JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

MITIGATING POWER OSCILLATIONS BY USING FUZZY LOGIC CONTROLLER BASED PV-STATCOM

DR.GADDAM SRIDHAR[1] THIRUMALA TEJASWINI[2] MEKALA ADITYA[3] BASA AKHIL[4]

VEMUNURI SAICHANDU[5]

[1]Professor, Department of EEE, Jyothishmathi institute of technology and science, Nustulapur, Karimnagar, TS, India
[2,3,4,5]Ug scholar, Department of EEE, Jyothishmathi institute of technology and science, Ramakrishna colony Nustulapur, Karimnagar, TS, India

ABSTRACT:

The concept of this paper is the control of PV solar farm as a STATCOM for increasing the power transferability of the network. It can be termed as PV STATCOM. The power system network is now becoming increasingly complicated, making it very difficult to preserve the power system's stability. Thus, we developed a POD controller for large solar photovoltaic farm operated with the integration of a Static Synchronous Compensators (STATCOM) which is a Flexible AC Transmission System (FACTS) device to improve voltage stability and to damp power oscillations in the system. This project proposes a new approach to implementing Flexible AC Transmission System (FACTS) devices in a multi-machine power system for local damping and reducing inter-area modes of oscillation based on Fuzzy logic controller (FLC). The proposed fuzzy controller gives less Total Harmonic Distortion (THD) with the PI controllers and mitigate the oscillations in the output power, thus enhancing the power quality. The model is designed using MATLAB / SIMULINK environment.

KEYWORDS:

STATCOM, FACTS, reactive power, power oscillation, real power generation

OBJECTIVE:

- To reduce the Total Harmonic Distortion.
- To increase the power transfer capacity of the network.
- To enhance power transferability of the transmission line.
- To overcome the drawbacks of conventional PV-STATCOM which are high distortions, low quality of power in the output.
- To mitigate power oscillations.

I.INTRODUCTION

In a power system, if low-frequency oscillation continues for a very long period of time, it can threaten the stability of the system. The majority of oscillation modes occur mainly in a frequency range of 2.0 Hz or less, and especially in the wide-area mode at 1.0 Hz or less. Low-frequency oscillations (LFO) are already present in power systems due to the power exchange between generating units operating in parallel, when interconnected through long transmission lines and also when non linear loads are connected at the load side. FACTS is defined as Flexible AC Transmission systems. These are static power-electronic devices installed in AC transmission networks to increase stability, power transfer capability and controllability of the networks through series and/or shunt compensation. These devices are installed along with the controllers for power oscillation damping (POD).

In this proposed paper we discuss about PV-STATCOM control for mitigating or reducing the power oscillations hence reducing THD and improving power transferability. A PV-STATCOM is the PV solar farm acting or converted into a STATCOM when power oscillations occur in the power system. Here the entire inverter capacity is used for reactive power generation for POD. The whole process of reducing power oscillations is discussed in this paper.

One of the major part of the controlling unit is the proposed Fuzzy Logic Controller (FLC). In the paper, FLC plays a major and vital role in reducing the THD. FLC is a real time controller and provides an accurate and faster response when compared other types of controllers. Therefore the paper discusses about how a PV-STATCOM works along with the proposed control techniques in order to minimize power oscillations.

This paper discusses about the concept and working of a PV STATCOM in section II. The methodology is being discussed in section III. The brief explanation about how the MATLAB/SIMULINK model works is given in section IV along with the proposed model. In section V the results are analysed which were obtained by executing the model. Finally the paper is concluded in section VI.

II. DESCRIPTION

In this paper working of PV-STATCOM is being explained and how it aids in enhancing the power transferability in order to ensure power quality in the power system is discussed. A PV-STATCOM is the PV solar farm acting or converted into a STATCOM when power oscillations occur in the power system. Here the entire inverter capacity is used for reactive power generation for POD.

When oscillations occur, the PV STATCOM is enabled. It stops its real power generation and shifts its whole inverter capacity for reducing those oscillations. The whole process of reduction of oscillations takes place in the power system network in the following process.

The PV array receives the sun light and generates dc current therefore inducing dc voltage. The MPPT maximizes the energy which is obtained from PV solar array. It is further given to the inverter which converts dc voltage into ac voltage. The triggering pulses for the inverter are provided by PWM (Pulse Width Modulation). The main function in the whole system is done by the controllers. The inner loop control enables the production of real and reactive power for a rotating plane and provides three phase indices which are used to generate the triggering pulses for inverter. The DC voltage controller is used to control the reference voltage using MPPT. Conventional PV controller is used in normal operation mode. Here the reactive power is zero. The Q-POD controller controls the reactive power of the PV STATCOM which is further used to reduce the power oscillations. Line current of the transmission line is considered as the control signal for this controller. The controller adds effective phase lead or lag to enhance the reduction of oscillations.

The Fuzzy logic controller is used instead of PI controller. The fuzzy method is carried out by Centroid method. If and then rule base is implemented here. Error between Vref and Vpv is one input and delay that is change in error with respect to time is another input. In membership functions 7 variables, 49 rules are present. The fuzzy method consists of three key phases

(1) Level of input

(2) Stage and processing

(3) Stage of Output

The error signal is provided as the input to the Fuzzy controller. The processing step consists of the membership and the values of truth to minimize the signal of error. In the output stage output volume is defuzzified into regulated defined output.

III. METHODOLOGY

PV STATCOM is a new design for voltage control with the use of existing PV inverter device at the PCC and for reactive power compensation. Photovoltaic solar power is produced by solar radiation through panels during the day. During the night, however, because of lack of solar radiation they become inactive. For reactive power compensation such as STATCOM, the entire capacity of PV inverter can be used during the night by installing a new supplementary controller, which is shown in Fig.1 with the current solar converter control system.

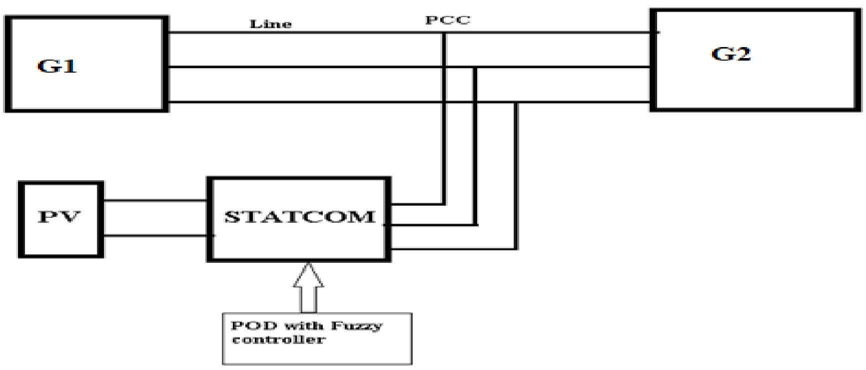

Fig1. PV system with STATCOM

The current inverter device of PV shown in Fig 2 is connected to a new PV STATCOM controller. There are two existing control loops in a traditional PV controller. Present control loops for the D-axis and Q-axis. d axis loop consists of two DC (PI-1, PI-2) controllers which control DC connection voltage over the DC-Link condenser and which regulate the active power generation on the input side of the inverter over the day and PI-3 controllers which regulate reactive power output around zero as a point of reference for the operational unitary power factor. D axis loops The Q axis loop controlling the response power between the grid and the PCC is linked by comparing the PCC voltage with the voltage reference and controlling the voltage variance, especially during back power flow, to the PI-4. For operating PV inverters, the STATCOM for the grid voltage control is connected. Any inverter bases renewable energy system such as solar, wind, fuel cell etc., can be used as a STATCOM via this additional control system.

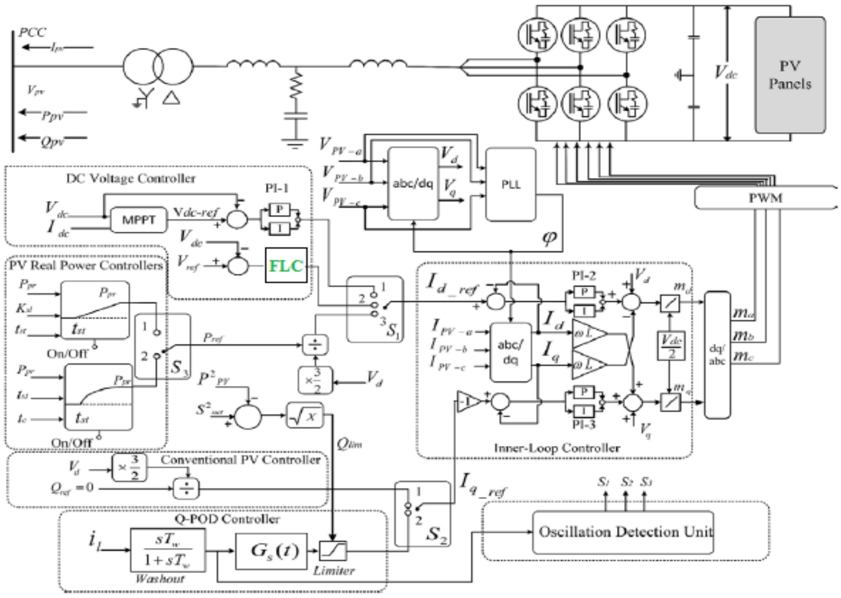

Fig. 2. PV-STATCOM controller POD with fuzzy controller

PV Panels and Inverter

A panel equivalent is described in the aggregated PV panels which produces PV dc current based on the V-I properties of PV panels. A three-step six-pulse configuration with an IC-conductor is known to be the aggregated solar farm inverter. A LCL filter based on links the PV inverter to the grid. The symbols Vpv, Qpv, Ppv, Ipv are the voltage, reactive reverse power, real power inverter and PCC inverter current.

DC Voltage Controller

Two components are used in the DC link controller; i) the MPPT (Maximum Power Power Point Tracking) and ii.) the DC link voltage controller. The MPPT block, uses Vdc and Idc for generating Vdc-ref reference voltage, produces IDref to the internal loop controller during traditional PV operating mode on the basis of the VI characteristic of the Photovoltaic panels. S1 is changed to the position2 in the STATCOM control mode and Vdc's DC voltage to the open circuit voltage PV panel is modified to disable the actual power injection from PV solar panels.

Fuzzy Controller

The fuzzy method consists of three key phases

(1) Level of input

(2) Stage and processing

(3) Stage of Output

The error signal is provided as a feedback to the input process of the Fuzzy controller. The processing step consists of the membership and the values of truth to minimize the signal of error. The output stage here defuzzifiers the output volume into the regulated defined output value.

The configuration of the fuzzy-based logic controller, divided into four:

1) Running

2) Basis of the law

3) Method of inference

4) Defuzzification

Currently, due to its basic structure, easy to design and low costs, the PI controller is the most used for industrial applications. Despite these benefits, if the object is extremely non linear and unpredictable, the PI controller fails. Thus, when developing a fuzzy logic controller it is much easier to preserve the advantages of the PI style control system. In this case, the control output is

$$Kp\Delta uf + ki \int e\, dt \qquad (3.1)$$

where kp and ki are the same as the traditional PI controller, and are the FLC output.

Fuzzification

Input variables are matched to fuzzy variables in fluzzification. A certain membership function exists for every fuszified variable. Three sets of fluids are used to float inputs and output: P (positive), Z (zero) and N (negative), as shown at Fig. 3. Error and derivative error are the inputs of the fuse controller.

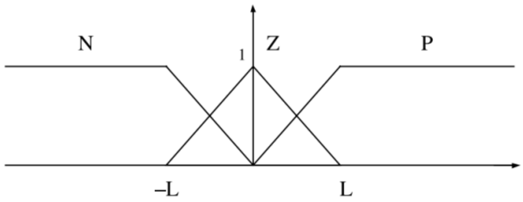

Fig.3. Membership functions for fuzzy controller.

The positive set's membership feature

$$\mu p(xi) = \begin{cases} 0 & xi < 0 \\ \frac{xi}{L} & 0 \le xi \le L \\ 1 & xi > L \end{cases}$$

Where xi marks the controller fuzzy inputs. The adverse member feature is similarly

$$\mu N(xi) = \begin{cases} 1 & xi < -L \\ \frac{-xi}{L} & -L \le xi \le 0 \\ 0 & xi > 0 \end{cases} \qquad (3.2)$$

And the membership feature is zero set:

$$\mu Z(xi) = \begin{cases} 0 & xi < -L \\ \frac{xi+L}{L} & -L \le xi \le 0 \\ \frac{-xi+L}{L} & 0 < xi \le L \end{cases} \qquad (3.3)$$

$$0 \qquad xi > L$$

Inference

The control decisions are taken on the basis of the fluctuated variables. Details provide guidelines to determine production decisions. Table 1 displays the controller's rule base. The min–max inference is applied to evaluate the level of membership for output variables.

Defuzzification

In numerical output, the output variables for the fuzzy inference method should be transformed. Use Zadeh operating rules and general defuzzifier for fuzzy controller output:

$$\Delta uf(k) = \frac{\sum_{i=1}^{9} \mu c(\mu f)\mu f}{\sum_{i=1}^{9} \mu c\,(\mu f)} \qquad (3.4)$$

PROPOSED FUZZY LOGIC CONTROLLER

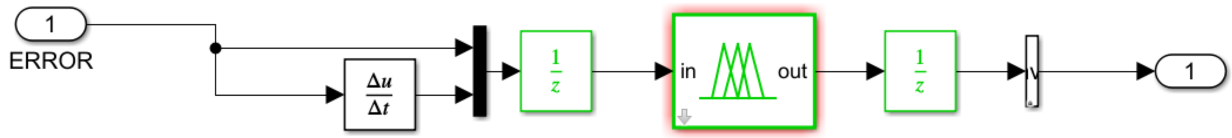

Fig.4. Proposed fuzzy controller.

TABLE I
PROPOSED FFUZZY RULES

Code/ Error	NB	NM	NS	ZE	PS	PM	PB
NB	PB	PB	PB	PB	NM	ZE	ZE
NM	PB	PB	PM	PB	PS	ZE	ZE
NS	PB	PM	PS	PS	PS	ZE	ZE
ZE	PB	PM	PS	ZE	NS	NM	NB
PS	ZE	ZE	NM	NS	NS	NM	NB
PM	ZE	ZE	NS	NM	NB	NB	NB
PB	ZE	ZE	NM	NB	NB	NB	NB

Where,
NB indicates Negative Big
NM indicates Negative Medium
NS indicates Negative Small
ZE indicates Zero Equal
PB indicates Positive Big
PM indicates Positive Medium
PS indicates Positive Small

IV. SIMULATION MODEL

The below fig.5 shows the simulation model of PV-STATCOM controller. The simulation model consists of PV solar array, an MPPT algorithm, three phase six pulse solar farm inverter, filters, three phase voltage and current measurement blocks, RLC load, inner loop controller, real power and reactive power (Q-POD) controllers, conventional PV controller and Fuzzy Logic Controller.

The PV solar array provides the PV dc current based on its ratings and the PV voltage is generated. The MPPT algorithm is employed in majority of PV inverters. The main function of MPPT is to maximize the energy available from connected solar module arrays at any time during the operation. The three phase six pulse inverter acts as a bridge between solar array module and grid. It converts the voltage from DC to AC in order to supply the grid. The RC and RL filters are introduced to reduce the harmonic content in the system voltages and currents.

The three phase voltage and current measurement blocks are introduced in order to measure the currents and three phase voltages which are obtained as a result of inverter operation. Further an RLC load is connected to the whole network. Now coming to the controllers the inner loop control perform an inverse Park transformation from a dq0 rotating reference frame to a three-phase (abc) signal and also perform a Park transformation from a three-phase (abc) signal to a dq0 rotating reference frame. These are used for generating the inverter triggering pulses using Pulse Width Modulation (PWM).

To output the PV power at unity power factor the PV controller is used. It is applicable only for regulating the PV reactive power. The Q-POD controller is used for controlling the PV STATCOM reactive power which helps in reducing or damping the power oscillations and impact of faults. The real power controller helps in restoring the real power which was present before the disturbance occurred after reducing or damping the power oscillations and impact of faults. This can take place in full PV STATCOM mode or in partial PV STATCOM mode.

The Fuzzy logic controller is used instead of PI controller. The fuzzy method is carried out by Centroid method. If and then rule base is implemented here. Error between Vref and Vpv is one input and delay that is change in error with respect to time is another input. In membership functions 7 variables, 49 rules are present. The fuzzy method consists of three key phases

(1) Level of input

(2) Stage and processing

(3) Stage of Output

The error signal is provided as a feedback to the input process of the Fuzzy controller. The processing step consists of the membership and the values of truth to minimize the signal of error. The output stage here defuzzifiers the output volume into the regulated defined output value.

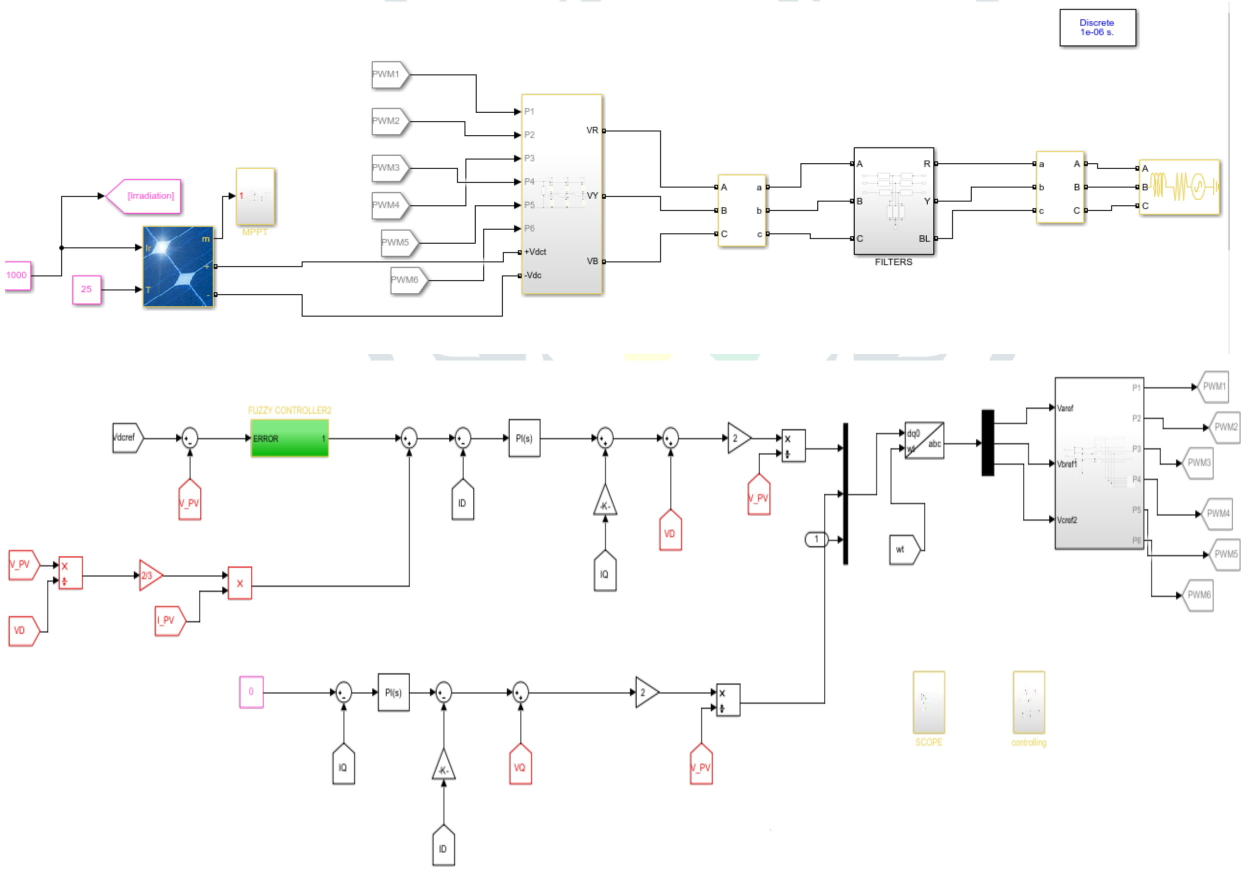

Fig. 5. Model of PV STATCOM controller

SIMULATION RESULTS

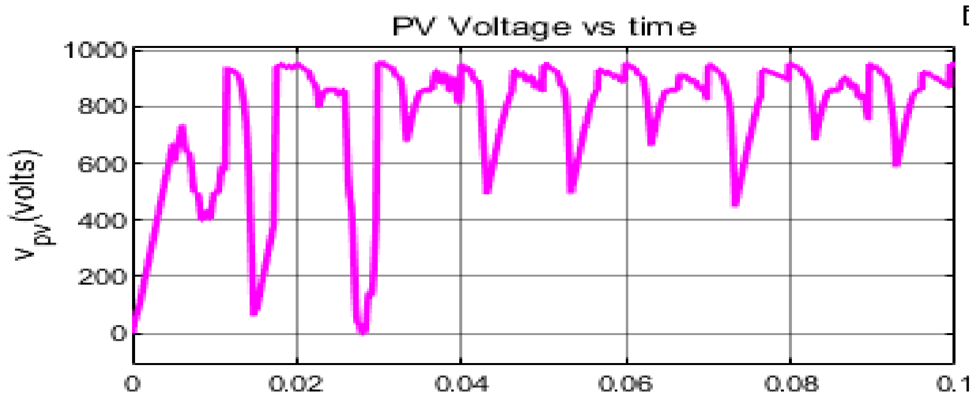

Fig.6. PV array voltage Vs time

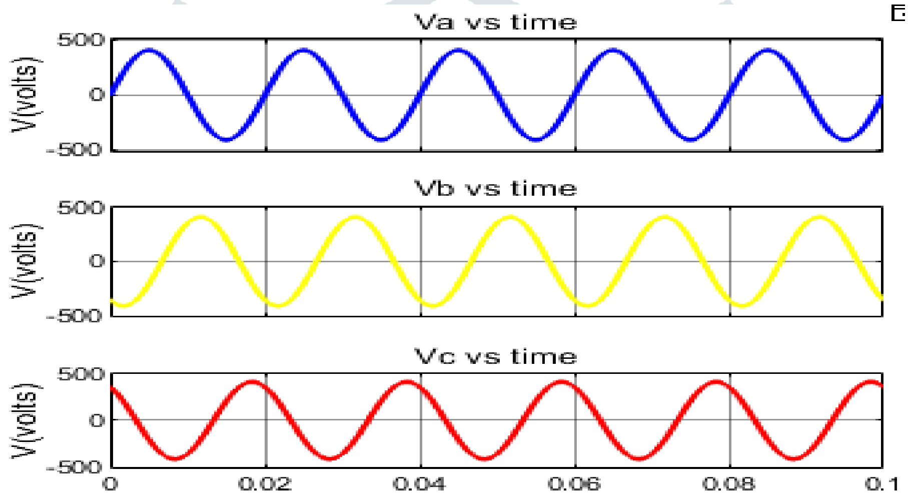

Fig. 7. Three phase voltages Va,Vb,Vc Vs time

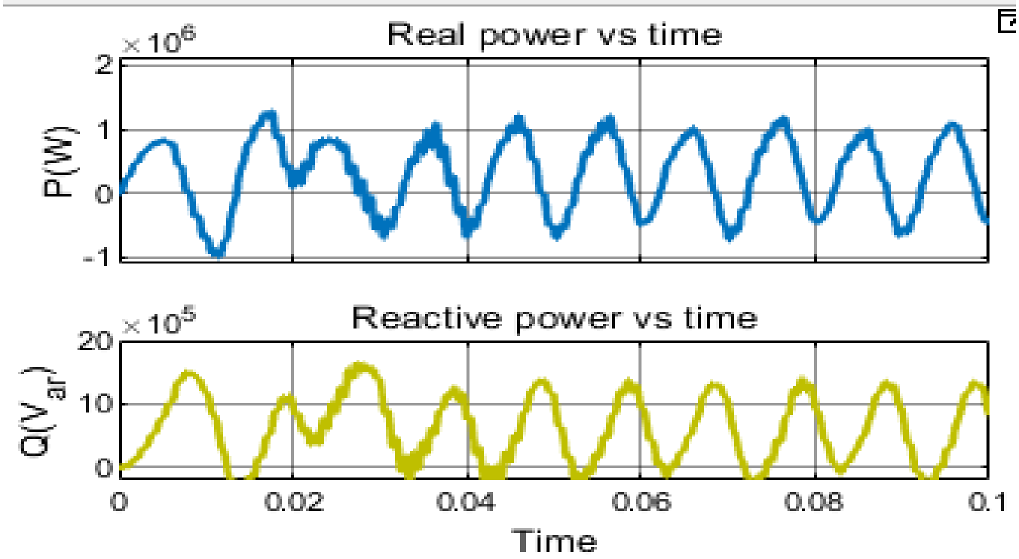

Fig. 8. Real power and Reactive power of PV STATCOM

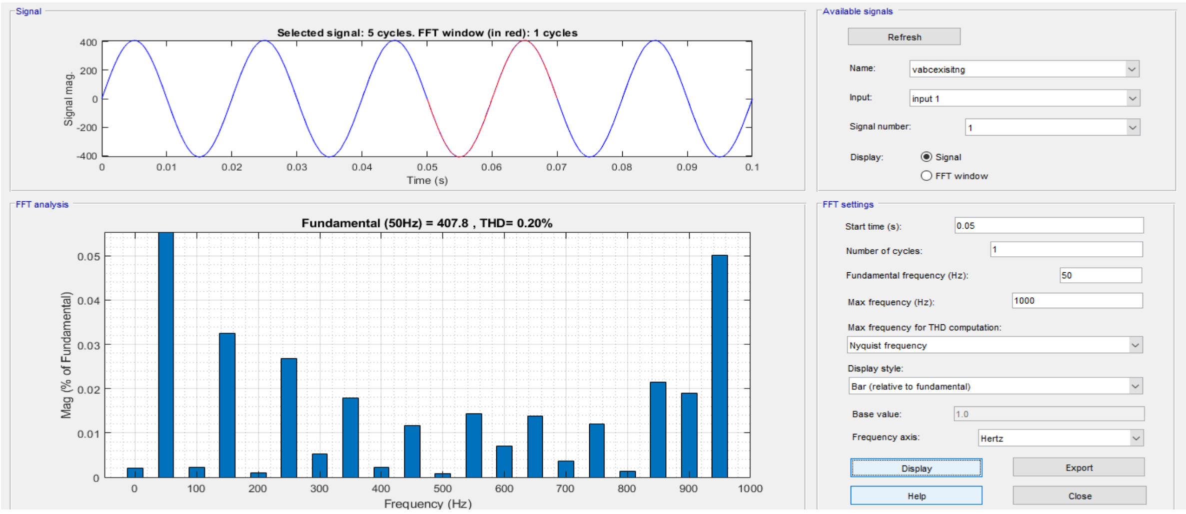

Fig. 9. THD% of voltage without fuzzy logic controller

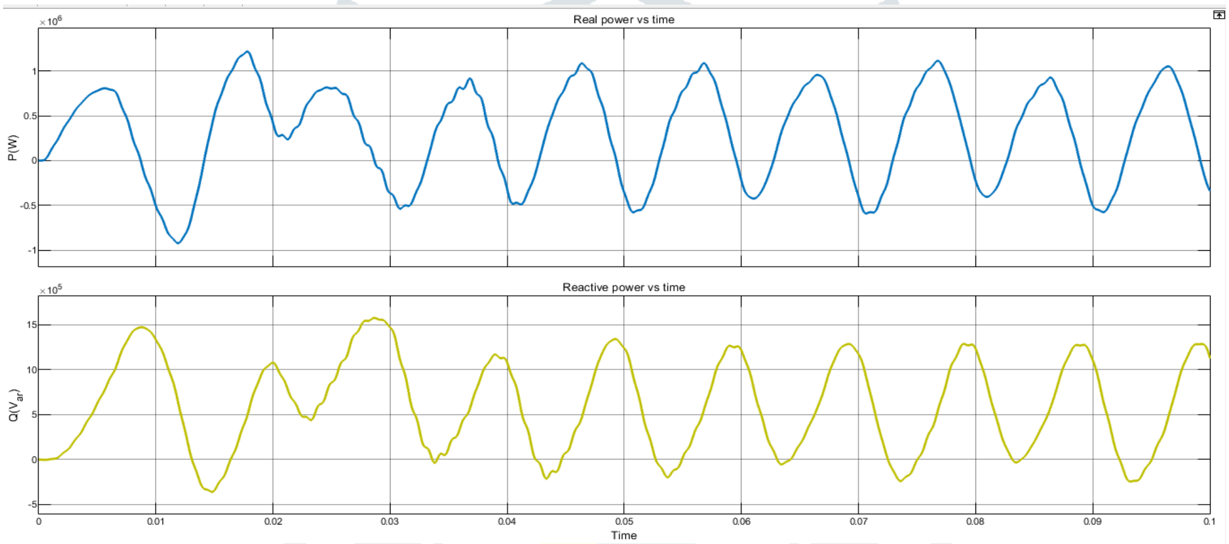

Fig. 10. PV-STATCOM real power and reactive power

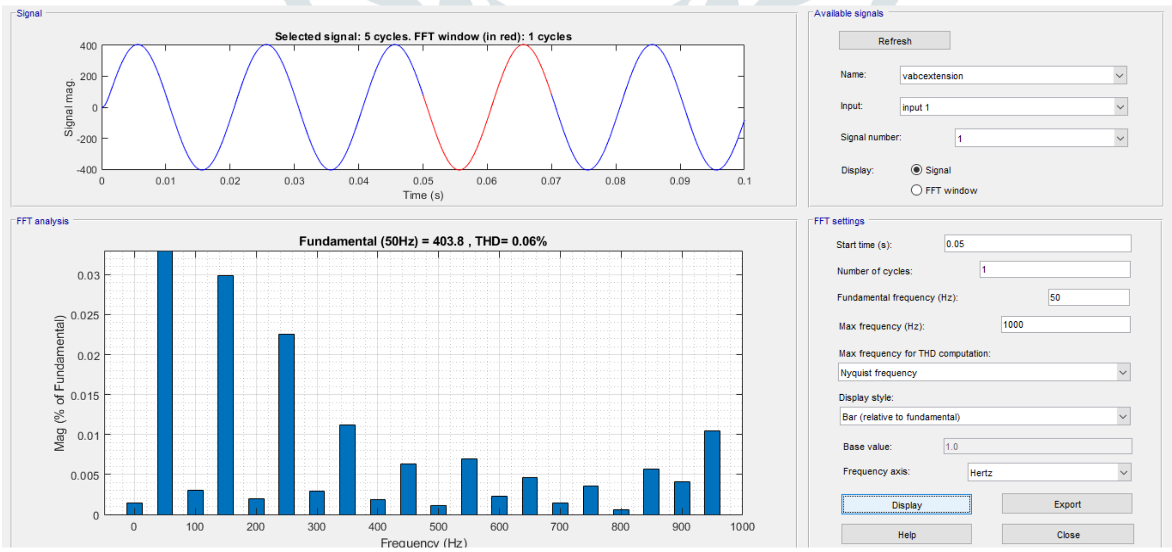

Fig. 11. THD% of voltage with fuzzy logic controller

VI. CONCLUSION

PV-STATCOM for POD is built in this paper through the use of fuzzy controller. The PV-STATCOM can, since it uses an existing infrastructure of a solar photovoltaic plant to transform it into a full-scale STATCOM of similar sizes, cost around 50-100 times lower than an equivalent STACOM. The alternative FACTS system PV-STATCOM is anticipated to produce substantial savings in the power transfer capacities of utilities. It also provides new revenue to solar farms with linked transmission, which will deliver a dramatically lower cost of STATCOM functionality 24/7. Of course, this technology must be introduced in compliance with acceptable agreements between utilities, device authorities, solar farms developers and inverter manufacturers. The goal of this article is to propose a new monitor for power oscillation by using a fluidized control system during the day and at night of a single PV solar farm as the PV-STATCOM. When the PV-STATCOM control on a variety of electrical proximity PV solar farms, PV-STATCOM controls shall require coordination similar to that of multiple FACTS equipment and HVDC and FACTS equipment. The synchronization of controls between many PV-STATCOMs will ensure that all participating PV-STATCOMs deliver power oscillation damping at the same time as the swing is damped. The proposed system THD% of voltage is less than the existing PI controller . This control synchronization involves comprehensive control designs and system studies beyond the reach of this paper.

REFERENCES

[1] N. Mithulananthan, C. A. Canizares, J. Reeve, and G. J. Rogers, "Comparison of PSS, SVC, and STATCOM controllers for damping power system oscillations," IEEE Trans. Power Systems, pp. 786-792, 2003.

[2] A. M. Simões, D. C. Savelli, P. C. Pellanda, N. Martins, and P. Apkarian, "Robust design of a TCSC oscillation damping controller in a weak 500-kV interconnection considering multiple power flow scenarios and external disturbances," IEEE Trans. power systems, vol. 24, pp. 226-236, 2009.

[3] R. K. Varma, V. Khadkikar, and R. Seethapathy, "Nighttime Application of PV Solar Farm as STATCOM to Regulate Grid Voltage," IEEE Trans. Energy Conversion, vol. 24, pp. 983-985, 2009.

[4] R. K. Varma, S. A. Rahman, and T. Vanderheide, "New Control of PV Solar Farm as STATCOM (PV-STATCOM) for Increasing Grid Power Transmission Limits During Night and Day," IEEE Trans. Power Delivery, vol. 30, pp. 755-763, 2015.

[5] R. Shah, N. Mithulananthan, and K. Y. Lee, "Large-scale PV plant with a robust controller considering power oscillation damping," IEEE Trans. Energy Conversion, vol. 28, pp. 106-116, 2013.