Improving The Performance of PV- STATCOM for Power Oscillation Damping

*1Garikina Srinu , 2K Dhanaraju
M. Tech Scholar, Department of EEE, KIET-II, Kakinada A.P,India.[1]
Asso.Professor ,Department of EEE, KIET-II, Kakinada, A.P, India.[2]
Corresponding Author:- *garikinasrinu206@gmail.com

Abstract- This paper presents a clever control of PV nearby planet group as a FACTS gadget STATCOM, named PV-STATCOM, for power wavering damping (POD) in transmission frameworks. In the proposed control, when power motions because of a framework aggravation are identified, the sunlight based homestead ceases its genuine power age work momentarily (barely any many seconds) and makes its whole inverter limit accessible to work as a STATCOM for POD. When power motions are damped, the sun based homestead reestablishes genuine power yield to its pre-unsettling influence level in an inclined way, while keeping the damping capacity initiated. This outcomes in a lot quicker reclamation than that predefined in lattice codes. During evening time, the sun oriented homestead performs POD with its whole inverter limit. It is displayed from MATLAB recreations that the proposed control gives huge expansion in power move limit on an all day, every day premise in frameworks which show both neighborhood inertial and between region oscillatory modes. The proposed PV-STATCOM is around 50-100 times less expensive than a comparable STATCOM for giving POD at a similar area. This clever control might conceivably bring huge reserve funds for transmission utilities and open up another income creating open door for sun based homesteads for giving POD. Fluffy rationale control is utilized in this paper for the better guideline of pv-statcom. The outcomes dissected through MATLAB/SIMULINK climate.

Key words- - Photovoltaic sunlight based power frameworks, voltage control, responsive power control, power swaying damping, FACTS, STATCOM, power transmission, PV slope rate Fuzzy rationale regulator.

1. Introduction

Low recurrence electromechanical power motions (regularly 0.1 - 2 Hz) are perceived as one of the significant restricting elements in power move over long transmission lines [1]. Ordinarily, these motions are damped by Power System Stabilizers (PSS) coordinated with simultaneous generators [1]. Be that as it may, Flexible AC Transmission System (FACTS) gadgets have been successfully used in power frameworks for damping these power motions and accordingly improving the power move capacity in transmission lines [2-4]. Exhibitions of different FACTS gadgets furnished with power wavering damping (POD) regulators are depicted in writing, for example, Static Var Compensators (SVC) [5], Static Synchronous Compensators (STATCOM) [6,7], Thyristor Controlled Series Compensators (TCSC) [8], and Convertible Static Compensator (CSC) [9].

Huge scope PV sun oriented homesteads more than 100 MW are as a rule progressively associated around the world. These incorporate Kamuthi (648 MW), in Tamil Nadu, India [10], Rancho Cielo Solar Farm (600 MW), Solar Star I and II (579 MW), Topaz Solar Farm (550 MW), Agua Caliente Solar Project (295 MW) California Valley Solar Ranch Farm (250 MW) in USA, and Huanghe HydropowerGolmud Solar Park in China (200 MW) [11-13].

The capability of decrease in power framework dependability with critical measure of inactivity less power infusion from PV sun oriented plants in the network is depicted in [14-16]. Shrewd PV inverter controls like Constant (off-solidarity) Power Factor, Volt/Var, Volt/Watt, Frequency Watt, Low/High Voltage Ride Through, Low/High Frequency Ride Through, and so forth, have been proposed [17] and furthermore exhibited for an enormous scope PV sunlight based ranch [18]. A clever control of PV sun oriented homestead as STATCOM (PV-STATCOM) was introduced for upgrading the network of wind ranches in the night [19] and for expanding power move limit through damping of force motions both during night and day

[20]. This control strategy used the whole inverter limit in the evening time and the inverter limit staying after genuine power age during daytime for power wavering damping. An eighth-request POD regulator for huge PV sun powered ranch was proposed in [21], though an energy work based plan of POD regulator was introduced in [22]. Both these regulators are somewhat complicated in plan. All the POD controls in the above projects [19-22] depend on excess inverter limit during daytime. Henceforth, the proposed POD capacity of sun based ranch is restricted during day, without a doubt becoming zero during long stretches of full sun.

This undertaking proposes a clever PV-STATCOM control for POD, in view of a patent-forthcoming innovation [23]. In this proposed control, if any unsettling influence happens in the power framework causing unwanted power motions, the PV sunlight based ranch independently handicaps its genuine power producing capacity for a brief period (ordinarily not exactly a moment), and makes its whole inverter limit accessible for working as STATCOM to moist power motions through responsive power adjustment. When the power motions are decreased to an OK level, the sun based homestead reestablishes its power yield to its pre-unsettling influence level in an inclined way.

One more clever commitment of this venture is that the POD work is kept enacted during the increase of capacity to its pre-unsettling influence esteem using the inverter limit staying after genuine power age. This forestalls any repeat of force motions and furthermore permits a lot quicker increase than endorsed by matrix codes [24] where such a damping capacity during slope up isn't conceived. While [19] and [20] have both introduced the control of PV sun oriented homestead as STATCOM, [19] has managed voltage control just during evening (not daytime) on a dissemination feeder.

The damping of force motions in transmission frameworks isn't analyzed in any way. Power swaying damping control in a Single Machine Infinite Bus (SMIB) transmission framework is portrayed in [20]. This control has been shown during evening with full inverter limit yet during daytime with just incomplete inverter limit. This STATCOM control has the accompanying constraints: I) it is accessible just when there is remaining inverter limit free after genuine power age, and ii) its capacity decays with expanding genuine power yield from sun based homestead, turning out to be totally zero during long periods of full sun.

The viability of the proposed PV-STATCOM for POD is exhibited on a Single Machine Infinite Bus (SMIB) framework [25], Two-Area power framework [1], and the 12 transport FACTS power framework [30] through point by point electromagnetic transient's examinations utilizing MATLAB programming. The Simplex improvement strategy inserted in MATLAB [26] is used to plan the POD regulator. In [27-29], the little sign Residue Analysis strategy is introduced for deciding the best areas of force framework stabilizer (PSS) in power frameworks. A similar strategy is used in this task to research the adequacy of explicit PV-STATCOM areas for POD.

II.CONCEPT OF PV-STATCOM

Fig.2.1 shows the regular genuine power yield of a PV sun based ranch P during a radiant day and the leftover receptive power limit Q during a 24-hour time span for that day. The proposed brilliant inverter PV-STATCOM has two methods of activity delineated in Fig.2.1, which is portrayed beneath:

Halfway PV-STATCOM mode:

In this mode, the PV inverter limit staying after genuine power age is used for STATCOM method of activity. This mode is accessible during daytime.Full PV-STATCOM mode: In this mode, the whole PV sunlight based homestead inverter limit ismade accessible for STATCOM method of activity.

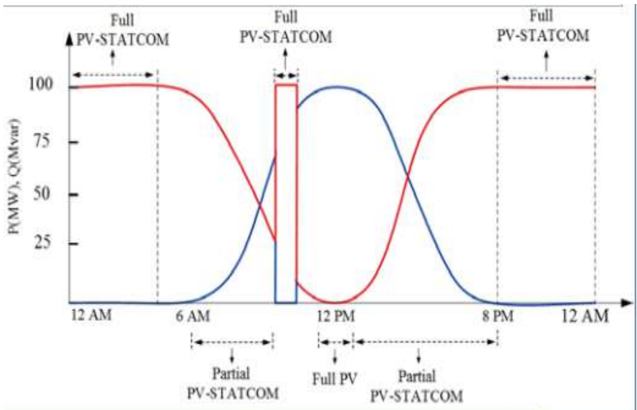


Fig. 2.1. PV Real and Reactive power during 24 hours on a sunny day

During daytime, as soon as any unacceptable low-frequency power oscillations due to any system disturbance are detected, the real power generation function is discontinued. The solar inverter is then transformed into a STATCOM with the entire inverter capacity made available for reactive power modulation. Depending upon the system need, reactive power up to the entire inverter capacity can be utilized for power oscillation damping. Once the low-frequency oscillations are damped, the real power generation function is reinstated. The solar farm then ramps up its real power output to the pre-disturbance level while continuing to perform POD in the Partial PV-STATCOM mode. During nighttime, the Full-STATCOM mode is available continuously for POD with reactive power modulation utilizing the entire inverter capacity. The solar farm has another operating mode termed Full PV mode, in which it generates real power based on available irradiance at unity power factor with no smart functions.

MODELING OF STUDY SYSTEMS:

Single Machine Infinite Bus (SMIB) System:

Fig. 5.2 illustrate the single line diagram of the large synchronous generator connected to an infinite bus through a 600 km line [25]. A 100 MW PV solar farm connected at the mid-point of the transmission line.

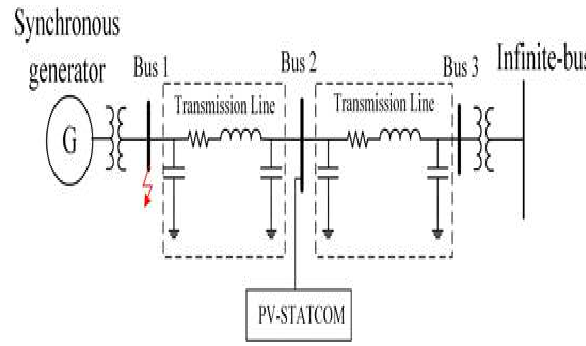


Fig. 2.2. Single-line diagram of an SMIB system with a 100 MW PV plant connected midline

Two-Area Four Machine System:

The Two-Area system having four generators connected with the 220 km tie-line [1] is depicted in Fig. 3. A 100 MW PV system is connected at the midpoint of the tie-line between buses 7 and 9. In both study systems, the synchronous generators are represented by their detailed sixth-order model and DC1-A-type exciter [1]. No Power System Stabilizer (PSS) are installed on generators. The parameters for SMIB system and the Two-Area system are provided in [1] and [25], respectively. The Two-Area system exhibits both local inertial mode and inter-area mode of oscillations in the power flow [1]

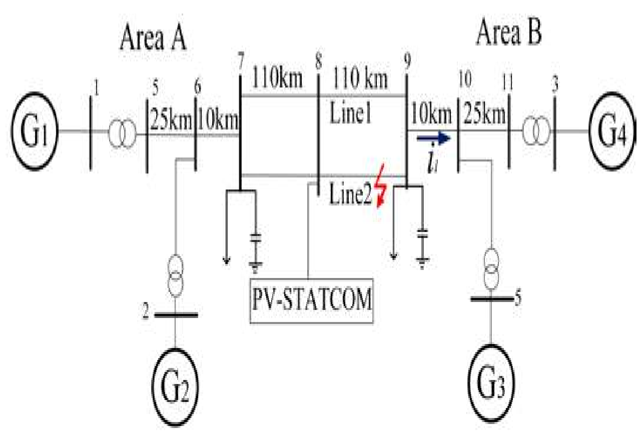


Fig. 2.3. Single-line diagram of Two-Area system with 100 MW PV plant connected midline.

12 Bus FACTS power system:

The 12 bus FACTS power system widely is used for studying the impact of FACTS controls [30, 31]. To demonstrate the effectiveness of the proposed controller, POD studies with PV-STATCOM are performed on the 12 bus FACTS power system having multiple oscillatory modes. In this study, no PSSs are considered on generators.

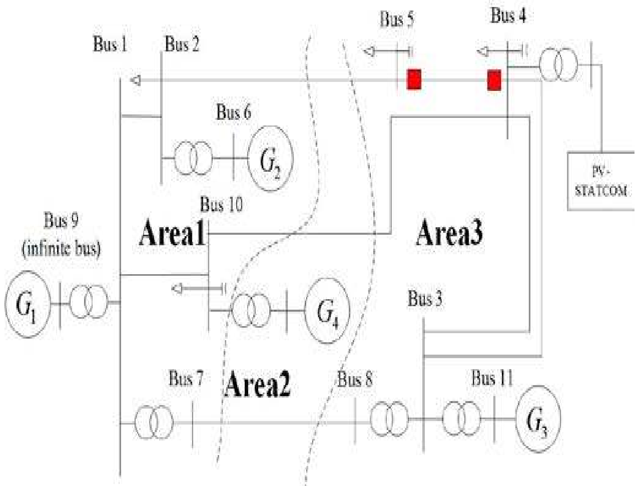


Fig. 2.4. 12 bus FACTS power system with 100 MW PV solar systems at bus 4

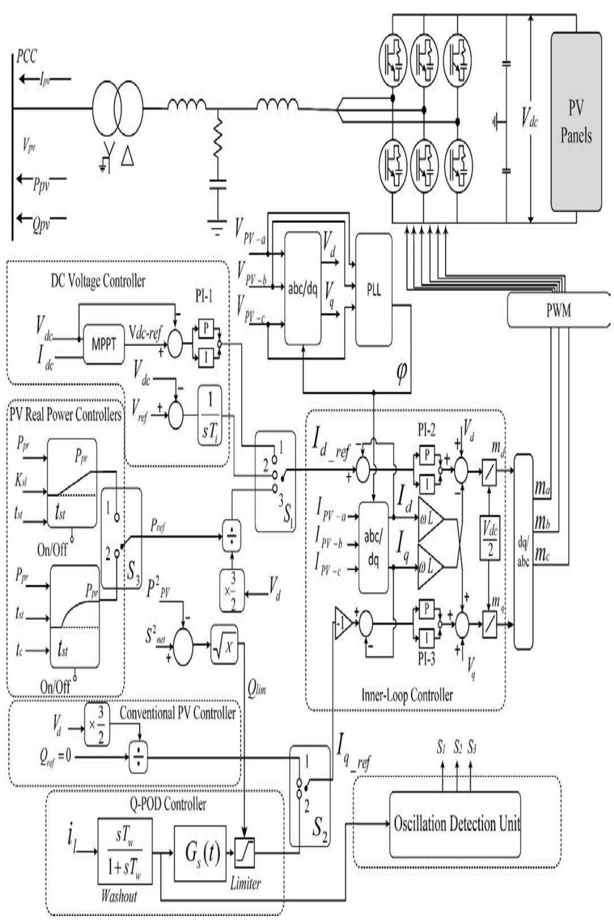


Fig. 2.5 PV-STATCOM controller

2.2 MODELING OF PV-STATCOM

Fig.2.5 depicts the various parts of the PV framework and the PV-STATCOM regulator, which are portrayed underneath. PV Panels and Inverter: The totaled PV boards are addressed by a comparable board model which creates PV dc current dependent on the V-I normal for the PV boards [32]. The collected sunlight based homestead inverter is viewed as of three-stage six-beat arrangement with a DC interface capacitor [33]. The PV inverter is associated with the matrix through a LCL channel planned dependent on [34]. The images Vpv, Qpv, Ppv, and Ipv address the voltage, inverter receptive power, inverter genuine power and inverter current at the PCC, individually.

Inward Loop Controller:

The inward circle regulator gives decoupled d-q pivot control of genuine and responsive power dependent on the d hub reference current Id_ref and q hub reference current Iq_ref, separately [33]. This regulator gives the balance records md and mq which are changed in the dq/abc square to the three stage tweak files mama, mb, and mc. These are utilized for creating inverter setting off beats utilizing Pulse Width Modulation (PWM) [31]. The ABC to dq change unit and Phase Locked Loop (PLL) unit are planned dependent on [33]. In Fig. 2.5 Vdc signifies the PV-STATCOM DC interface voltage while Vd, Id, Vq, Iq address the direct and quadrature voltages and flows of PV framework, individually.

DC Voltage Controller:

The DC voltage regulator has two parts: I) the Maximum Power Point Tracking (MPPT) block with a PI regulator, and ii) a DC voltage regulator [35]. During customary PV working mode, in light of the VI trait of the PV boards, the MPPT block uses Vdc and Idc to create the reference voltage Vdc-ref, which in the long run delivers Id_ref for the inward circle regulator. In STATCOM control mode, S1changes to situate 2 and the DC voltage Vdc is managed to PV board open circuit voltage to handicap genuine power infusion from the PV sunlight based chargers [36]. The open-circuit voltage is certifiably not a steady and relies upon the occurrence irradiance and temperature. For the explicitly used PV board in the sun based ranch, the biggest open circuit voltage acquired from different (maker provided) power-voltage attributes for various practically common temperatures and sunlight based irradiance [32] is picked as Vref for the DC interface voltage regulator module in Fig. 2.5

Ordinary PV regulator:

The customary PV regulator manages the inverter receptive power to such an extent that PV power yield is at solidarity power factor [33]. This regulator has been embraced from [33], [35], and [37] and is used uniquely during typical activity of the power framework in which solidarity power factor is needed for PV frameworks. In this control, Q is set to zero during consistent state activity bringing about Iq_ref = 0. It is explained that this regulator is deactivated during aggravations, for example during power motions. In the present circumstance, Iq_ref is created with the Q-POD regulator in a shut circle way.

III. Fluffy CONTROLLER:

The word Fuzzy means unclearness. Fluffiness happens when the limit of snippet of data isn't obvious. In 1965 Lotfi A. Zahed propounded the fluffy set hypothesis. Fluffy set hypothesis shows monstrous potential for successful addressing of the vulnerability in the issue. Fluffy set hypothesis is a superb numerical device to deal with the vulnerability emerging because of unclearness. Understanding human discourse and perceiving transcribed characters are some normal occasions where fluffiness shows.

Fluffy set hypothesis is an augmentation of old style set hypothesis where components have changing levels of participation. Fluffy rationale utilizes the entire span somewhere in the range of 0 and 1 to depict human thinking. In FLC the info factors are planned by sets of participation capacities and these are called as "Fluffy SETS".

Fluffy set contains from an enrollment work which could be characterizes by boundaries. The worth somewhere in the range of 0 and 1 uncovers a level of enrollment to the fluffy set. The most common way of changing the fresh contribution over to a fluffy worth is called as "fuzzificaton." The yield of the Fuzzier module is interfaced with the standards. The essential activity of FLC is built from fluffy control rules using the upsides of fluffy sets overall for the mistake and the difference in blunder and control activity.

The outcomes are consolidated to give a fresh yield controlling the yield variable and this cycle is called as
"DEFUZZIFICATION."

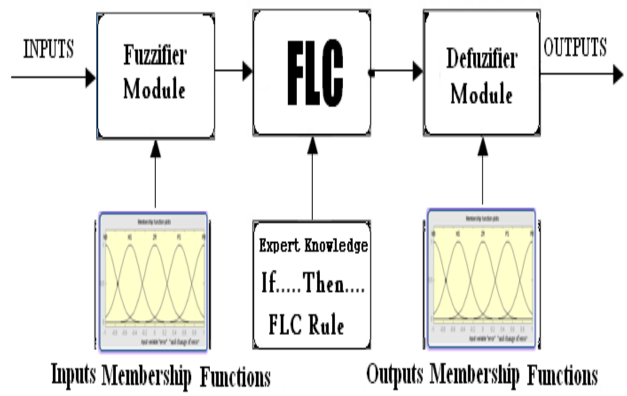


Fig 3.1: block diagram of fuzzy logic Controller

3.2 Fuzzy rules:

In the fuzzy control, input and output variables are the size of the form to describe in words, so to select special vocabulary to describe these variables, generally used in "big, medium and small" Three words to express the controller input and output variables state, plus the positive and negative directions, and zero, a total of seven words : { negative big, negative medium, negative small, zero, positive small, middle, CT } , the general terms used in the English abbreviation prefix : {NB , NM, NS , ZE, PS , PM, PB}.

IV.Simulink Model and Results

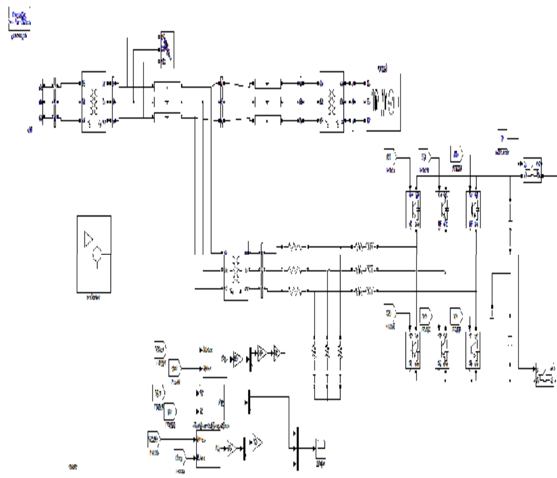


Fig4.1Simulink Block Diagram

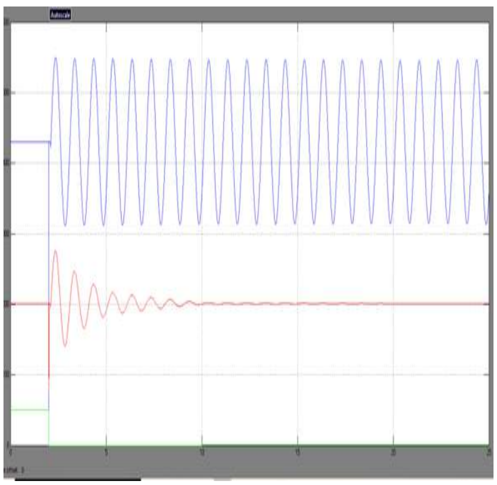


Fig. 4.2. Maximum power transfer capability of the SMIB system

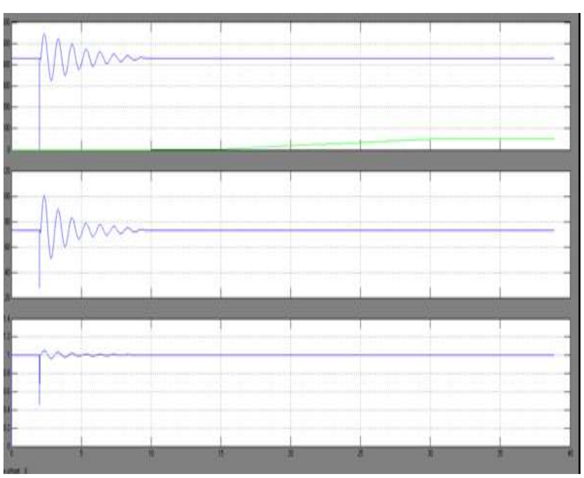
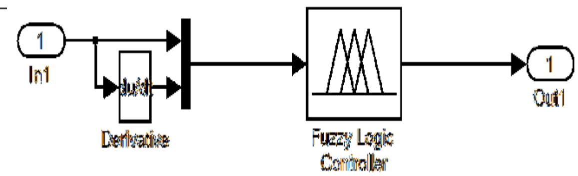


Fig. 4.3 (a) Midline and PV system real powers, (b) PV-STATCOM reactivepower, (c) Midline voltage during POD and normal ramped power restoration



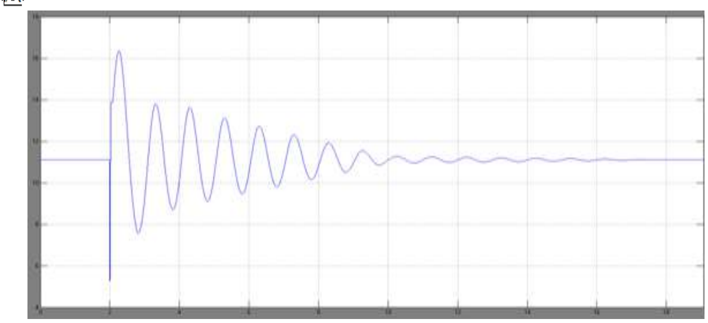


Fig. 4.3. Nighttime using fuzzy logic controller (a) Midline real power without POD with PV-STATCOM control, (b) Midline real power with Full PV-STATCOM POD Control, (c) PVSTATCOM reactive power

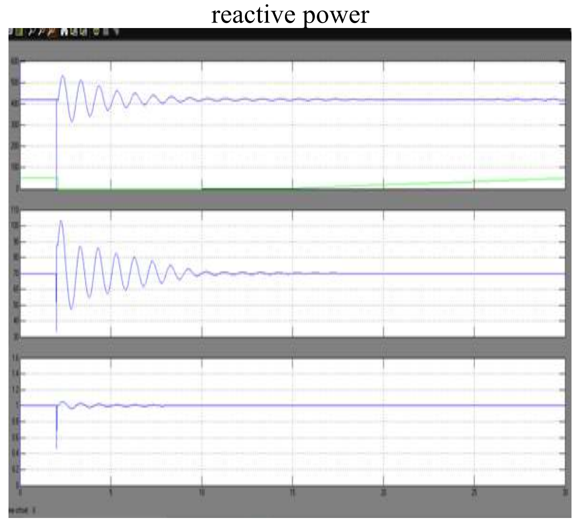


Fig. 4.5(a) Midline and PV real power, (b) PV reactive power, (c) Midlinevoltage during POD and power restoration in a fast ramped manner.

CONCLUSION

This project presents a novel smart control of transmission line connected large PV solar system as a STATCOM, termed PV-STATCOM, for damping power oscillations and thereby substantially increasing the power transfer capacity of the network. The proposed control provides POD through reactive power modulation utilizing the entire inverter capacity during nighttime. During daytime the solar farm discontinues its real power generation function very briefly (about 15 sec) and utilizes its entire inverter capacity for POD. It sub sequently restores power generation to its pre-disturbance level in a gradual manner while keeping the POD function activated utilizing the remaining inverter capacity. EMTDC/PSCAD simulation studies demonstrate the effectiveness of the proposed PV-STATCOM control in a single machine infinite bus (SMIB) system which exhibits local inertial oscillatory mode, two-area system which displays both local inertial and inter-area modes of oscillations, and the 12 bus FACTS power system which has multiple inter area modes of oscillations.

In SMIB system, a 100 MW midline connected PV solar system increases the power transfer capacity by 230 MW, whereas in the Two-Area system a 100 MW PV solar system increases the power transmission limit by 200 MW. Moreover, the proposed power restoration technique keeping POD activated is more than 3 times faster than that specified by grid codes (without POD function). This PV-STATCOM is expected to be about 50-100 times lower in cost than an equivalent STATCOM as it utilizes the existing infrastructure (substation, bus-work, transformers, circuit breakers, protection systems, etc.) of a PV solar farm to transform it into a full scale STATCOM of similar size. The PV-STATCOM as an alternate FACTS device is expected to bring significant savings for utilities seeking to increase their power transmission capacity. It also opens a new revenue making opportunity for transmission connected solar farms to provide 24/7 STATCOM functionality at substantially lower cost. Implementation of this technology of course requires appropriate agreements among utilities, system regulators, solar farm developers and inverter manufacturers. The objective of this project is to propose a novel control of a single PV solar farm as PV-STATCOM for power oscillation damping during day and night. If the PV-STATCOM control is implemented on multiple PV solar farms in electrical proximity, the PV-STATCOM controls will need to be coordinated in a similar manner as coordination of multiple FACTS devices, and HVDC and FACTS devices .The control Coordination among multiple PV-STATCOMs will ensure that all the participating PV-STATCOMs will simultaneously provide power oscillation damping and concurrently return to normal operation after the oscillations are damped out. Fuzzy logic control is used in this paper for the better regulation of pv-statcom.This control coordination requires detailed control design and system studies, which are outside the scope of the present project.

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