Due to limitations and environmental issues of conventional energy sources, continuous efforts are going on to increase the use of renewable energy sources for generation of electrical power. Some researchers have come up with new solutions in the area of renewable energy sources in terms of power quality improvement while dealing with distribution systems [18-20]. At the distribution side, use of automated, computing devices is increasing day by day such as Personal computers, printers, scanners, fax machines etc. and many other nonlinear loads, so power quality has become major concern among the electric utilities. These type of power electronic based sensitive loads inject harmonics into the line and responsible to the waveform distortions that results poor power factor also. All the power quality mitigation controllers which are used in distribution systems are known as custom power devices (CPD's) [1, 3-6]. Among all controllers, DSTATCOM is most effective solution of power quality problems [1, 2, 7-13]. DST A TCOM is shunt connected device and it is widely used as power quality mitigation device. The performance of DSTATCOM depends upon the control algorithms [1, 2, 7- 13, 18-20] those are used to generate reference source current. In this paper PV based DST A TCOM is used so the DC voltage regulation is also very important that can vary with the irradiation level. To control the DSTATCOM, dq and pq based algorithms [7-13] are used Simulation results demonstrate the effectiveness of controller of DST A TCOM for reactive power compensation, harmonic reduction and load balancing under the unbalanced conditions.

II. D-STATCOM

D-STATCOM is considered as the most effective and widespread conditioners amongst the CPD family because of its ability to hand over power quality problems. The basic and fundamental unit of D-STATCOM is VSC with which a capacitance is connected on the DC-side. It is connected in shunt connection with the distribution network with the help of a transformer and a low pass filter (LPF). The LPF is used to minimize ripples and compensate for harmonics. A lot number of research papers exist which deals with D-STATCOM. In these works, D-STATCOM has been implemented using different control techniques (for the generating reference current components) such as IRP theory, active and reactive power theory, instantaneous symmetrical components theory, indirect control scheme, SRF theory, hysteresis control and so on [11]-[14]. For any compensation technique such as D-STATCOM the main goal and objective is to have a fast response, easy control, less complexity and easy implementation. For this reason, an improved control algorithm for D-STATCOM will be designed in order to respond towards power quality problems in a most effective way.

III. MODELLING OF PV ARRAY

$$I = I_L - I_0 \left(e^{\frac{q(V-IR_s)}{AKT}} - 1 \right) - \frac{V-IR_s}{R_{SH}} \quad (1)$$

Where

I = Solar cell output current

V = Solar cell output voltage

I_0 = Diode saturation current,

q = Charge of an electron (1.602×10^{-19} C)

A = Diode quality factor

k = Boltzman constant (1.381×10^{-23} J/K)

T = Absolute temperature (K)

R_s = Series resistances of the solar cell

R_{SH} = Shunt resistances of the solar cell

The output current-voltage characteristics of a PV module is expressed by following equation, where n_p and n_s are the number of solar cells in parallel and series respectively.

$$I \approx n_p I_L - n_p I_0 \left(e^{\frac{q(V-IR_s)}{n_s AKT}} - 1 \right) \quad (2)$$

With the help of these equations a 100KW PV array has been modelled in MA TLAB.



Fig. 3.2 Equivalent circuits of PY array

SRF (Synchronous Reference Theory) based Control Theory This theory is also known as dq control theory because in this theory three phase currents are transformed into the synchronously rotating dq frame [2,8,10-13,18-20]. This theory uses the following equations for the transformation that is well known Parks transformation:

$$\begin{bmatrix} i_{Ld} \\ i_{Lq} \end{bmatrix} = \frac{2}{3} \begin{bmatrix} \sin \omega t & \sin(\omega t - \frac{2\pi}{3}) & \sin(\omega t + \frac{2\pi}{3}) \\ \cos \omega t & \cos(\omega t - \frac{2\pi}{3}) & \cos(\omega t + \frac{2\pi}{3}) \end{bmatrix} \begin{bmatrix} i_{La} \\ i_{Lb} \\ i_{Lc} \end{bmatrix} \quad (3)$$

Eq.3 shows the basic representation of SRF based control. in the given figure average values of i_d and i_q are estimated after passing these values from low pass filters. Two PI controllers are used, one is to regulate the DC link voltage and another is to maintain the PCC voltage as constant. These values are represented by i_{ed} and i_{eq} and can be find out with the help of following equations[2, 10-13,18-20]:

$$i_{cd} = K_{pd}V_{dce} + K_{id} \int V_{dce} dt \quad (4)$$

$$i_{cq} = K_{pd}V_e + K_{iq} \int V_e dt \quad (5)$$

Simulation Diagram

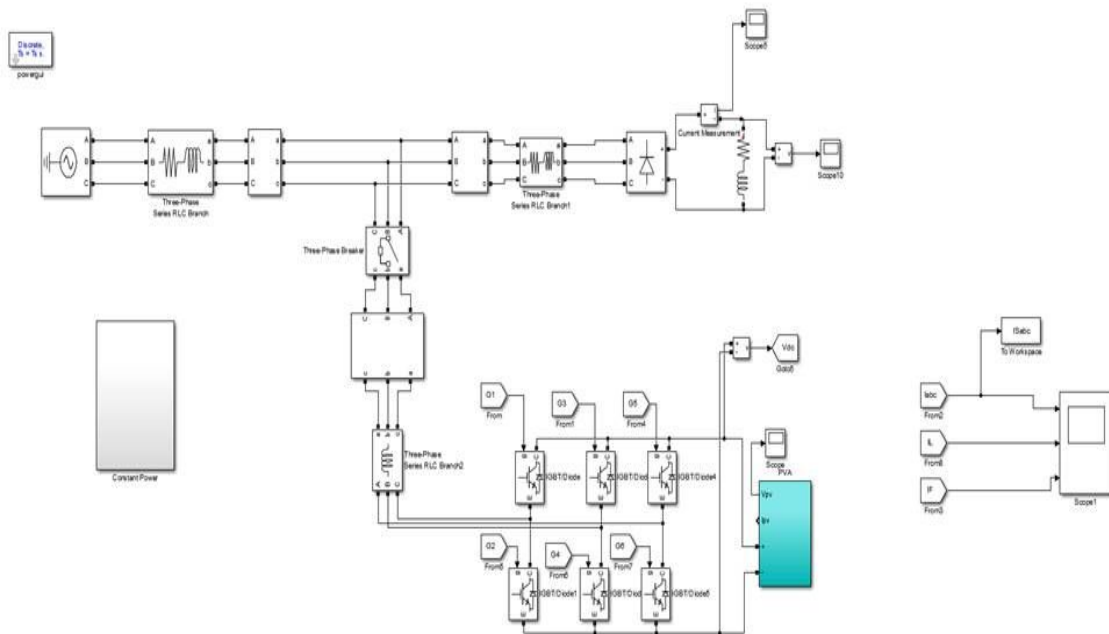


Fig 3.3 MA TLAB/SIMULINK model of PV based DSTATCOM

IV. RESULTS AND DISCUSSIONS

SRF based control theory: In the Fig. 6 simulation results are shown for SRF controller with non-linear load Irradiation of PV system is considered as 1000W/m². The performance of DSTATCOM is analyzed in PFC and ZVR mode both. Fig. 7 shows the simulation results for ZVR mode. In both the modes, one phase(phase C) is opened from 0.4 seconds to 0.5 seconds to create the load unbalancing. In PFC mode, during the unbalanced condition source currents are balanced and are in phase with source voltage that shows unity power factor operation. DC voltage is also maintained constant that verifies the effectiveness of the whole system. In ZVR mode PCC voltage is maintained constant at 340 Volts during the unbalanced conditions as well.

IRP based control theory: Fig. 8 and 9 show the simulation results for IRP control theory in PFC and ZVR modes respectively. Dynamic performance clearly shows the effectiveness of the PV based DST A TCOM system.

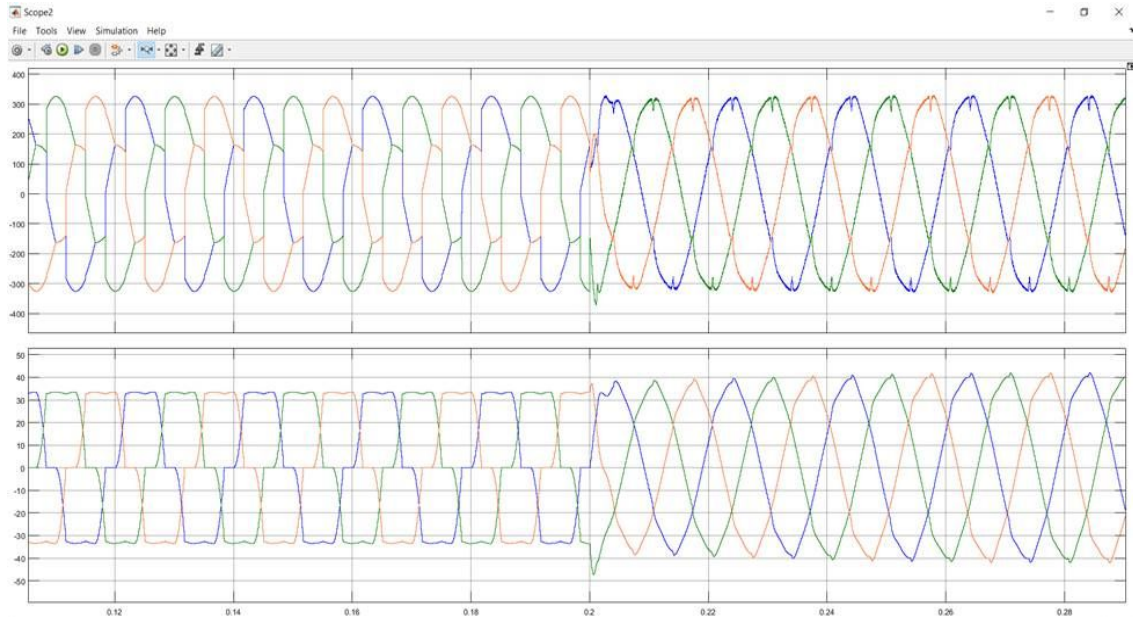


Fig 3.4 Performance Analysis of SRF control theory in PFC mode

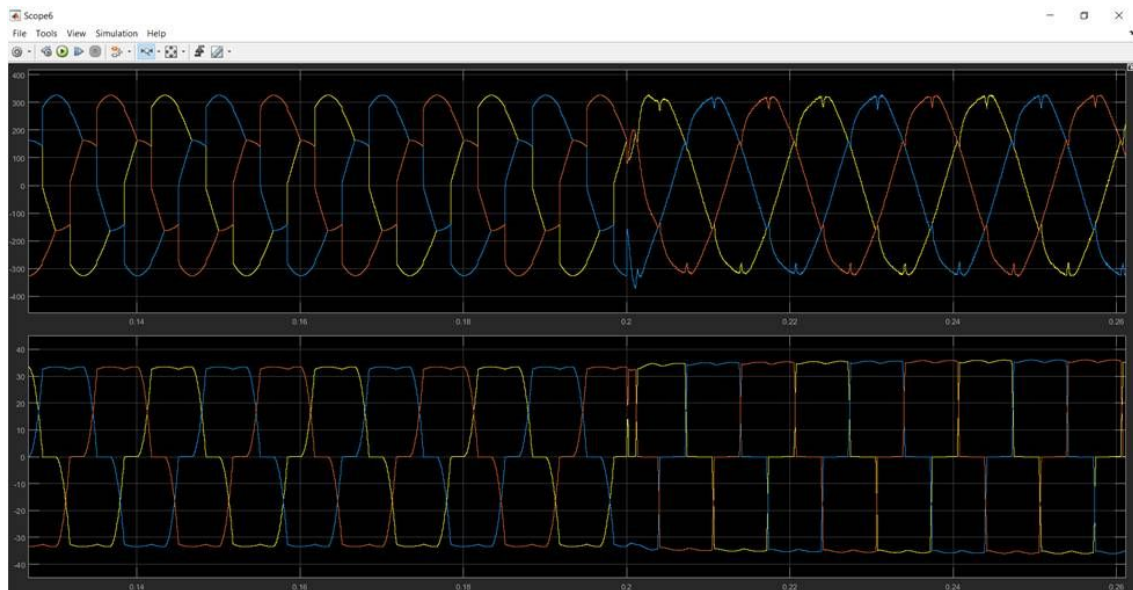


Fig 3.5 Performance Analysis of SRF control theory in ZVR mode

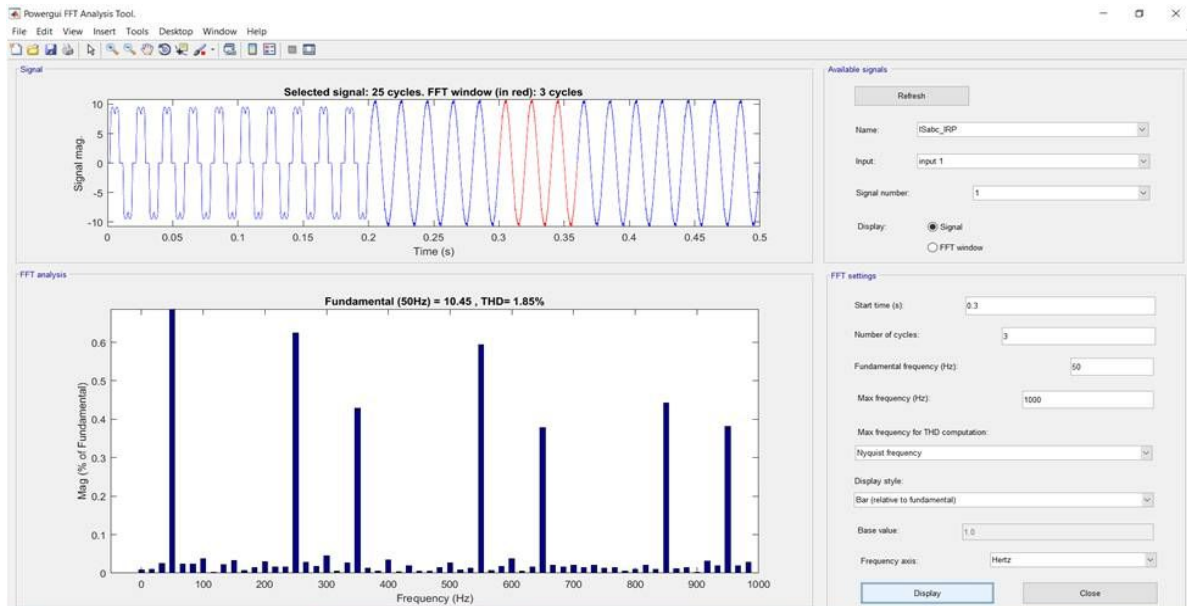


Fig 3.6 FFT Analysis (THD 1.85%) Performance Analysis of IRP control theory in PFC mode

V. CONCLUSION

In this paper complete simulation model of PV based DST A TCOM is developed using MAT AB/SIMULINK . Performance of the proposed system is analyzed for PFC and ZVR modes using SRF and IRP based control theories. DC bus voltage regulation is also achieved in each case. Power Quality Improvement is achieved in terms of Power factor improvement, Harmonic reduction and DC bus voltage control.

System Parameters

Source: 415 volts, 50 Hz

Switching Frequency: 10 KHz

DC bus voltage: 800 V DC

capacitor: 10000 /IF

Interfacing inductor: 3.5 Mh

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