THE USING OF PV SOLAR FARM AS STATCOM FOR THE CONTROLING INCREASING GRID POWER TRANSMISSION LIMITS DURING NIGHT AND DAY

. [1]Ashish Kumar, [2]Prakash Narayan Tiwari, [3]Nand Lal Shah, [4]Sitaram Pal, [5]Reeta Pawar
[1] M.Tech Student, [2]Assistant Professor, [3]Assistant Professor, [4]Assistant Professor, [4] Professor
[1] Electrical & Electronics Engineering Department
1 Rabindranath Tagore University, Bhopal, India.

ABSTRACT

This paper presents a new control strategy for grid integrated PV solar farm so that it can operate as STATCOM, for improving grid power transmission capacity. Solar farms produce power during day and are completely inactive in nights. The whole ratings of PV Solar Farm, which remain dormant during night, are utilized with voltage and damping control to increase power transmission capacity. The inverter capacity left after the real power production is used to perform above objective. This new control strategy of PV Solar Farm improves power transmission capacity, for which other expensive alternatives are used such as series/shunt capacitor or separate flexible AC transmission system controllers.

KEYWORDS: flexible ac transmission systems (FACTS), Inverter, photovoltaic solar power system, STATCOM, damping control, reactive power control, transmission capacity,

I. INTRODUCTION

Flexible AC transmission system (FACTS) controllers are being increasingly considered to increase the available power transfer limits/capacity (ATC) of existing transmission lines [1]–[4], globally. New research has been reported on the nighttime usage of a photovoltaic (PV) solar farm (when it is normally dormant) where a PV solar farm is utilized as a STATCOM a FACTS controller, for performing voltage control, thereby improving system performance and increasing grid connectivity of neighboring wind farms [5], [6]. New voltage control has also been proposed on a PV solar farm to act as a STATCOM for improving the power transmission capacity [7]. Although, [8] and [9] have proposed voltage-control functionality with PV systems, none have utilized the PV system for power transfer limit improvement. A full converter-based wind turbine generator has recently been provided with FACTS capabilities for improved response during faults and fault ride through capabilities The photoelectric effect was first noted by French physicist Edmund Becquerel in 1839. He proposed that certain materials have property of producing small amounts of electric current when exposed to sunlight. In 1905, Albert Einstein explained the nature of light and the photoelectric effect which has become the basic principle for photovoltaic technology. In1954 the first photovoltaic module was built by Bell Laboratories. A photovoltaic system makes use of one or more solar panels to convert solar energy into electricity. It consists of various components which include the photovoltaic modules, mechanical and electrical connections and mountings and means of modifying the electrical output.

II. PHOTOVOLTAIC TECHNOLOGY

The Photovoltaic system directly converts sunlight into electricity. PV cell is the basic device of PV system. These PV cells may be grouped to form panels or array. The output voltage and current available at the terminals PV device directly feed to the small loads such as lightning system and dc motors. PV system consists of PV modules also called PV panels which are power generating devices. For large scale PV system, number of PV modules is connected in series to form a ‘string’ and number of string having parallel with each other to form ‘array’. Photovoltaic modules having PV cells also in series and shunt configuration connection. PV cell is nothing but the formation of pn-junction from the doping of p-type and n- type substrates that are able to produce DC current and DC voltage due to PV effect on semiconductors. Due to series and shunt combination of cells in the module there isincrease in level of voltage and current.

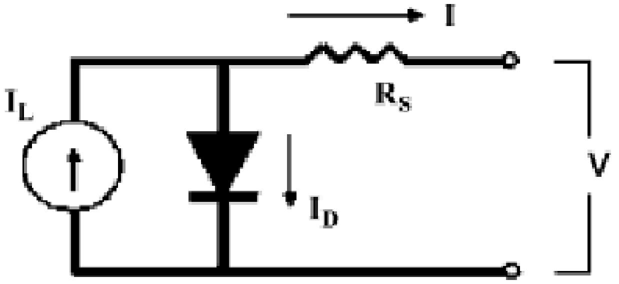


Fig 1 Four-Parameter Model of solar cell equivalent circuit

III. STATIC SYNCHRONOUS COMPENSATOR (STATCOM)

The STATCOM is a solid-state-based power converter version of the SVC. Operating as a shunt-connected SVC, its capacitive or inductive output currents can be controlled independently from its terminal AC bus voltage. Because of the fast-switching characteristic of power converters, STATCOM provides much faster response as compared to the SVC. In addition, in the event of a rapid change in system voltage, the capacitor voltage does not change instantaneously; therefore, STATCOM effectively reacts for the desired responses. For example, if the system voltage drops for any reason, there is a tendency for STATCOM to inject capacitive power to support the dipped voltages. STATCOM is capable of high dynamic performance and its compensation does not depend on the common coupling voltage. Therefore, STATCOM is very effective during the power system disturbances. Moreover, much research confirms several advantages of STATCOM. These advantages compared to other shunt compensators include

IV. BASIC OPERATING PRINCIPLES OF STATCOM

The STATCOM is connected to the power system at a PCC (point of common coupling), through a step-up coupling transformer, where the voltage-quality problem is a concern. The PCC is also known as the terminal for which the terminal voltage is UT. All required voltages and currents are measured and are fed into the controller to be compared with the commands.

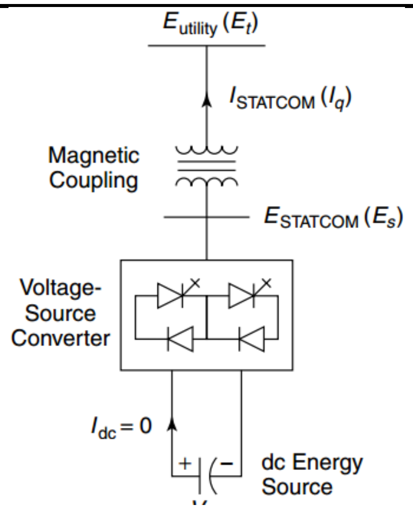


Fig 2. STATCOM operation in a power system.

V. FACT CONCEPT

Flexible AC Transmission Systems, called FACTS, got in the recent years a well-known term for higher controllability in power systems by means of power electronic devices. Several FACTS-devices have been introduced for various applications worldwide. A number of new types of devices are in the stage of being introduced in practice. In most of the applications the controllability is used to avoid cost intensive or landscape requiring extensions of power systems, for instance like upgrades or additions of substations and power lines. FACTS-devices provide a better adaptation to varying operational conditions and improve the usage of existing installations.

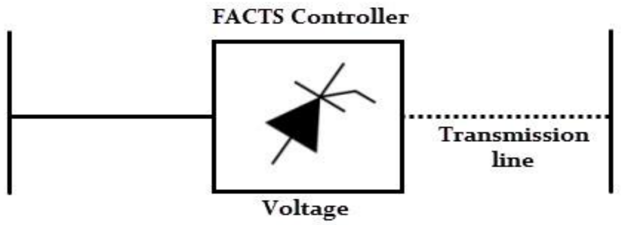


Fig 3 The basic model of FACTS device

The controller then performs feedback control and outputs a set of switching signals (firing angle) to drive the main semiconductor switches of the power converter accordingly to either increase the voltage or to decrease it accordingly. A STATCOM is a controlled reactive-power source. It provides voltage support by generating or absorbing reactive power at the point of common coupling without the need of large external reactors or capacitor banks. Using the controller, the VSC and the coupling transformer, the STATCOM operation is illustrated in Figure below.

V. SYSTEM MODELS

The single-line diagrams of two study systems: Study System 1 and Study System 2 are depicted in Fig. 1(a) and (b), respectively. Both systems are single-machine infinite bus (SMIB) systems where a large equivalent synchronous generator (1110 MVA) supplies power to the infinite bus over a 200-km, 400-kV transmission line. This line length is typical of a long line carrying bulk power in Ontario

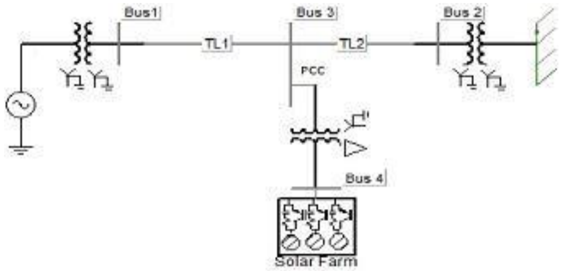


Fig.4 Single-line diagram of (a) study system I with a single solar farm (DG)

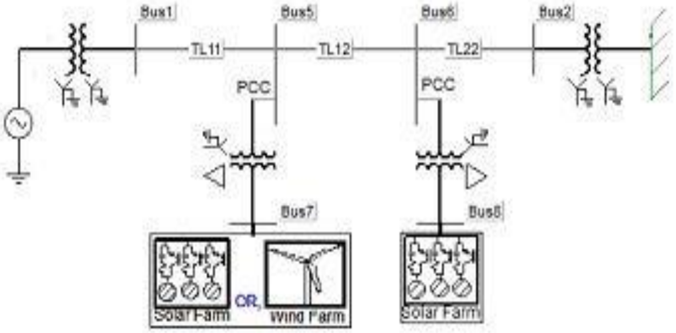


Fig.4 (b) Single-line diagrams of (b) study system II with a solar farm

(DG) and a solar/wind farm (DG).

In Study System 2, two 100-MVA inverter- based distributed generators (DGs) are connected at1/3 (bus 5) and 2/3 (bus 6) of the line length from the synchronous generator This paper describes a new control method to maintain the STATCOM DC link voltage to a minimum value in their paper. The additional PV cell acts as a backup to the STATCOM DC link voltage source. It serves as a source to the STATCOM DC link capacitor when the capacitor voltage is below a particular limit. This control method along with STATCOM improves the output waveform quality and improves the reliability of the system

V (A) .System Model

The synchronous generator is represented by a detailed sixth order model and a DC1A-type exciter. The transmission-line segments TL1, TL2, TL11, TL12, and TL22, shown in Fig. 1, are represented by lumped pi-circuits. The PV solar DG, as shown in Fig. 2, is modeled as an equivalent voltage-source inverter along with a controlled current source as the dc source which follows the - characteristics of P V panels. The wind DG is likewise modeled as an equivalent voltage-source inverter. In the solar DG, dc power is provided by the solar panels, whereas in the full-converter-based wind DG, dc power comes out of a controlled ac–dc rectifier connected to the PMSG wind turbines, depicted as “wind Turbine-Generator-Rectifier (T-G- R).” The dc power produced by each DG is fed into the dc bus of the corresponding inverter.

(B). Control System

(1) Conventional Reactive Power Control

The conventional reactive power control only regulates the reactive power output of the inverter such that it can perform unity power factor operation along with dc-link voltage control. The switching

(2) PCC Voltage Control

In the PCC voltage control mode of operation, the PCC voltage is controlled through reactive power exchange between the DG inverter and the grid. The conventional control channel is replaced by the PCC voltage controller in Fig.3. It depends upon the set point voltage at the PCC the amount of reactive power flow from the inverter to the grid. To achieve the fastest step response, least settling time, the parameters of the PCC voltage controller is tuned by a systematic trial-and-error method and a maximum overshoot of 10%–15%.

(3) Damping Control

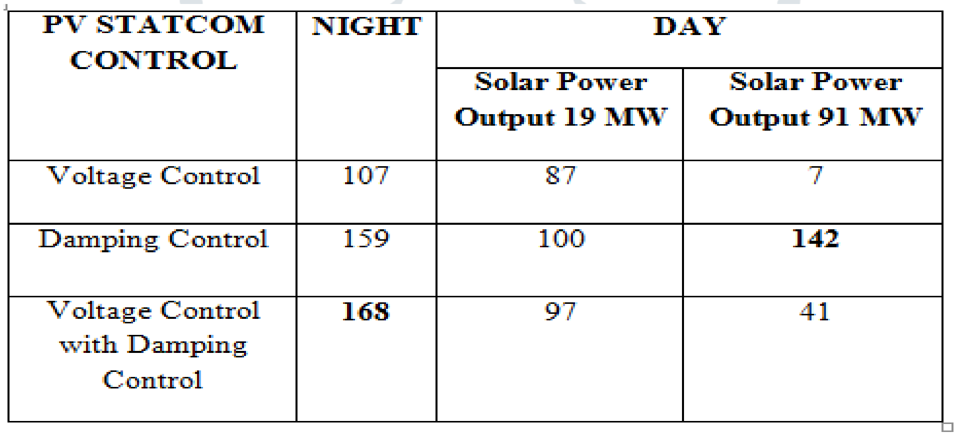
A novel auxiliary damping controller is added to the PV control system and shown in Fig.3.This controller utilizes line current magnitude as the control signal. The output of this controller is added with the signal.

VI. Case Study 1: Power Transfer Limits in Study

Conventional Reactive Power Control with Novel Damping Control: A new control study is proposed here.

TABLE I

Increase in the stable power transfer limit (in megawatts) 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	107	87	7
Damping Control	159	100	**142**
Voltage Control with Damping Control	**168**	97	41

VII. Complete DG (solar/wind) system model

In this study, the solar DG is assumed to operate with its conventional reactive power controller and the DG operates at near unity power factor. For the nighttime operation of solar DG, the dc sources (solar arrays) are disconnected, and the solar DG inverter is connected to the grid using appropriate controllers, as will be described. Power transmission limits are now determined for the following four cases. The stable power transmission limits obtained from transient stability studies and the corresponding load-flow results are presented in Table I where represents the inductive power drawn respectively. At first, the base-case generator operating power level is selected for performing the damping control design studies. This power level is considered equal to the transient stability limit of the system with the solar farm being disconnected at night.

The objective of this paper is only to demonstrate a new concept of using a PV solar farm inverter as a STATCOM using these reasonably good controller parameters. In this controller, although the line current magnitude signal is used, other local or remote signals, which reflect the generator rotor- mode oscillations, may also be utilized

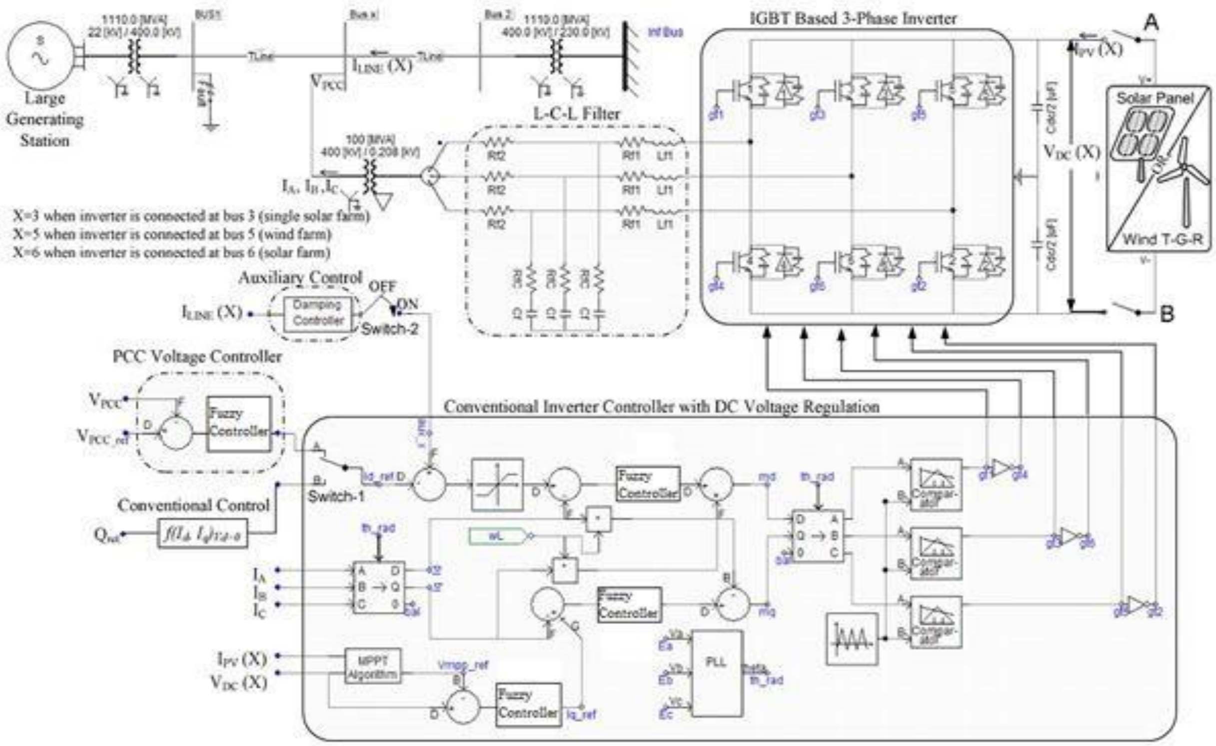


Fig.5 Complete DG (solar/wind) system model with a damping controller and PCC voltage-control system

VIII. SIMULINK MODEL

Fig. 6 shows the MATLAB Simulink model of System Architecture with non-linear load.

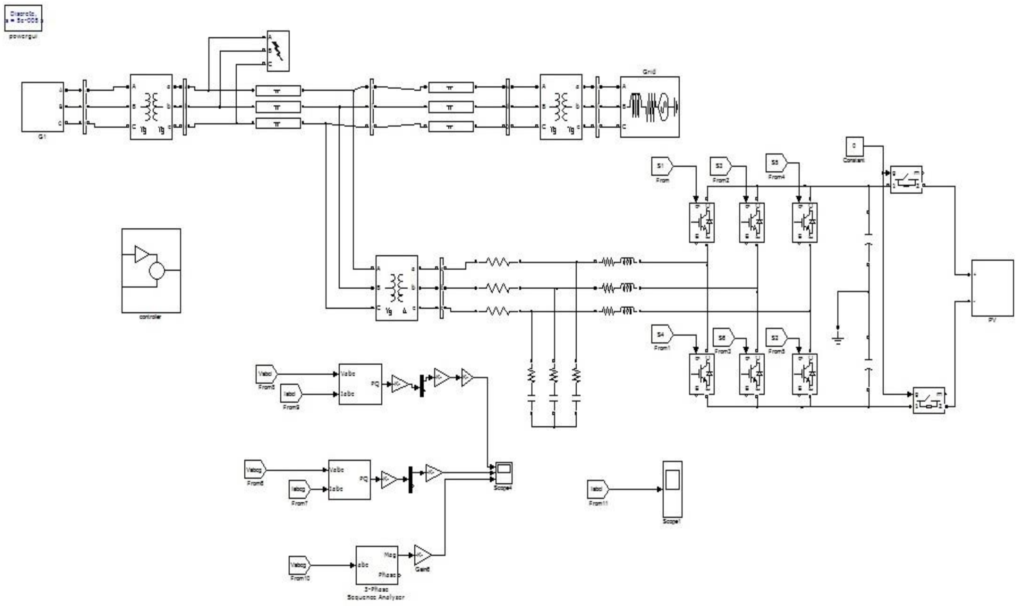
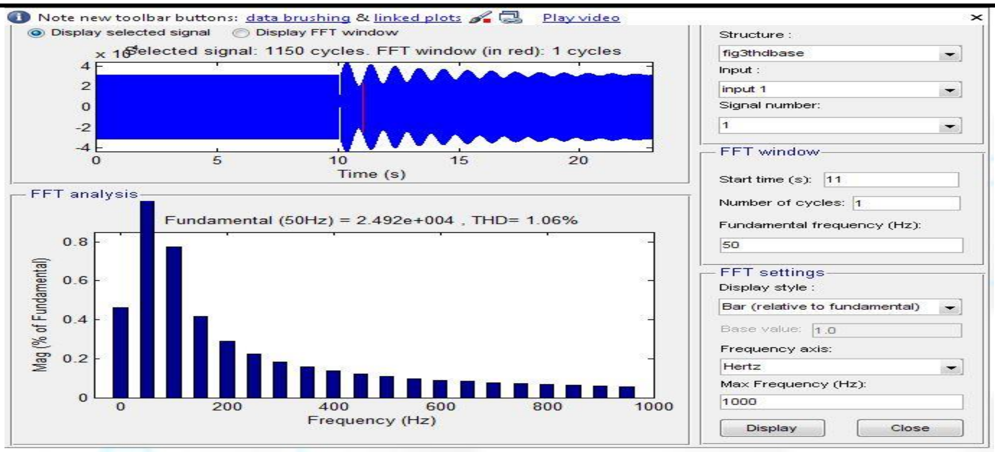


Fig. 6 Simulink model of System Architecture.

IX. NON-LINEAR LOAD

Simulation results are given here for non-linear load. Figure-7.1 shows the graphical representation of increasing grid power transmission limits during night and day and Figure- 7.1 shows the FFT analysis of increasing grid power transmission limits during night and day.



Note new toolbar buttons: data brushing & linked plots Play video

● Display selected signal ○ Display FFT window

Selected signal: 1150 cycles. FFT window (in red): 1 cycles

Fundamental (50Hz) = 2.492e+004 , THD= 1.06%

Structure : fig3thdbase

Input : input 1

Signal number: 1

FFT window

Start time (s): 11

Number of cycles: 1

Fundamental frequency (Hz): 50

FFT settings

Display style : Bar (relative to fundamental)

Base value: 1.0

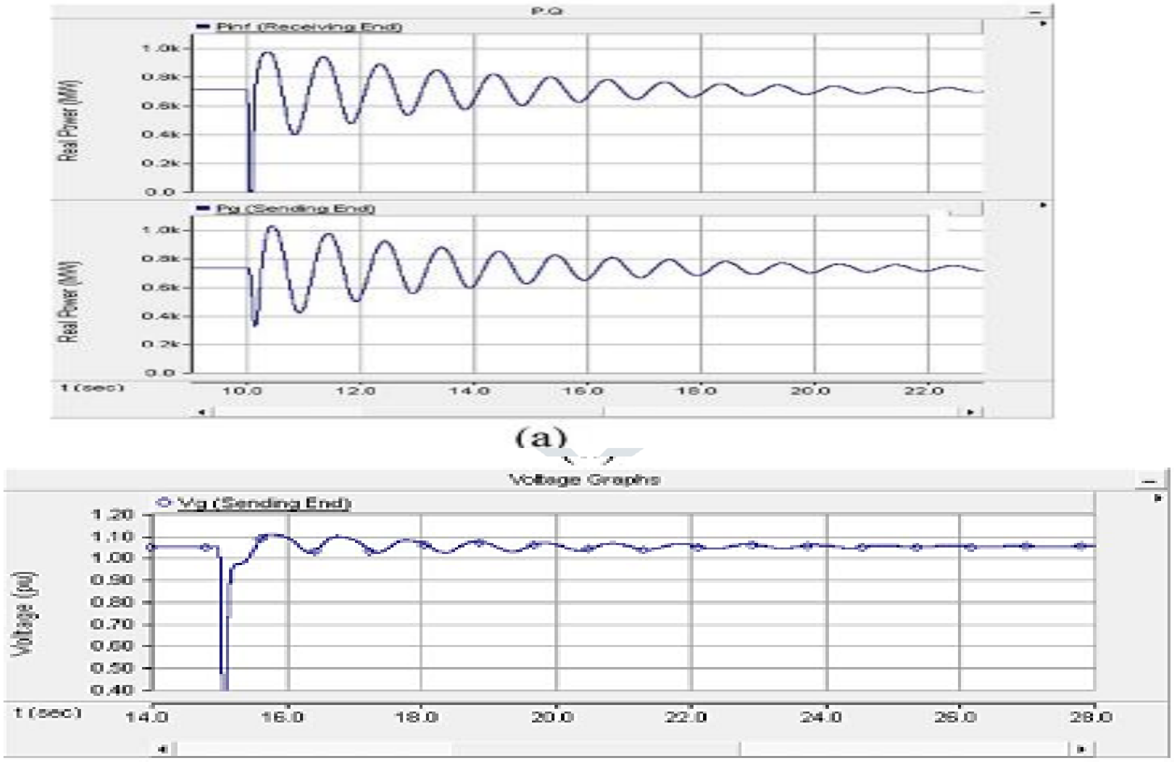
Frequency axis: Hertz

Max Frequency (Hz): 1000

Fig.7 The FFT analysis of source voltage.

X. Power Transfer Limits in Study System:

The Conventional Reactive Power, Control with Novel Damping Control. In this study, the solar DG is assumed to operate with its conventional reactive power controller and the DG operates at near unity power factor. The night time operation of solar (DG), the dc sources are disconnected, and the solar DG inverter is connected to grid using appropriate controllers the stable of power transmission limits obtained from transient stability studies and the corresponding load. During night with conventional reactive Power Controllers.



(a)

(b)

Fig8 (a): Maximum.(b) Voltage at the generator terminal nighttimes power transfer (731 MW) from the generator when solar DG remains idle

(731MW), when the solar DG is simply sitting idle during night and is disconnected from the network. This power-flow level is chosen to the base value against which the improvements in power flow with different proposed controllers are compared .The real power from generator and that entering the infinite bus for this fault study.

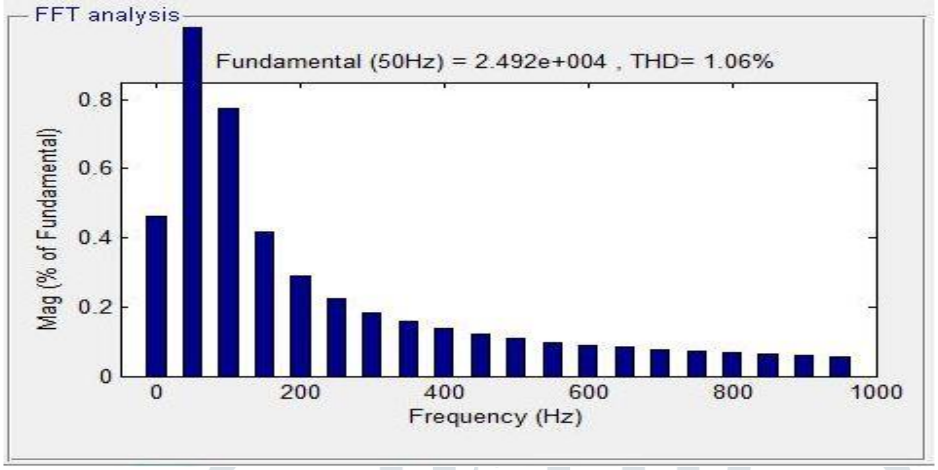


Fig.9 Spectrum analysis of the source current with STATCOM

IX. CONCLUSION

Power system performance depends on the flow of real and reactive power and adequate control method is required to control the flow of real and reactive power in the system. In this paper a novel concept of utilizing a photovoltaic (PV) solar farm inverter as STATCOM, called PV-STATCOM using fuzzy controller is proposed. The PV-STATCOM operation opens up a new opportunity for PV solar DGs to earn revenues in the nighttime and daytime in addition to that from the sale of real power during the day. FACTS controllers are versatile in controlling either by impedance varying or by using switching power electronics method. Solar farms are idle during nights. This new control of PV solar system as STATCOM is called PV-STATCOM. The main function of the LCL filter is to reduce high-order harmonics on the output side; however poor design may cause a distortion increase. Three different types of STATCOM controls are proposed for the PV solar DG and inverter-based wind DG. These are pure voltage control, pure damping control, and a combination of voltage control and damping control. The proposed method is verified by using the simulations.

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