ISSN (Online) 2394-2320

International Journal of Engineering Research in Computer Science and Engineering (IJERCSE)

Vol 4, Issue 12, December 2017

Compensation of Reactive Power With Fuzzy Based Control of PV Solar Farm as Pv-Statcom during Day and Night

[1] G. Poorna, [2] T. Vinay Kumar

[1][2] Assistant Professor, EEE Department, Bhoj Reddy Engineering College for Women

Abstract;- **In this paper, we are implementing a concept of the photovoltaic (PV) solar farm inverter as STATCOM, called PV-STATCOM using fuzzy controller is proposed in this paper, for improving stable power transfer limits of the interconnected transmission system. During daytime, the inverter capacity left after real power production is used. During night time it utilizes the entire solar farm inverter capacity. And during various operating conditions system has different real and reactive power flow which is required to be controlled to enhance the system power transfer capability, transient stability and reduce the losses in the system. For this purpose, the recent trend is the use of FACTS control devices. Here we are using the fuzzy controller when compared to other controllers for the better performance. Therefore, the fuzzy controller is the most suitable for the human decision-making mechanism, providing the operation of an electronic system with decisions of experts. The main aim of the LCL filter is to reduce high-order harmonics on the output side; however poor design may cause a distortion increase. Power transfer increases are also demonstrated in the same power system for: 1) two solar farms operating as PV-STATCOMs and 2) a solar farm as PV-STATCOM and an inverter-based wind farm with similar STATCOM controls. By using the fuzzy controller for a nonlinear system allows for a reduction of uncertain effects in the system control and improves the efficiency. By using the simulation results we can analyze the proposed method.**

Index Terms— Damping control, flexible ac transmission systems (FACTS), inverter, photovoltaic solar power systems, Fuzzy logic controller, reactive power control, STATCOM, transmission capacity, voltage control, wind power system.

I. INTRODUCTION

The main energy sources of renewable energy are solar, wind, rain, tides, waves and geothermal heat. These renewable energy sources are providing backup in electricity generation and rural (off-grid) energy services. Though these renewable energy sources are not much cost effective in comparison to traditional conventional energy sources. FLEXIBLE AC transmission system controllers are being increasingly considered to increase the available 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.

Solar Photovoltaic is a system which uses solar panels for converting solar energy to electrical energy. Photovoltaic effect is a phenomenon in which electrons are excited into a higher state of energy by photons of light due to which these electrons act as a charge carrier for the flow of current. New voltage control has also been proposed on a PV solar farm to act as a STATCOM for improving the power transmission capacity. This paper proposes novel voltage control, together with auxiliary damping control, for a grid-connected PV solar farm inverter to act as a STATCOM both during night and day for increasing transient stability and consequently the power transmission limit.

This paper describes about a technology which utilizes PV solar farm as a STATCOM during night time. This technology of utilizing a PV solar farm as a STATCOM is called “PV-STATCOM.” It utilizes the entire solar farm inverter capacity in the night and the remainder inverter capacity after real power generation during the day, both of which remain unused in conventional solar farm operation. Similar STATCOM control functionality can also be implemented in inverter-based wind turbine generators during no-wind or partial wind scenarios for improving the transient stability of the system.

In this paper a simple open-loop control method has been presented such that PV solar plant could be used as STATCOM, in dark periods without sunlight, to control the voltage or for load reactive power compensation and voltage control. This work improves the power factor, which enhances the efficiency of the

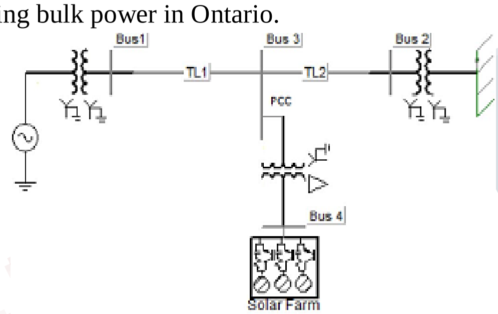
ISSN (Online) 2394-2320

International Journal of Engineering Research in Computer Science and Engineering (IJERCSE)
Vol 4, Issue 12, December 2017

line and reduces the losses of the line due to reduction in load current. This paper also presents the comparative simulation study of STATCOM with PI controller and fuzzy controllers and hence shows that performance of STATCOM is better with fuzzy controller in comparison with PI controller. The improvement in the stable power transmission limit is investigated for different combinations of STATCOM controllers on the solar and wind farm inverters, both during night and day.

SYSTEM MODELS

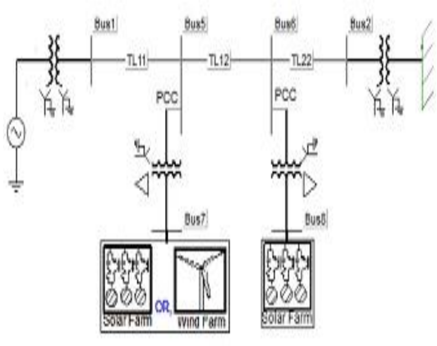
The single-line diagrams of two study systems: Study System 1 and Study System 2 are depicted in Fig. 1(a) and (b), respectively. Both systems are single-machine infinite bus (SMIB) systems where a large equivalent synchronous generator (1110 MVA) supplies power to the infinite bus over a 200-km, 400-kV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



(a)

Fig. 1. Single-line diagram of (a) study system I with a single solar farm (DG)

In Study System 1, a 100-MW PV solar farm (DG) as STATCOM (PV-STATCOM) is connected at the midpoint of the transmission line.



(b)

Fig. 1. Single-line diagram 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 at 1/3 (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. In this case, the wind farm employs permanent-magnet synchronous generator (PMSG)-based wind turbine generators with a full ac-dc-ac converter. It is understood that the solar DG and wind DG employ several inverters. However, for this analysis, each DG is considered to have a single equivalent inverter with the rating equal to the total rating of solar DG or wind DG, respectively.

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 PV 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.

To avoid this resonance from contaminating the system, several damping techniques have been proposed. One way is to incorporate a physical passive element, such as, a resistor in series with the filter capacitor.

LCL filter is usually placed between the inverter and the grid to attenuate the switching frequency harmonics produced by the grid-connected inverter. Compared with L filter, LCL filter has better attenuation capacity of high-order harmonics and better dynamic characteristics.

ISSN (Online) 2394-2320

International Journal of Engineering Research in Computer Science and Engineering (IJERCSE)
Vol 4, Issue 12, December 2017

LCL filter has good current ripple attenuation even with small inductance values. However it can bring also resonances and unstable states into the system. Therefore, the filter must be designed precisely according to the parameters of the specific converter.

The MPPT algorithm [12] is used to operate the solar DGs at its maximum power point all of the time and is integrated with the inverter controller. The wind DG is also assumed to operate at its maximum power point, since this proposed control utilizes only the inverter capacity left after the maximum power point operation of the solar DG and wind DG. For PV-STATCOM operation during nighttime, the solar panels are disconnected from the inverter and a small amount of real power is drawn from the grid to charge the dc capacitor.

Each phase has a pair of IGBT devices which converts the dc voltage into a series of variable-width pulsating voltages, using the sinusoidal pulse width modulation (SPWM) technique. An L-C-L filter is also connected at the inverter ac side.

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. Fig. 2 presents the block diagrams of various subsystems of two equivalent DGs.
The switching signals for the inverter switching are generated through two current control loops in - -0 coordinate system. The inverter operates in a conventional controller mode only provided that "Switch-2" is in the "OFF" position.

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 "Q" control channel is replaced by the PCC voltage controller in Fig.3.

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 are 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.

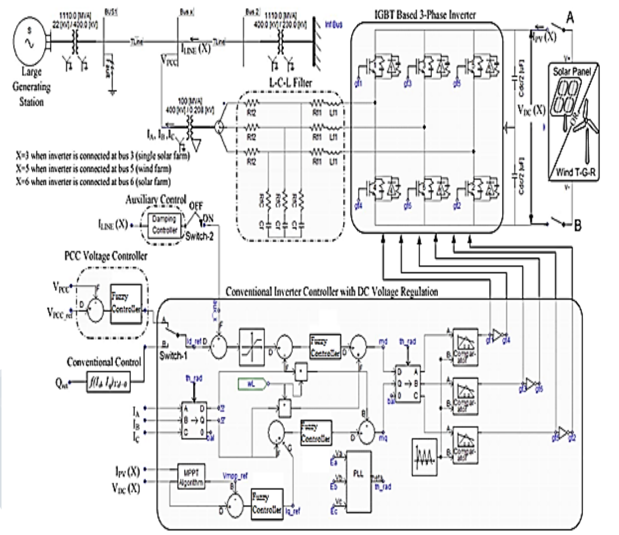


Fig. 3. Complete DG (solar/wind) system model with a damping controller and PCC voltage-control system.

The transfer function of this damping controller is expressed as in

$$F_D = G.\frac{sT_W}{1+sT_W}.\left(\frac{1+sT_1}{1+sT_2}\right) \quad (1)$$

The transfer function is comprised of a gain, a washout stage, and a first-order lead-lag compensator block. This controller is utilized to damp the rotor-mode oscillations of the synchronous generator and thereby improve system transient stability. The damping controller is activated by toggling "Switch-2" to the "ON" position.

This damping controller can operate in conjunction with either the conventional reactive power control mode or with the PCC voltage-control mode by toggling "Switch-1" to position "B" or "A,".

III. FUZZY LOGIC CONTROLLER

In FLC, basic control action is determined by a set of linguistic rules. These rules are determined by the system. Since the numerical variables are converted into linguistic variables, mathematical modeling of the system is not required in FC.

IFERP connecting engineers... developing research

ISSN (Online) 2394-2320

International Journal of Engineering Research in Computer Science and Engineering (IJERCSE)

Vol 4, Issue 12, December 2017

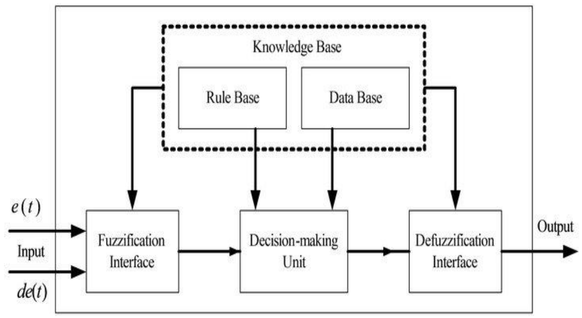


Fig.4.Fuzzy logic controller

The FLC comprises of three parts: fuzzification, interference engine and defuzzification. The FC is characterized as i. seven fuzzy sets for each input and output. ii. Triangular membership functions for simplicity. iii. Fuzzification using continuous universe of discourse. iv. Implication using Mamdani's, 'min' operator. v. Defuzzification using the height method.

TABLE I: Fuzzy Rules

Change in error	Error						
	NB	NM	NS	Z	PS	PM	PB
NB	PB	PB	PB	PM	PM	PS	Z
NM	PB	PB	PM	PM	PS	Z	Z
NS	PB	PM	PS	PS	Z	NM	NB
Z	PB	PM	PS	Z	NS	NM	NB
PS	PM	PS	Z	NS	NM	NB	NB
PM	PS	Z	NS	NM	NM	NB	NB
PB	Z	NS	NM	NM	NB	NB	NB

Fuzzification: Membership function values are assigned to the linguistic variables, using seven fuzzy subsets: NB (Negative Big), NM (Negative Medium), NS (Negative Small), ZE (Zero), PS (Positive Small), PM (Positive Medium), and PB (Positive Big). The Partition of fuzzy subsets and the shape of membership CE(k) E(k) function adapt the shape up to appropriate system. The value of input error and change in error are normalized by an input scaling factor. In this system the input scaling factor has been designed such that input values are between -1 and +1. The triangular shape of the membership function of this arrangement presumes that for any particular E(k) input there is only one dominant fuzzy subset. The input error for the FLC is given as

$$E(k) = \frac{P_{ph(k)} - P_{ph(k-1)}}{V_{ph(k)} - V_{ph(k-1)}} \quad (2)$$

$$CE(k) = E(k) - E(k-1) \quad (3)$$

Inference Method: Several composition methods such as Max–Min and Max-Dot have been proposed in the literature. In this paper Min method is used. The output membership function of each rule is given by the minimum operator and maximum operator. Table 1 shows rule base of the FLC.

Defuzzification: As a plant usually requires a non-fuzzy value of control, a defuzzification stage is needed. To compute the output of the FLC, „height" method is used and the FLC output modifies the control output. Further, the output of FLC controls the switch in the inverter. In UPQC, the active power, reactive power, terminal voltage of the line and capacitor voltage are required to be maintained. In order to control these parameters, they are sensed and compared with the reference values. To achieve this, the membership functions of FC are: error, change in error and output

The set of FC rules are derived from

$$u = -[\alpha E + (1-\alpha)*C] \quad (4)$$

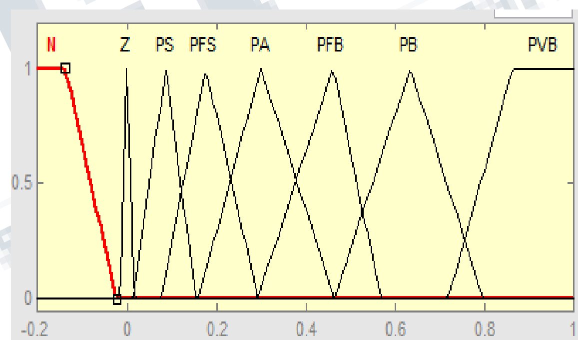


Fig 5 input error as membership functions

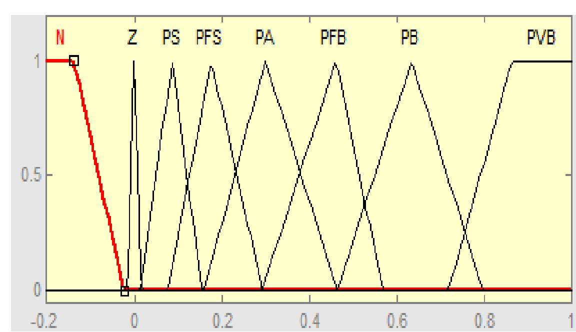


Fig 6 change as error membership functions

ISSN (Online) 2394-2320

International Journal of Engineering Research in Computer Science and Engineering (IJERCSE)
Vol 4, Issue 12, December 2017

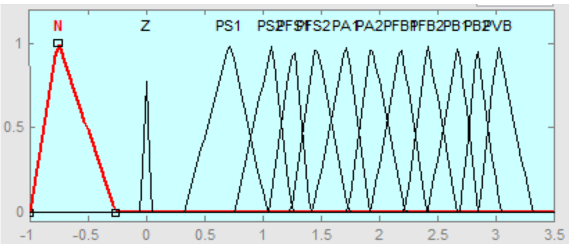


Fig.7 output variable Membership functions

Where α is self-adjustable factor which can regulate the whole operation. E is the error of the system, C is the change in error and u is the control variable.

SYSTEM STUDIES

Transient stability studies are carried out using simulation, for both the study systems during night and day, by applying a three-line-to-ground (3LG) fault at bus 1 for five cycles. The damping ratio is used to express the rate of decay of the amplitude of oscillation [20]. For an oscillatory mode, the damping ratio is defined as

$$\xi = -\frac{\sigma}{\sqrt{\sigma^2+\omega^2}} \text{, and } \sigma = \frac{1}{\tau} \qquad (5)$$

Where, τ is the time constant.

Therefore, for a 5% damping ratio of the rotor mode having an oscillation frequency of 0.95 Hz, as considered in this study, the post fault clearance settling time of the oscillations to come within 5%.

A. Case Study 1: Power Transfer Limits in Study System 1

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. 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 II 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.

TABLE II
POWER FLOWS AND VOLTAGES FOR STUDY SYSTEM I FOR SOLAR DG WITH CONVENTIONAL REACTIVE POWER CONTROL AND PROPOSED DAMPING CONTROL BOTH DURING NIGHTTIME AND DAYTIME (1.05 p.u.)

Simulation Description		Gen.Bus	PCC/Middle Bus (3)			Inf.Bus
		Pg (MW)	Vpcc (pu)	Psolar (MW)	Qsolar (MVAr)	Pinf (MW)
Nightime	Conventional Operation of Solar DG	731	1.010	0	0	-708
	Solar DG with Damping Controller	890	1.000	-0.20	0.08	-819
Daytime	Conventional Operation of Solar DG	723	1.010	19	-0.50	-720
		719	1.008	91	-0.20	-786
	Solar DG with Damping Controller	823	1.000	19	-0.06	-821
		861	0.994	91	-0.20	-821

Solar DG Operation During Night with Conventional Reactive Power Controllers:

The maximum stable power output from the generator is 731 MW when the solar DG is simply sitting idle during night and is disconnected from the network. This power-flow level is chosen to be the base value against which the improvements in power flow with different proposed controllers are compared and illustrated later in Table III.

TABLE III
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

ISSN (Online) 2394-2320

International Journal of Engineering Research in Computer Science and Engineering (IJERCSE)
Vol 4, Issue 12, December 2017

The real power from generator and that entering the infinite bus for this fault study are shown in Fig. 8(a).

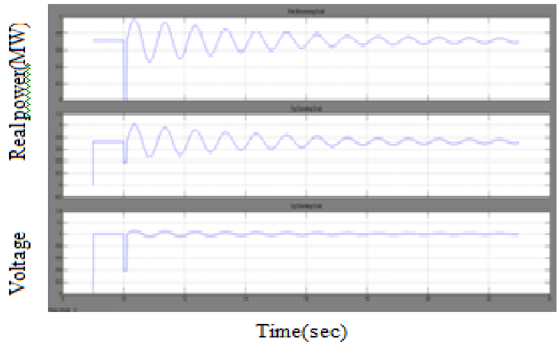
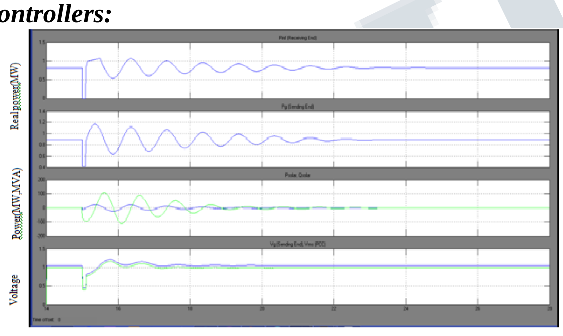


Fig. 8. (a) Maximum nighttime power transfer (731 MW) from the generator when solar DG remains idle

(b) Voltage at the generator terminal.

The sending-end voltage at the generator is shown in Fig. 8(b) which shows a voltage overshoot of 1.1 p.u.

Solar DG Operation During the Night With Damping Controllers:



(a)

Fig. 9. (a) Maximum nighttime power transfer (850 MW) from the generator with solar DG using the damping controller. (b) Voltages at the generator terminal and DG PCC.

The damping controller utilizes the full rating of the DG inverter at night to provide controlled reactive power and effectively damps the generator rotor-mode oscillations. The voltages at generator bus and at the PCC bus are depicted in Fig. 9(b).

The oscillations in the solar PV power output during nighttime, as seen in Fig. 9, are due to the active power exchanged by the solar inverter both during the charge and discharge cycles in trying to maintain a constant voltage across the dc-link capacitor, thereby enabling the inverter to operate as a STATCOM.

Solar DG Operation During the Day with a Conventional Reactive Power Controller: The conventional control of a PV solar DG does not seem to alter the stable transmission limit in any appreciable manner.

Solar DG Operation During the Day With a Damping Controller: The quantities Pg,, Pinf, Psolar and Qsolar are shown for the cases without the damping controller and with the damping controller in Figs. 10 and 11, respectively.

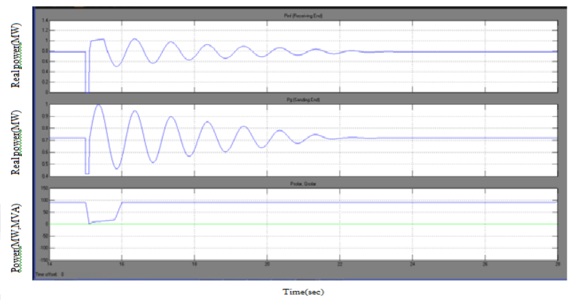


Fig. 10. Maximum daytime power transfer (719 MW) from the generator with solar DG generating 91-MW real power.

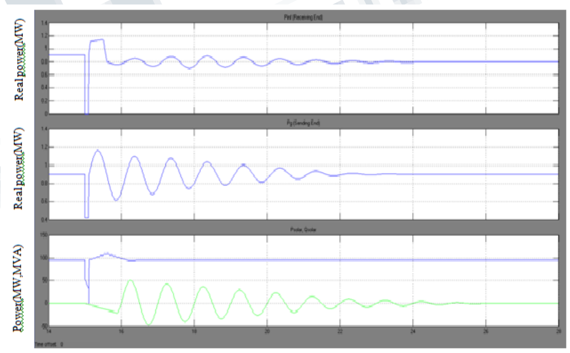


Fig. 11. Maximum daytime power transfer (861 MW) from the generator with solar DG generating 91-MW real power and using the damping controller.

The power transfer capacity increase in the daytime is expected to be lower than the nighttime, since only a part of the total inverter capacity is available for damping control during the day. However, it is noticed from Table II that the maximum power transfer during night time (850 MW) is actually less than the maximum power transfer value during the daytime (861 MW).

2) PCC Voltage Control with the Novel Damping Control:

IFERP
connecting engineers... developing research

ISSN (Online) 2394-2320

International Journal of Engineering Research in Computer Science and Engineering (IJERCSE)
Vol 4, Issue 12, December 2017

Transient stability results for a new control strategy involving PCC voltage control, together with damping control, are shown in Table IV for the following four cases.

TABLE IV
POWER FLOWS AND VOLTAGES FOR STUDY SYSTEM I FOR SOLAR DG WITH THE PROPOSED PCC VOLTAGE CONTROL AND DAMPING CONTROL DURING NIGHTTIME AND DAYTIME (1.05 p.u.)

Simulation Description		Gen. Bus	PCC/Middle Bus (3)			Inf. Bus
		Pg (MW)	Vpcc (pu)	Psolar (MW)	Qsolar (MVAr)	Pinf (MW)
Nighttime	Solar DG with voltage controller	789	0.988	-1.5	-95.8	-761
		824	0.990	-0.8	-66.0	-793
		830	1.000	-0.3	-9.5	-801
		833	1.010	-0.5	46.8	-803
		803	1.022	-1.5	99.0	-775
	Solar DG with both voltage and damping controller	855	1.000	-0.3	4.0	-824
		899	1.010	-1.2	85.0	-866
Daytime	Solar DG with voltage controller	781	0.990	19.0	-90.0	-773
		815	1.000	19.0	-13.7	-804
		782	1.021	19.0	86.0	-775
		726	0.99	91.0	-43.0	-792
		719	1.000	91.0	-44.0	-786
	Solar DG with both voltage and damping controller	823	1.000	19.0	-9.0	-813
		755	1.000	91.0	-41.0	-817

Solar DG Operation During the Night with a Voltage Controller:

The increase in the power transfer limit depends upon the choice of reference values for PCC voltage. In the best scenario when is regulated to 1.01 p.u., the maximum power output from the generator increases to 833 MW, compared to 731 MW when the solar DG operates with conventional reactive power control.

Solar DG Operation During the Day with the Voltage Controller:

The power transfer increases for both low (19 MW) and high (91 MW) power output from the solar farm are seen to be highly sensitive to the PCC bus voltage set point. It is also noted that with lower availability of reactive power capacity after real power production, the ability to change the bus voltage is limited, which leads to a lower increase in power transmission capacity.

Solar DG Operation During the Night with Both Voltage and Damping Controllers:

The generator and infinite bus power are depicted in Fig. 12(a), and corresponding voltages are shown in Fig. 12(b).

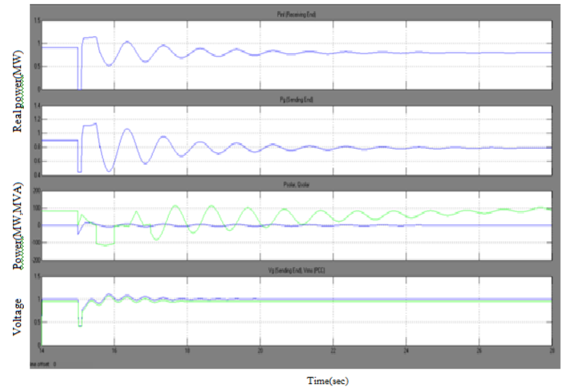


Fig. 12. (a) Maximum nighttime power transfer (899 MW) from the generator while the solar DG uses a damping controller with voltage control and (b) voltages at the generator terminal and solar DG PCC (1.01 p.u.).

Although, the rotor-mode oscillations settle faster, the power transfer cannot be improved beyond 899 MW due to high overshoot in voltages.

Solar DG Operation During the Day With voltage and Damping Controllers:

A further increase in power transfer is observed when both voltage control and damping control are employed, compared to case 2) when only the voltage controller is utilized. For Study System 1, the net increase in power transfer capability as achieved with different PV-STATCOM controls in comparison with that obtained from conventional reactive power control of the solar DG, is summarized in Table III. The maximum increase in the power transfer limit during nighttime is achieved with a combination of voltage control and damping control, whereas the same during daytime is accomplished with damping control alone.

This is because at night, the entire megavolt-ampere rating of the solar DG inverter is available for reactive power exchange, which can be utilized for achieving the appropriate voltage profile at PCC conducive for increasing the power transfer, as well as for increasing the damping of oscillations. During daytime, first, the generation of real power from the solar DG tends to increase the voltage at PCC [5] and second, the net reactive power availability also gets reduced especially with large solar real power outputs. Therefore, it becomes difficult with limited reactive power to accomplish the appropriate voltage profile at PCC for maximum power transfer and to impart adequate damping to the oscillations.

ISSN (Online) 2394-2320

International Journal of Engineering Research in Computer Science and Engineering (IJERCSE)
Vol 4, Issue 12, December 2017

TABLE V
POWER FLOWS AND VOLTAGES FOR STUDY SYSTEM II FOR BOTH SOLAR DG AND WIND DG WITH CONVENTIONAL REACTIVE POWER CONTROL AND PROPOSED DAMPING CONTROL BOTH DURING NIGHTTIME AND DAYTIME (1.05 p.u.)

Control system		Gen. Bus	Wind DG at Bus (5)		Solar DG at Bus (6)		Inf. Bus
		Pg (MW)	Vwnd (pu)	Pwnd (MW)	Vsol (pu)	Psol (MW)	Pinf (MW)
Nighttime (Psolar = 0)	Conventional Control	**Case 1-** None of the DGs generate real power					
		731	1.019	0	1.004	**0**	**-708**
		Case 2- Only wind DG generates real power but both DGs operate with conventional reactive power control					
		716	1.017	**95**	1.01	0	**-785**
		729	1.018	**20**	1.003	0	**-726**
	with damping controller.	**Case 3-** None of the DGs generate real power but both DGs operate with damping control					
		960	0.998	-0.7	0.982	-0.2	**-918**
		Case 4- Only wind DG generates real power but both DGs operate on damping control					
		936	0.995	**95**	0.976	-0.3	**-987**
		948	0.998	**20**	0.981	-0.7	**-927**
Daytime (Psolar ≠ 0)	Conventional Control	**Case 5-** Both DGs generate real power					
		700	1.016	**95**	1.000	**95**	**-865**
		726	1.019	**20**	1.004	**20**	**-743**
		Case 6- Only solar DG generates power					
		719	1.017	0	1.002	**95**	**-790**
		730	1.018	0	1.003	**20**	**-727**
	with damping controller.	**Case 7-** Both DGs generate real power with damping control.					
		930	0.99	**95**	0.972	**95**	**-1073**
		923	1.0	**20**	0.983	**20**	**-924**
		Case 8 - Only solar DG generates real power but both DGs operate on damping control.					
		938	0.998	-0.5	0.98	**95**	**-991**
		944	0.999	-0.3	0.982	**20**	**-925**

B. Case Study 2: Power Transfer Limits in Study System II

In this study, the proposed damping control strategy is compared with the conventional reactive power control strategy for Study System II shown in Fig. 1(b). A three-phase-to-ground fault of 5 cycles is applied to the generator bus at 8 s. The following eight cases are studied:

1) Night time:

Case1 – None of the DGs Generate Real Power: The maximum power transfer limit is 731 MW as in Table I.

Case2– Only Wind DG Generates Real Power. Both DGs Operate with Conventional Reactive Power Control:

The power transfer limit decreases slightly with increasing wind power output.

Case3 – None of the DGs Generate Real Power but Both DGs Operate With Damping Control: The different variables, generator power, infinite bus power, real power of wind DG, reactive power of the wind DG, real power of the solar DG, and the reactive power of the solar DG are illustrated in Fig. 13.

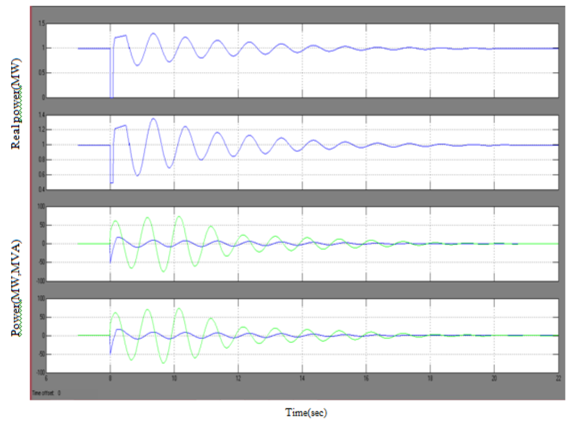


Fig. 13. Maximum nighttime power transfer from the generator with both DGs using the damping controller but with no real power generation.

Even though the entire ratings (100 MVar) of the wind DG and solar DG inverters are not completely utilized for damping control, the power transfer limit increases significantly to 960 MW.

Case4 – Only Wind DG Generates Real Power but Both DGs Operate on Damping Control: There is only a marginal improvement in the power limit with decreasing power output from the wind DG.

2)Day time:

Case5 – Both DGs Generate Real Power: The power transfer limit from the generator decreases as the power output from both DGs increase.

Case6 – Only Solar DG Generates Power: The power transfer limit from the generator decreases as the power output from the solar DG increases. However, no substantial changes in power limits are observed compared to the case when both DGs generate power (Case 5).

Case7– Both DGs Generate Real Power and Operate on Damping Control: This case is illustrated by different variables , , , , , and in Fig. 9. The power limit does not change much with increasing power output from both DGs.

Case8 – Only Solar DG Generates Real Power but Both DGs Operate on Damping Control:

The power limit does not appear to change much with increasing power output from the solar DG. For Study System 2, the net increases in power transfer limits

IFERP
connecting engineers... developing research

ISSN (Online) 2394-2320

International Journal of Engineering Research in Computer Science and Engineering (IJERCSE)
Vol 4, Issue 12, December 2017

accomplished with the proposed novel damping control for different real power outputs from both DGs compared to those attained with the conventional operation of both DGs, are depicted in Table IV.

TABLE IV
INCREASE IN POWER TRANSFER LIMITS FOR STUDY SYSTEM II
WITH DIFFERENT DG POWER OUTPUTS

DG Real Power Outputs (MW)	Power Limit Increase (MW)
NIGHT	
Psolar = 0, Pwind = 0	230
Psolar = 0, Pwind = 20	216
Psolar = 0, Pwind = 95	219
DAY	
Psolar = 20, Pwind = 20	194
Psolar = 95, Pwind = 95	241
Psolar = 20, Pwind = 0	219
Psolar = 95, Pwind = 0	213

The proposed damping control on the two DGs (of rating 100 MW each) in the night increases the power transfer limits substantially by about 220 MW. The improvement is slightly less when wind DG produces high power. During daytime, the proposed damping control on both DGs also increases the power transfer limits substantially.

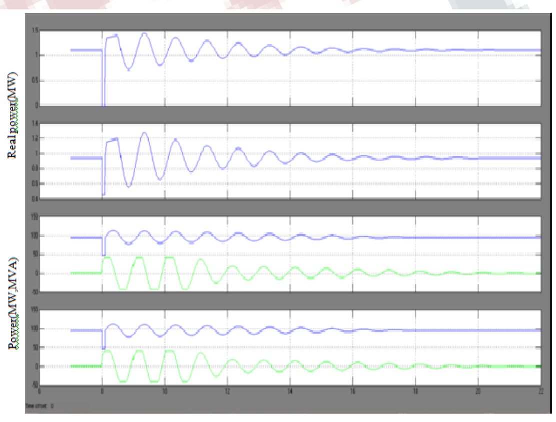


Fig. 14. Maximum daytime power transfer from the generator while both DGs generate 95 MW, each using a damping controller.

IMPLEMENTATION OF PV-STATCOM ON LARGE-SCALE SOLAR SYSTEMS

For the first time in a utility network of Ontario on a 10-kW PV solar system the PV-STATCOM technology will be showcased. The 10-kW solar system will be utilized for voltage regulation and power factor correction in addition to generating real power. The PV-STATCOM will be allowed to connect to the wires of the utility. These include: 1) PV-STATCOM controller testing with matlab simulation studies; 2) controller validation using real-time digital simulation (RTDS) [21]; and, finally, 3) a full-scale 10-kW lab-scale demonstration of the PV-STATCOM.

CONCLUSION

According to the Power system performances which depend upon the flow of real and reactive power and adequate control method which is required to control the flow of real and reactive power in the system. Therefore according to the paper we explain about the concept of utilizing a photovoltaic (PV) solar farm inverter as STATCOM, called PV-STATCOM using fuzzy controller which is proposed. Here we are using the fuzzy controller compared to other controllers. The fuzzy controller is the most suitable for the human decision-making mechanism, providing the operation of an electronic system with decisions of experts. 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. Therefore, the major concept of the LCL filter is to decreases high-order harmonics on the output side; however poor design may cause a distortion increase. There are various 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. By using the simulation result we can verify the proposed system.

REFERENCES

[1] R. M. Mathur and R. K. Varma, Thyristor-Based FACTS Controllers for Electrical Transmission Systems. Hoboken, NJ, USA: Wiley/IEEE, 2002.

[2] S. A. Rahman, R. K. Varma, and W. Litzenberger, "Bibliography of FACTS applications for grid integration of wind and PV solar power systems: 1995–2010, IEEE working group report," presented at the IEEE Power Energy Soc. Gen. Meeting, Detroit, MI, USA, Jul. 2011.

[3] Y. Xiao, Y. H. Song, C.-C. Liu, and Y. Z. Sun, "Available transfer capability enhancement using FACTS devices," IEEE Trans. Power Syst., vol. 18, no. 1, pp. 305–312, Feb. 2003.

[4] Cross Texas Transmission, Salt fork to gray project. 2014. [Online]. Available: http:// www. crosstexas.c om/ SFWind.htm

[5] R. K. Varma, V. Khadkikar, and R. Seethapathy, "Nighttime application of PV solar farm as STATCOM to regulate grid voltage," IEEE Trans. Energy Convers., vol. 24, no. 4, pp. 983–985, Dec. 2009.

[6] R. K. Varma and V. Khadkikar, "Utilization of solar farm inverter as STATCOM," U.S. Provisional Patent, Sep. 15, 2009.

[7] R. K. Varma, S. A. Rahman, and R. Seethapathy, "Novel control of grid connected photovoltaic (PV) solar farm for improving transient stability and transmission limits both during night and day," in Proc. World Energy Conf., Montreal, QC, Canada, 2010, pp. 1–6.

[8] R. A. Walling and K. Clark, "Grid support functions implemented in utility-scale PV systems," in Proc. IEEE Power Energy Soc, Transm. Distrib. Conf. Expo., 2010, pp. 1–5.

[9] F. L. Albuquerque, A. J. Moraes, G. C. Guimaraes, S. M. R. Sanhueza, and A. R. Vaz, "Photovoltaic solar system connected to the electric power grid operating as active power generator and reactive power compensator," Solar Energy, vol. 84, no. 7, pp. 1310–1317, Jul. 2010.

[10] A. Beekmann, J. Marques, E. Quitmann, and S. Wachtel, "Wind energy converters with FACTS Capabilities for optimized integration of wind power into trans. and dist. systems," in Proc. CIGRE, Calgary, AB, Canada, 2009.