Based on PV's New Control Strategy A Fuzzy Logic Controller Is Used To Track Power Oscillation Damping.

Bandaru Nageswararao[1], Bojjagani Ramesh[2]
M.Tech Student, Department of EEE, KITS Engg.College, Divili, A.P, India.[1]
Asso. Professor & HOD, Department of EEE, KITS Engg College, Divili, A.P, India.[2]

Abstract- In order to dampen power oscillations (POD) in transmission networks, this paper provides a novel control of a PV solar system as a STATCOM, or PV-STATCOM. It is suggested that the solar farm temporarily (few tens of seconds) stop generating real power in response to power oscillations caused by system disturbances and instead use its complete inverter capacity as a STATCOM for POD. Power oscillations are dampened as soon as they occur, and the solar farm gradually returns to its pre-disturbance output level. Faster restoration is possible because of this method rather than the grid codes. During the night, the entire inverter capacity of the solar farm performs POD. MATLAB simulations indicate that the suggested control increases power transfer capacity significantly and continuously in systems that exhibit both local inertial and inter-area oscillatory modes. To provide POD at the same location, the proposed PV-STATCOM is 50-100 times less expensive than an analogous STATCOM. POD (power outage detection) is a new business prospect for solar farms that can save transmission companies money. In order to regulate pv-statcom more effectively, this paper utilises fuzzy logic control. MATLAB/SIMULINK was used to analyse the data.

Key words- statcom, MATLAB, POD.

INTRODUCTION

Oscillations in power transfer over long transmission lines (usually between 0.01 and 2 Hz) have long been recognised as one of the most significant limiting factors. Power System Stabilizers (PSS) connected with synchronous generators have traditionally dampened these oscillations [1]. FACTS devices, which dampen power oscillations and improve transmission line power transfer, have been successfully used in power systems to this end [2-4]. Static Var Compensators (SVC) [5], Static Synchronous Compensators (STATCOM) [6,7], Thyristor Co-ordinated Series Compensators (TCSC) [8], and Convertible Static Compensator (CSC) [9] are examples of FACTS devices using POD controllers that have been studied in detail. It is becoming increasingly common to connect large-scale PV solar farms in excess of 100 megawatts (MW). In addition to these, there are numerous other projects around the world, such as Kamuthi in Tamil Nadu, India, Rancho Cielo Solar Farm in California, Solar Star I and II in the United States, Topaz Solar Farm in the United States, Agua Caliente in the United States, and Huanghe Hydropower Golmud Solar Park in China [11-13]. PV solar plants on the grid have the potential to reduce power system stability by injecting considerable amounts of inertia-less power, as shown in [14-16]. Constant (off-unity) Power Factor, Volt/Var, Watt/Voltage, Frequency Watt, and Low/High Voltage/High Frequency Ride Through are only a few of the intelligent PV inverter controls that have been suggested [17] and proven on a large-scale PV solar farm [18]. To improve wind farm connectivity at night [19] and increase power transfer capacity by dampening power oscillations day and night [20], a new control of PV solar farm as STATCOM (PV-STATCOM) was presented. Power oscillation damping was achieved by utilising the entire inverter capacity at night and the inverter capacity remaining after real power generation at daytime.

Furthermore, this project's use of inverter capacity left over after actual power generation means that the POD function remains enabled during the ramp-up of power to its pre-disturbance value. When ramp-up dampening isn't anticipated in grid codes [24], this prevents power oscillations from occurring again and also allows for a faster ramp-up than what's required. In contrast to [19] and [20], which both present PV solar farm control as STATCOM, [19] exclusively addresses voltage control on a distribution feeder at night (and not during the day). Transmission system dampening of power oscillations is not addressed at all. [20] describes how to dampen power oscillations in a SMIB (Single Machine Infinite Bus) transmission. It has been proved at night with full inverter capacity, but only at daytime with only 50% inverter capacity. Only the leftover inverter capacity after real power creation makes this STATCOM control possible, and its capability diminishes as the solar farm's real power output rises, eventually dropping to zero during hours of full sun.

Based on comprehensive electromagnetic transients investigations utilising MATLAB software, the proposed PV-STATCOM for POD is demonstrated on a Single Machine Infinite Bus (SMIB), Two-Area power system, and 12 bus FACTS power system. To build the POD controller, we used the MATLAB [26]

Simplex optimization method. Relatively small signal residual analysis (RSRA) can be used to locate power system stabiliser (PSS) locations in power systems [27-29]. In this study, the usefulness of specific PV-STATCOM locations for POD is being investigated using the same technique.

II. THE PV-STATCOM CONCEPT

P and Q in Fig.2.1 represent the average daily actual power output of a PV solar farm in direct sunlight, as well as the remaining reactive power capacity for that day. Figure 2.1 shows two modes of operation for the proposed smart inverter PV-STATCOM:

Partially utilising the PV inverter's remaining capacity for STATCOM mode operation, this mode is called partial PV-STATCOM. During the day, you can use this mode. If you choose this option, you can use the entire power of your solar farm's inverters for your STATCOM system.

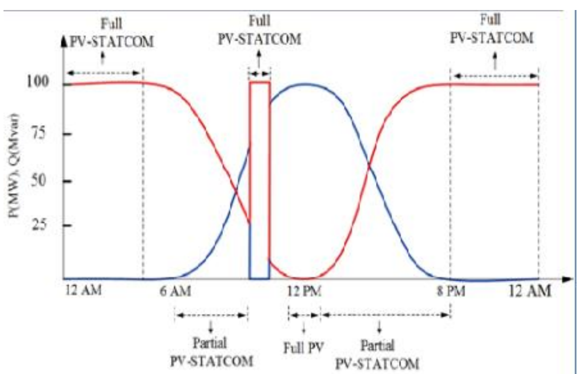


Fig. 2.1. PV Real and Reactive power during 24 hours on a sunny day

Real power generation is suspended throughout the daytime if low-frequency power oscillations are detected as a result of any system disturbance. For reactive power modulation, the complete inverter capability of the solar inverter is made available. Reactive power up to the inverter's full capacity can be used to dampen power oscillations. Low-frequency oscillations are dampened, and the power generating function is restored. To restore the solar farm's normal power output, the Partial PV-STATCOM mode is activated to conduct POD. Full-STATCOM mode is always available for POD with reactive power modulation employing the complete inverter capacity during the nighttime hours. Full PV mode, in which the solar farm generates real power based on available irradiance at unity power factor without smart functionalities, is another operating mode for the solar farm.

Structural Modeling of the Learning Environment

An infinite bus (SMIB) system:

This diagram shows the single line schematic of the big synchronous generator connected to an infinite bus through a 600 km line [25]. At the midpoint of the transmission line, a 100 MW PV solar farm was connected.

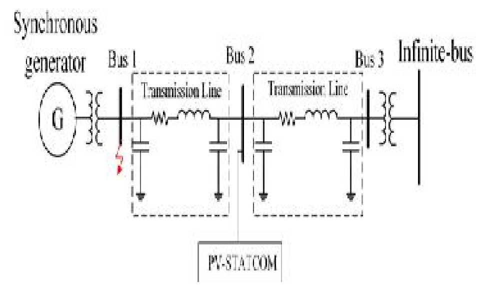


Fig. 2.2. Single-line diagram of an SMIB system with a 100 MW PV plant connected midline

As shown in Fig. 3, a 220 km tie-line connects the four generators in the Two-Area system [1]. The midway of the tie-line between buses 7 and 9 is connected to a 100 MW PV installation. A sixth-order model and DC1-A exciter are used in both systems to represent the synchronous generators. Generators do not have Power System Stabilizers (PSS). In [1] and [25], the parameters for the SMIB system and the Two-Area system are given. The power flow in the Two-Area system oscillates in both local inertial mode and inter-area mode [1].

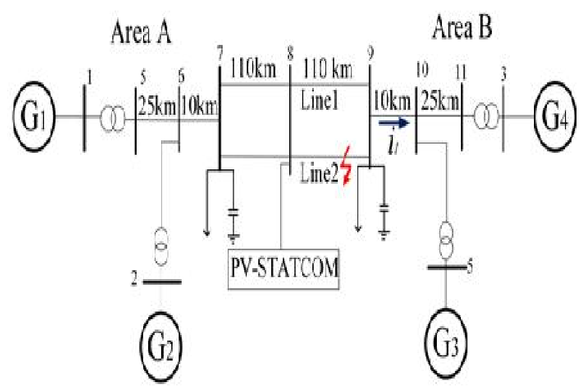


Fig. 2.3. Single-line diagram of Two-Area system with 100 MW PV plant connected midline.

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.

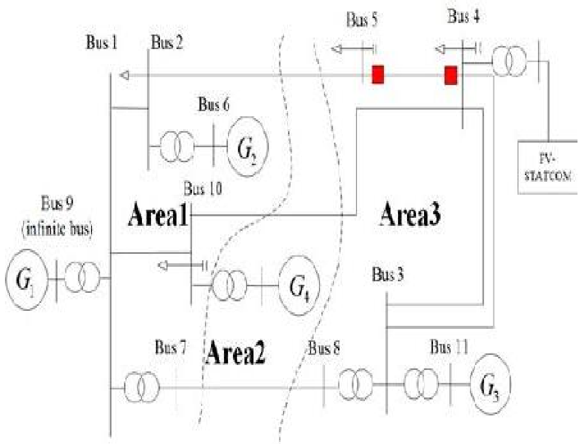


Fig. 2.4. 12 bus FACTS power system with 100 MW PV solar systems at bus 4

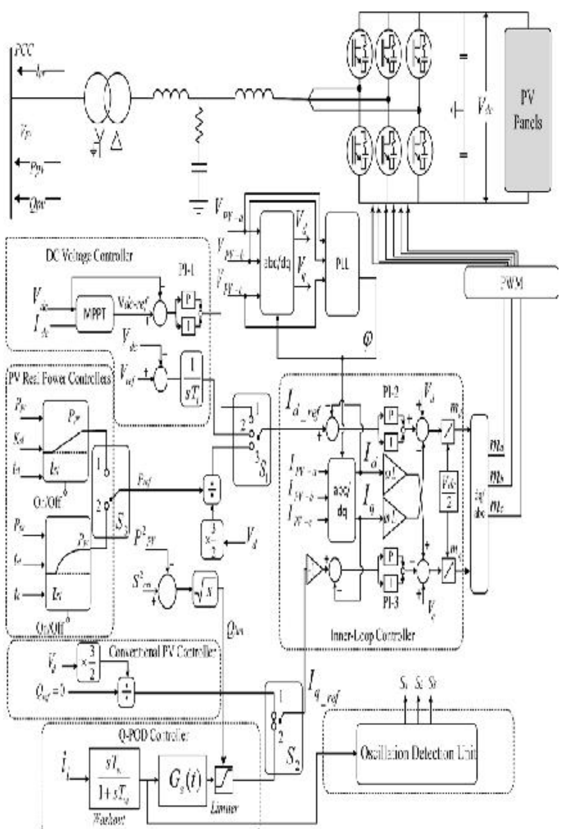


Fig. 2.5 PV-STATCOM controller

2.2 MODELING OF PV-STATCOM

Figure 2.5 depicts the PV system and its controller, the PV-STATCOM, in more detail. PV Modules with Inverter: Solar panels are aggregated into an equivalent panel model that generates dc current using the V-I characteristic of each individual solar panel With a DC link capacitor, a three-phase, six-pulse arrangement is suggested for the combined solar farm inverter An LCL filter based on connects the PV inverter to the grid. The PCC's voltage, inverter reactive power, inverter real power, and inverter current are all represented by the symbols Vpv, Qpv, Ppv, and Ipv.

The controller of the inner loop:

Decoupled d-q axis power regulation is provided by the inner loop controller using the Id ref and Iq ref reference currents, respectively. As part of this controller, you get three phase modulation indices in the form of the three indices md, mq, and ma. Pulse Width Modulation (PWM) is utilised to generate inverter triggering pulses is the basis for the ABC to dq conversion and the Phase Locked Loop (PLL) unit. Direct and quadrature voltages and currents of the PV system are shown in Fig. 2.5 by using the Vdc (PV-STATCOM DC link voltage) as a descriptor.

Control of DC Voltage:

There are two parts to a DC voltage controller: Both an MPPT controller and a DC voltage controller are included in the system. To generate the reference voltage Vdc-ref, the MPPT block uses Vdc and Idc in traditional PV operation mode based on the VI characteristics of the PV panels, resulting in Id ref for the inner loop controller. During STATCOM control mode, the S1 switches to position 2 and the DC voltage Vdc is controlled to PV panel open circuit voltage in order to prevent genuine power injection from the PV solar panels. The open-circuit voltage is dependent on incident irradiance and temperature and is not a constant value. As shown in Fig. 2.5, the maximum open circuit voltage determined from various (manufacturer supplied) power-voltage characteristics for various realistically prevalent temperatures and sun irradiance is used as Vref for the DC link voltage controller module.

Fuzziness controller III is here.

Uncertainty is the etymology of the term "fuzzy". When the boundaries of a piece of information aren't clear-cut, fuzziness occurs. Floppy sets were first proposed in 1965 by Lotfi A. Zahed. Fuzzy set theory has a lot of promise for dealing with problems that have a lot of unknowns. Uncertainty caused by vagueness can be handled by using fuzzy set theory. A common occurrence of fuzziness is in the understanding of spoken language and the recognition of handwritten characters.

Set theory is extended to include items with various degrees of membership in fuzzy sets. To describe human reasoning, fuzzy logic uses the entire range between 0 and 1. Sets of membership functions, referred to as "FUZZY SETS," are used in FLC to map input variables.

Members of a fuzzy set are defined by a membership function that can be specified using parameters. A value ranging from 0 to 1 indicates the extent to which an object belongs to the fuzzy set. It's called

"fuzzificaton" when the input data is transformed into fuzzy values. The Fuzzier module's output is connected to the rules. In order to perform the basic functions of FLC, fuzzy control rules are used, which are based on fuzzy set values in general.
"DEFUZZIFICATION" is the process of combining the findings to produce a clean output that regulates the output variable.

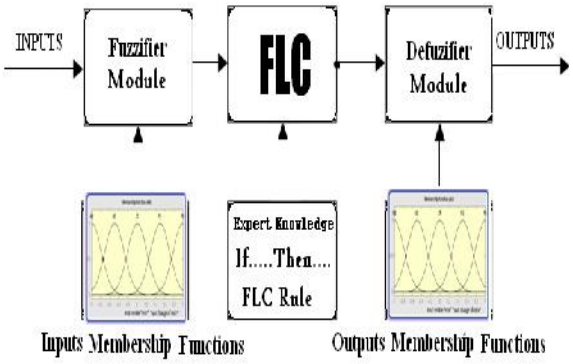


Fig 3.1: block diagram of fuzzy logic Controller

3.2 Fuzzy rules:

fuzzy control uses "large, medium, and small" language to describe input and output variables since they are the size of the form that can be described in words. All of these terms are abbreviated in English as follows: NB (for negative), NC (for positive), NZ (zero), PS (positive small), PM (positive medium), PB (positive big), NB (negative medium), NZ (zero), PM (positive big), and CT (positive tiny).

IV.Simulink Model and Results

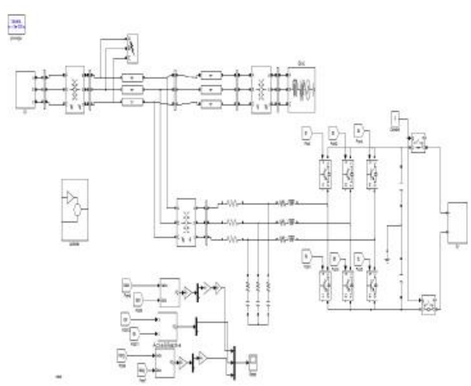


Fig4.1Simulink Block Diagram

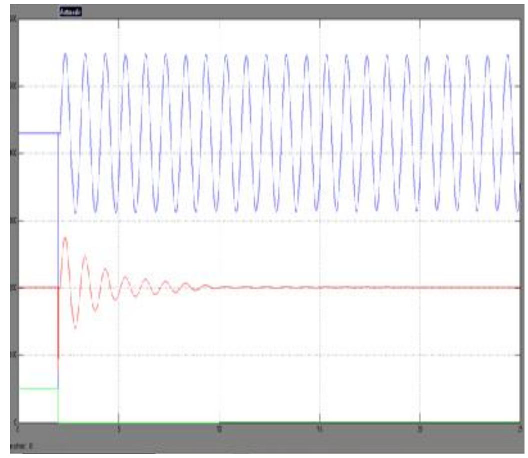


Fig. 4.2. Maximum power transfer capability of the SMIB system

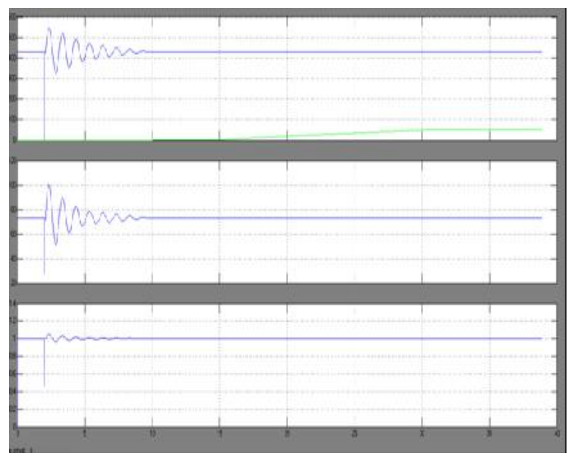
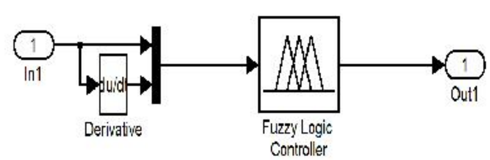


Fig. 4.3 (a) Midline and PV system real powers, (b) PV-STATCOM reactivepower, (c) Midline voltage during POD and normal ramped power restoration



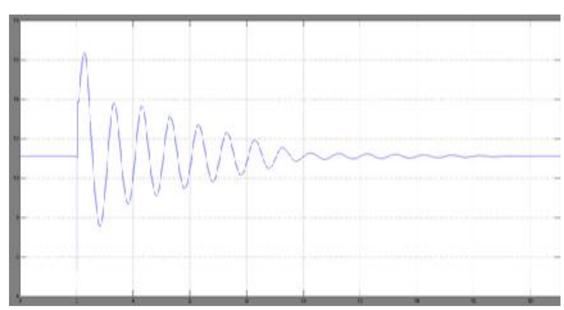


Fig. 4.3. Nighttime using fuzzy logic controller (a) Midline real power without POD with PV-STATCOM control, (b) Midline real power with Full

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 study proposes a novel smart control of a big PV solar system coupled to a transmission line as a STATCOM, known as PV-STATCOM, for dampening power oscillations and boosting the network's power transfer capacity. This control offers POD through reactive power modulation using the entire inverter capacity at night. Solar farms use their entire inverter capacity for POD (power on demand) during the daylight just for a small period of time (approximately 15 seconds). A gradual return to pre-disturbance levels of power generation is achieved by reactivating the POD function using the remaining inverter capacity. PV-STATCOM control has been shown to be effective in EMTDC/PSCAD simulation studies on a single machine infinite bus (SMIB) system that exhibits local inertial oscillatory mode, a two-area system that exhibits local inertial and inter-area oscillations as well as a twelve-bus FACTS power system that has multiple inter-area oscillations.

The power transfer capacity of a 100 MW midline-connected PV solar system in the SMIB system is increased by 230 MW, but in the Two-Area system, the power transmission limit is increased by 200 MW by a 100 MW PV solar system. More than three times faster than grid codes, the proposed power restoration method keeps POD enabled (without POD function). With this new PV-STATCOM, you can get a full scale STATCOM for a fraction of what you'd pay for a traditional one because it makes use of the existing PV solar farm infrastructure (substations, bus-work, transformers, circuit breakers, protection systems, etc.). Utilities looking to expand their power transmission capacity will save money by using the PV-STATCOM as an alternative FACTS device. Transmission-connected solar farms can now provide 24/7 STATCOM capabilities for a significant reduction in cost.

REFERENCES

[1] P. Kundur, N. J. Balu, and M. G. Lauby, Power system stability and control vol. 7: McGraw-hill New York, 1994.

[2] N. G. Hingorani and L. Gyugyi, Understanding FACTS: concepts and technology of flexible AC transmission systems: Wiley-IEEE press, 2000.

[3] R. M. Mathur and R. K. Varma, Thyristor-based FACTS controllers for electrical transmission systems: John Wiley & Sons, 2002.

[4] Y. Xiao, Y. Song, C.-C. Liu, and Y. Sun, "Available transfer capability enhancement using FACTS devices," IEEE Trans. Power systems, vol. 18, pp. 305-312, 2003.

[5] X. Y. Bian, Y. Geng, K. L. Lo, Y. Fu, and Q. B. Zhou, "Coordination of PSSs and SVC Damping Controller to Improve Probabilistic Small-Signal Stability of Power System With Wind Farm Integration," IEEE Trans. Power Systems, vol. 31, pp. 2371-2382, 2016.

[6] M. Haque, "Improvement of first swing stability limit by utilizing full benefit of shunt FACTS devices," IEEE Trans. Power Systems, pp. 1894-1902, 2004.

[7] 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.

[8] 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.

[9] S. Arabi, H. Hamadanizadeh, and B. B. Fardanesh, "Convertible static compensator performance studies on the NY state transmission

system," IEEE Trans. Power Systems, vol. 17, pp. 701-706, 2002.

[10]The World's Largest Solar Plant Is Now Online in India.Available:http://www.popularmechanics.com/science/green-tech/a24063/worldslargest-solar-plant-india/

[11]C.Tiba and E. d. A. Ricardo, "Siting PV plant focusing on the effect of local climate variables on electric energy production–Case study for Araripina and Recife," Renewable Energy, vol. 48, pp. 309-317, 2012.

[12]Fact Sheet California Valley Solar Ranch. Available: https://us.sunpower.com/sites/sunpower/files/media-library/fact-sheets/fscalifornia-valley-solar-ranch-factsheet.pdf

[13]A. Sharma, "A comprehensive study of solar power in India and World," Renewable and Sustainable Energy Reviews, vol. 15, pp. 1767-1776, 2011.

[14] R. Shah, N. Mithulananthan, R. Bansal, and V. Rama chandaramurthy, "A review of key power system stability challenges for large-scale PV integration," Renewable and Sustainable Energy Reviews, vol. 41, pp. 1423-1436, 2015.

[15]S.Eftekharnejad, V. Vittal, G. T. Heydt, B. Keel, and J. Loehr, "Small Signal Stability Assessment of Power Systems With Increased Penetration of Photovoltaic Generation: A Case Study," IEEE Trans. Sustainable Energy, vol. 4, pp. 960-967, 2013.

[16]B. Tamimi, C. Cañizares, and K. Bhattacharya, "System stability impact of large-scale and distributed solar photovoltaic generation: the case of Ontario, Canada," IEEE Trans. Sust. Energy, vol. 4, pp. 680-688, 2013.

[17]B. Seal, "Common functions for smart inverters, version 3," ed: EPRI Report 3002002233, Palo Alto, CA, 2013.

[18]M.Morjaria, D. Anichkov, V. Chadliev, and S. Soni, "A Grid-Friendly Plant: The Role of Utility-Scale Photovoltaic Plants in Grid Stability and Reliability," IEEE Power and Energy Magazine, vol. 12, pp. 87-95, 2014.

[19]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.

[20]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.