INCREASING POWER TRANSFER CAPACITY USING STATCOM

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ABSTRACT

The paper we are present the improvement in voltage stability in power system by transmitting power in an grid connection from generation to load a STATCOM is used connected to the stability node of the studied system that is figured out based on power calculation results. The analyses voltage results and time domain response are presented in the order to estimate the effectiveness of the used STATCOM to the studied system the higher demand for electric power and poor reactive power management has prompted voltage stability problems in the power system and power quality problem and ensure voltage stability Based on this fact, PV-STATCOM in a grid interconnected solar farm of a Distributed Generation system. There are various compensation devices in FACTS. The analysis an also modeling of a PV farm inverter as STATCOM by which voltage regulation also on a single machine used system with midpoint connection to the transmission and PV – STATCOM by using the MATLAB and SIMULINK..

Keyword : - *PV panal solar power systems, FACTS, inverter , fuzzy logic controller ,reactive power control, STATCOM, transmission , voltage control, damping control*

1. INTRODUCTION

To increase power transfer limits (ATC) of a transmission line FACTS controllers are increasingly considered. PHOTOVOLTAIC (PV) power systems are more essential in modern grid connected network because of abundantly available solar energy. Nowadays, PV power systems have more used for major research purposes, because of its simple analysis which system performance and interface with utility grids with the help of demonstrating and computer simulation. A new research on the utilization of PV panel which is shunt connected reactive power compensator called as STATCOM device during night time farm have been reported for control of voltage The concept of displaying and recreation of Single Machine Infinite Bus comprising of solar farm and inverter which are used as STATCOM device along with the fuzzy logic for increasing the stable power transmission in an distribution network. A STATCOM device is mainly used to improve whole system performance in an transmission and also in an distribution systems through the control of voltage and damping of power oscillations. Harmonic analysis in an grid solar system is performed in two cases such as without STATCOM device and with STATCOM device.

SMIB system consists of a single Photovoltaic solar farm as an STATCOM at the center in an transmission system. The proposed framework is executed utilizing the MATLAB/SIMULINK model for stability studies by applying three phase fault and Total Harmonic Distortion values (THD) are investigated for PV solar farm inverter with and without STATCOM. Harmonic mitigation or optimal power flow in the grid connected system. In proposed work fuzzy logic technique is utilized to relieve the harmonic as better enhancement of power flow in the grid. The FACTS is an idea based on power-electronic controllers, which improves the use of transmission network capacity to enhance the value of power transfer capability. SSC or STATCOM is one of the recently utilized FACTS devices for grid power transmission limit. Available power transfer (ATC) can be enhanced by utilizing FACTS controllers in existing transmission lines. For small and medium power applications, compensation of VAR and also the load of harmonics has been proposed using IGBT i.e. insulated gate bipolar transistor as a switching device. A STATCOM device is mainly used to improve the performance in transmission and also distribution systems through the control of voltage and damping of power oscillations. Harmonic analysis of a grid connected solar system is performed in two cases such as

1) Without STATCOM device
2) With STATCOM device

Single Machine Infinite Bus consists of a single PV solar farm using as STATCOM at the centre of transmission line. The proposed system is implemented using the MATLAB/SIMULINK model for stability studies by applying three phase fault and Harmonic Distortion (THD) are investigated for PV solar farm with and without STATCOM. Most of papers discussed about either with harmonic mitigation or optimal power in the grid connected system. In proposed work, DQ control technique is used to mitigate the harmonic as well as better enhancement of power flow in the grid connected system.

2. PROPOSED MODEL

The single line diagram of the grid connected PV system is represented in Fig.1. The single line diagram comprises of a Solar PV panel connected at the point of PCC/middle bus of the transmission line with step up transformer. All the parameters of the whole system are specified in the Appendix. Grid connected solar PV system design The PV panel generates maximum DC power with its PV panels based on solar insolation and temperature, which is shown in Fig. 1 by incorporating the Maximum Power Point Tracking algorithm. Among the MPPT algorithms, incremental conductance algorithm is mainly used because of its high efficiency which is used to operate the solar DGs at its maximum power point voltage and it is integrated with inverter controller. Fig.1. Block diagram of grid interconnected Solar PV system The DC terminal of the inverter consists of a capacitor so that the DC link is maintained constant. The DC power output from the solar panel is transformed into AC power output with inverter to supply the AC network. The inverter includes semiconductor devices configured in a 'matrix' of switches and a controller which controls the switching devices. Quality of output power from the inverter can be improved by using the filter. The output voltage obtained from the inverter which is integrated with the network voltage by using a step up coupling transformer. The inverter switch IGBT and controller works as an inverter to which an MPPT feedback system is obtain to improve the signal and rate to input ratio coming from the PV

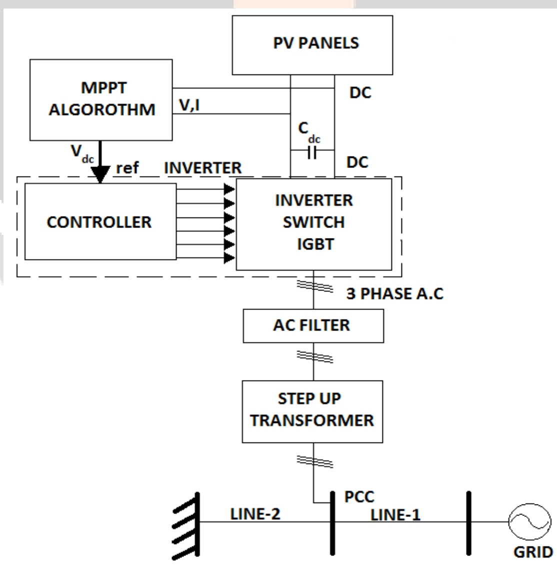

Fig – 2.1

2.1 System Description

The PV panel is connected at the middle bus/PCC bus of a grid connected power transmission system as represented in Fig.2 (a). The DC output obtained by the PV panel during day time is an source to the STATCOM device, as shown in Fig.2 (b). The total quantity of real power injected in the grid from PV panel depends on the DC input voltage. During night time operation the DC source detached so that the real power injected in grid will be zero. The inverter used in the proposed system which consists of three pair of IGBTs along with its snubbed circuits as represented in Fig.2 (b). A large DC link capacitor is used in maintaining the DC link voltage constant by reducing the ripples in DC terminal. According to the gate signals given to each paired IGBT devices, the DC voltage transformed a series of three phase sinusoidal voltages. Gate signals for each of the IGBT devices is generated by comparing the resulting three phase sinusoidal modulating signal with high frequency carrier signal or triangular wave as represented in Fig.2 (a). An L-C-L filter is used at the AC terminal of the inverter to eliminate harmonics thereby raising the power quality. Step up transformer is used to put together the inverter output voltage level.

Table -1: System Parameters and Ratings

S.NO	PARAMETERS	RATINGS
1	Grid voltage	3phase,25kV
2	Frequency	60Hz
3	Inductance MVA	900 MVA
4	Line series inductance	0.08H
5	Transformer 1 Rating	Primary voltage =25kV Secondary Voltage= 400kV MVA Rating =900MVA
6	Transformer 2 Rating	Primary voltage =400kV Secondary Voltage= 230kV MVA Rating =900MVA
7	Inverter parameters	DC link voltage=510V DC link capacitance=1000μF Switching frequency=5kHz

2.2 Control Technique for STATCOM

In this work "D-Q control technique" is used for Real power and Reactive power , Harmonic mitigation in grid connected PV system. The DQ transformation is a form of coordinates from the 3 phase stationary coordinate system to DQ rotate coordinate system. This transformation is made in two steps: 1) Transformation from the 3-phase stationary coordinate system to the 3-phase, so-called α β, coordinate system. 2) Transformation from the α β coordinate system to the DQ rotate coordinate system. Synchronous reference outline control, otherwise called DQ control, utilizes a reference outline change module to change the network current and voltage. By methods for this, the control factors move toward becoming DC values; thus, filter and control can be easily achieved. The α β γ transform in a space vector transformation of time-domain signals (e.g. voltage, current, etc) from a natural 3-phase coordinate system (a b c) into a stationary 2-phase reference frame (α β γ).

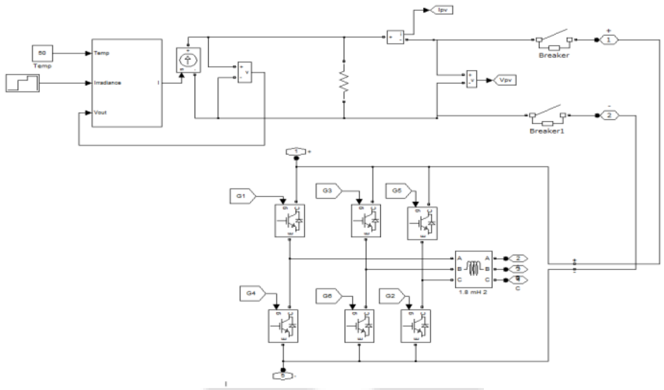

Fig -2(a)

2.3 Modeling control

i. Reactive Power Controller:

A Mamdani fuzzy control with two input variables and one output variable is designed using MATLAB and realized using a PIC microcontroller. Current (I) and Power Factor (cos ϕ) are the two input variables and I sin ϕ is the output variable. The current and power factor has eight membership functions which either triangular or trapezoidal. The fuzzy rules are set in view of the information and working of framework. The fuzzy rule base are initialized

Active power, P = V I cos θ
Reactive power, Q = V I sin θ
Apparent Power, S= √(P2 + Q2) =VI

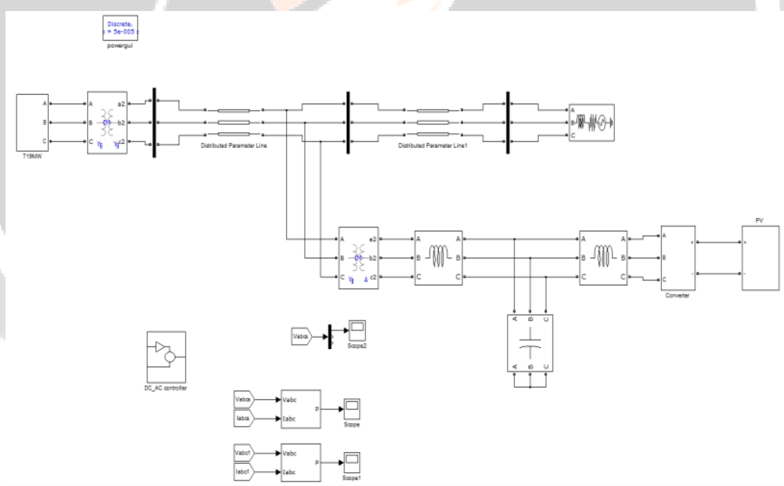

Fig -2(b)

ii. Voltage Controller:

Fuzzy variables are as ΔV, ΔVdc , Δed , Δeq , the fuzzy sets of all linguistic characteristics of negative large (NL),negative medium(NM) ,positive(P) ,positive medium (PM) and positive big(PB) are arrange to each variable and equal triangular functions which selected as the fuzzy membership functions .Both inputs to the fuzzy controllers have the same membership function, The subintervals XI are heuristically selected base on its characteristics of each control loop which will provide the best damping or stabilize performance . A fuzzy rule base is been assigned for each combination in input and output variable.

iii. Damping Controller:

The form of all the membership functions (MF) depend on type's of application, like monotonic, triangular, trapezoidal and bell-shaped. The triangular is the most effective MF, since it is form by the straight lines. Here triangular MF is used. The inputs are fuzzified using five fuzzy sets: positive big (PB), positive small (PS), zero (ZO), negative small (NS), and negative big (NB). The input and output are in the range of [-8,8].

3. FUZZY LOGIC CONTROLLER

The fuzzy controller is applied in the proposed micro grid power system, as shown To obtain the desired SOC value, the fuzzy controller is designed to be in charging or discharging mode's for the proposed micro grid system. The input variables of fuzzy control are ΔSOC and ΔP and also the output variable is ΔI. The definition of input and also output variables are listed as follows:

$$\Delta SOC = SOC\ command - SOC\ now \quad (1)$$

$$\Delta P = PL - (P\ solar + P\ pv) \quad (2)$$

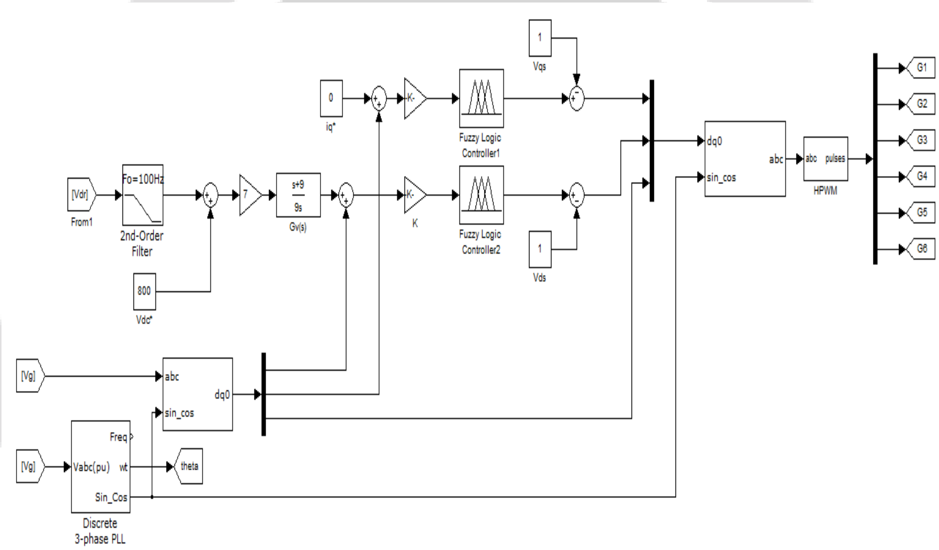

Fig -3

Table -2 : TABULAR FORM OF RULES

ΔI	ΔP					
		NL	NM	P	PM	PB
ΔSOC	NL	PB	PB	P	NM	NL
	NM	PB	PB	PM	P	NM
	P	NM	NM	NM	NM	NM
	PM	NM	P	NM	NM	NL
	PB	NL	NL	P	PM	NL

4. RESULTS AND DISCUSSION

The FLC comprises of three parts: fuzzification, interference engine and defuzzification. The FLC is characterized as:

i. Five fuzzy sets for all input an output.
ii. Triangular membership functions are for the simplicity.
iii. Fuzzification using continuous universe discourse.
iv. Implication using Mamdani's, 'min' operator.
iv. Defuzzification use the height method.

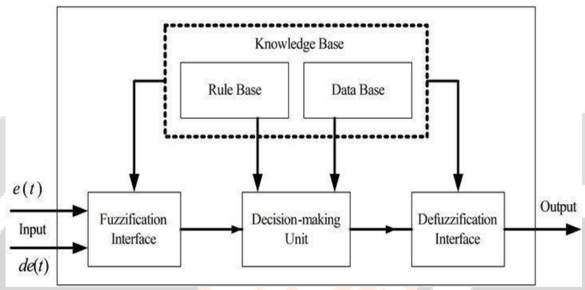

Fig – 4.1

4.1 Fuzzification:

To linguistic Membership function values are appointed to the etymological factors, utilizing five fuzzy subsets: PB (Positive Big), PS (Positive Small), P (Positive) NM ,(Negative medium) and NL (Negative Large) .The Partition of the fuzzy subsets the state of the participation work adjust the shape of the appropriate system. The value of input error, change in error normalized by an input scale factor. In this system the input scale factor has been designed such that input values are between -1 and +1. The triangular state of participation work this course of action presumes that a specific contribution there is just a single overwhelming fluffy subset.

4.2 Inference:

A few creation techniques like Max–Min , Max-Dot are been used in the theory . Min method is implemented . The yield enrollment capacity of each lead are by the base administrator and greatest administrator. Table 1 demonstrates FLC rule base.

4.3 Defuzzification:

A defuzzification arrange and non fluffy estimation of control is the thing that a plant generally requires. "Tallness" technique is utilized and to process yield of FLC and to control yield FLC yield is utilized. Later on the switch in the inverter is controlled by yield of FLC. To maintain UPQC, the capacitor voltage , terminal voltage of the line , reactive power ,active power are required. With the help of reference values these parameters are sensed ,compared and controlled. To achieve this, the membership functions of FC are: error, change in error and output The set of FC rules are derived from

$$u=-[\alpha E + (1-\alpha)*C]$$

The Power transfer capability of the given study system is evaluated by the proposed method based on the following criteria. A three phase fault is applied at the transformer with 400kV near the generator side at bus B1.The oscillation observed in the PV power is essentially due to the oscillation in the PCC voltage that is significantly low and continues as long as the voltage oscillation occurs at the PCC. The rated decay of the amplitude of oscillation is expressed using the damping ratio . Maximum generator power output for the proposed system with and without STATCOM is obtained using the MATLAB/Simulink model. Total Harmonic Distortion (THD) is also obtained for the proposed system by conducting fault studies.

Table -3 :POWER FLOW AND VOLTAGE WITHOUT STATCOM

SIMULATION DESCRIPTION	GENERATOR BUS	PCC BUS	PCC BUS	PCC BUS	INFINITE BUS
	Pg(MW)	Vpcc	(pu)	Ppcc	(MW)
SOLAR DG WITH VOLTAGE AND DAMPING CONTROLLER	650	1.00	9.55	7.5	-623

Table -4 :POWER FLOW AND VOLTAGE WITH STATCOM

SIMULATION DESCRIPTION	GENERATOR BUS	PCC BUS	PCC BUS	PCC BUS	INFINITE BUS
	Pg(MW)	Vpcc	(pu)	Ppcc	(MW)
SOLAR DG WITH VOLTAGE AND DAMPING CONTROLLER	719	1.00	9.56	7.12	-657

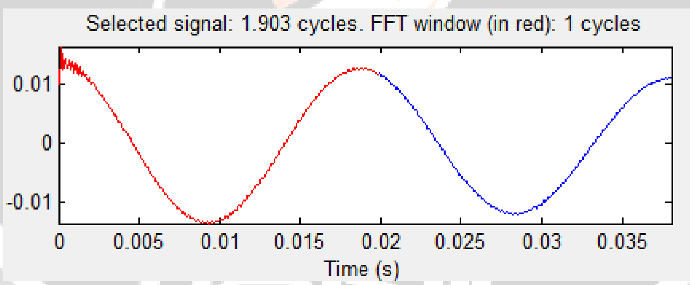

Fig – 4.2 Signal Analysis without STATCOM

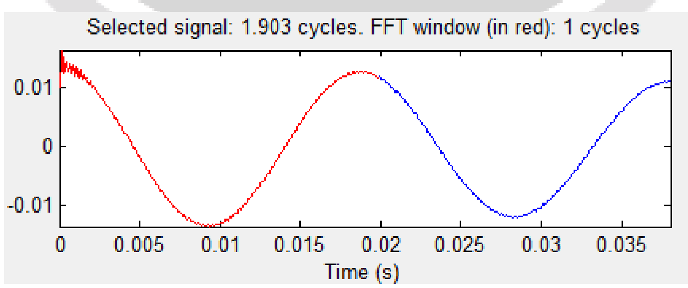

Fig – 4.3 Signal Analysis with STATCOM

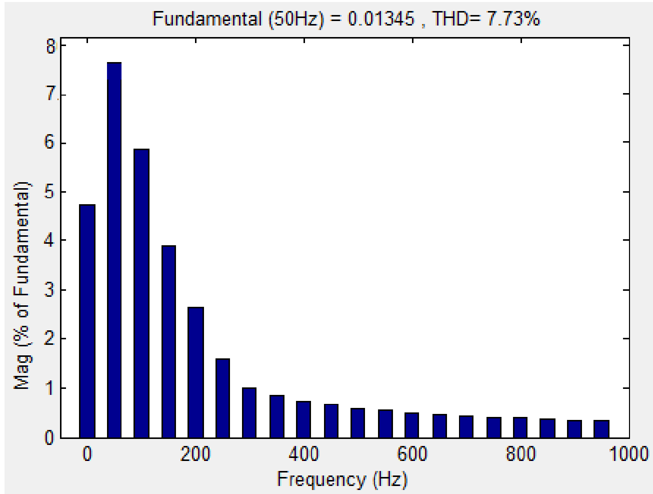

Fig – 4.4 FFT Analysis with THD 7.73%

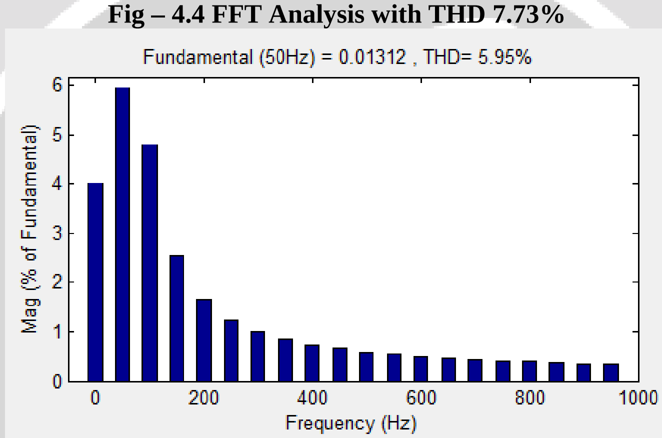

Fig – 4.5 FFT Analysis with THD 5.95 %

The different study results are given in Table 3 and Table 4. From Table 3,it is watched that the most extreme power transfer from the generator Pg is 650MW for solar DG with voltage and damping controller when STATCOM device is not coupled to the grid connected solar power system. The real power obtained from the generator Pg is shown in Fig.4.4 . From Table 3, it is watched that the maximum power transfer from the generator Pg is 719 MW for solar DG with voltage and damping controller when STATCOM device is coupled to the system. The real power obtained from the generator Pg is shown in Fig.4.5. However, it is noticed from Table 3 and Table 4 that maximum power transfer without connecting STATCOM device is less than the maximum power transfer with STATCOM device. The grid power transmission limit enhancement depends on the selection of reference values for the voltage at the purpose of normal coupling Vpcc

Thus the Table 3 and 4 indicates

That, the maximum power obtained from the generator Pg increases from 650 MW to 719 MW with the PCC voltage Vpcc at 1.00 pu.

(a). Maximum power output of the generator (650 MW) Pg without STATCOM

(b). Maximum power output of the generator (719MW) Pg with STATCOM

TABLE I . PERFORMANCE DETAILS WITH LINEAR LOAD

Controller	V_t in volts	Steady state error in volts		Deviation in volts	Overshoot In volts	Under shoot In volts
		Before load change	*After load change*			
PI	320	3.74	2.35	1.39	0.28	0.25
FLC	320	0	0	0	0	0.13

TABLE II . PERFORMANCE DETAILS WITH NONLINEAR LOAD

Controller	Steady state error in volts		Deviation in volts	Overshoot In volts	Under shoot In volts
	Before load change	*After load change*			
PI	1.8	2	0.2	0.12	0.1
FLC	0.1	0.4	0.3	0.15	0.05

TABLE III. PERFORMANCE DETAILS WITH DYNAMIC LOAD

Controller	During starting				After loading		
	Steady state error	*overshoot*	*Undershoot*	*Settling time*	*Steady state error*	*overshoot*	*Undershoot*
PI	3.5	3.19	10.62	1.1	2.4	0.26	0.17
FLC	0	0.26	5.9	0.13	0	0.15	0.23

4. CONCLUSIONS

A model of photovoltaic sun based ranch as a STATCOM devise is displayed in this paper where it can operate with voltage and damping controller to increase the power transmission capability of the transmission network. System stability studies have been analyzed on a grid connected power transmission network with PV solar farm placed at the middle of the transmission line using the MATLAB/Simulink model. Harmonic analysis is carried out by calculating the value of Total Harmonic Distortion (THD) for the proposed framework with and without connecting STATCOM device and the conclusions are made as follows:

1.10MW solar panel which is utilized with the proposed control strategies without connecting a STATCOM device can produce the power transfer capacity of 650 MW and the Total Harmonic Distortion (THD) is obtained to be 7.74%.

2.10MW solar panel which is utilized with the proposed control strategies while connecting a STATCOM device can increase the power transfer capacity to 719 MW and the Total Harmonic Distortion (THD) is reduced to be 5.95%.

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BIOGRAPHIES

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