DESIGN OF CPAT BASED UPFC FOR WIND FARMS

[1]Zakiya Zeenath,[1]B. Parasuram
M.Tech Student, Assistant Professor
[1,2]Department of Electrical& Electronics Engineering
[1,2]Bheema Institute of Technology & Science, Adoni, A.P, India

Abstract: *One of the most difficult research areas is improving the transient stability of the power system. Additionally, conventional power grid systems suffer from the following issues that lower their efficiency, such as low transmission line usage and load imbalance brought on by a lack of control. Utilizing FACTS devices is one way to address these issues. The most effective FACTS device for controlling power flow in the transmission system is the UPFC, and it performs admirably. The STATCOM and SSSC two transformers, two power converters, and a shared DC link capacitor make up the traditional UPFC system. However, this UPFC is large and expensive, and its application is restricted. We suggest a new UPFC based on a CPAT a power electronics integrated transformer for wind farm use to reduce the drawbacks and maximize the benefits of UPFCs. The results demonstrate that UPFC may use subsynchronous damping controllers in conjunction with UPFC's primary controllers to reduce SSR in wind farm installations. Additionally, it appears that the series transformer converter dramatically changes the system resonance characteristics, but the shunt transformer converter only has a minor impact on SSR. On a typical power system model with integrated wind turbines, simulations are run.*

Keywords: *Back-to-back converter, CPAT, FACTS, Power Electronics Integrated Transforme, SRR, UPFC, Wind farms*

1. INTRODUCTION

With the fast development of installed capacity of wind farms system, the large wind turbine generators (WTGs) are combined into the electric power grids systems. This method of power generation should be used to send energy through a transmission system that can handle high power flows. The series compensation is regarded as an efficient way to raise the total and available transfer capability (TTC and ATC) for an existing transmission network. Sub-synchronous resonance (SSR), which has the potential to be the cause of the failure of the turbine-generator shaft and the instability of the power system, may, however, manifest in such compensated networks. Torsional interactions (TI) and induction generator (IG) effects are two possible components of SSR. The SSR produced by the induction generator effect is very dangerous for a radially connected wind farm that is running at the end of a series compensated transmission line. Flexible ac transmission systems (FACTS) are widely acknowledged to be able to ease the SSR[1]. The application of various FACTS devices to reduce SSR in series compensated wind farm connections was attempted in very few articles [2][3][4][5][6]. SSR mitigation in a series compensated wind farm was looked at using SVC and TCSC. An innovative STATCOM controller for minimizing SSR has been suggested and it is possible to implement a distinct unified power flow controller (UPFC) that makes use of partial force converters by exchanging any force transformer for a custom power active transformer (CPAT)[7]. As a result, any force transformer now has an integrated UPFC. FACTS have proven to be efficient SSR mitigation techniques. Numerous studies have tried to apply different FACTS devices to minimise SSR in series-compensated wind farms based on real-world and theoretical data. The most adaptable of the FACTS components, the UPFC, almost allows for simultaneous control of all fundamental power system variables, such as voltage amplitude and angle, line impedance, and power flows. In light of these important capabilities, it could be a good idea to reduce SSR in conjunction with systems that provide series compensation. There has been a lot of research done on UPFC in SSR damping. To mitigate the drawbacks and exploit the qualities of UPFC system, we propose a new UPFC based on a CPAT a power electronics integrated transformer for Wind farm application. CPAT provides flexibility to operation of power system and allows having fewer windings and smaller core size.

The contributions are as follows:

- We have investigated the issues and challenges in Wind farm
- Understood the benefits of CPAT based UPFC for wind farm
- Designed PV/WT using PMBLDCG and UPFC using power electronic integrated transformer for wind farm

- We have modeled the PV/WT using PMBLDCG CPAT based UPFC system wind farm using SIMULINK tool
- Also we have carried out the simulation analysis of CPAT based UPFC systems

2. RELATED WORK

H. Lee et al. 2019[8] suggested a unique UPFC topology with N: 2 transformers and developed a 3-phase UPFC employing 3-single phase transformers. To lower the power and voltage rating of transformers and switches, this technology is used with an auto transformer. Installation areas and cost savings are two advantages of the suggested technology.

M.A. Elsaharty et al. [9] conducted research on the application of power electronics integrated transformers (PEIT) for power distribution system correction in 2018. They looked at the unified power-quality controller (UPQC) application for the CPAT system control to offset reactive power demands and reduce inrush current in the grid system. They also looked into how to control the CPAT system to lessen harmonic grid current and load voltages.

P. Li et al. [10] conducted research on the viability of applying the MMC-UPFC system in China's 500kV Suzhou power network in 2017. They ran the simulation to confirm and evaluate the impact on power flow and voltage regulation, and they looked into how using UPFC for regulation could prevent overloading important transmission sections during the winter when under significant load.

Y. Liu, et al. [11] investigated the transformer-free UPFC system for connecting two synchronous AC grid systems with a greater phase difference in 2016. Finding the actual power flow between two generators is possible with the phase difference determination.

In 2016, F. Z. Peng et al. [12] completed the design and analysis of a transformer-free UPFC system, which is built using a cascaded multilevel inverter system. It offers advantages such a transformer-free, lighter system, improved efficiency, increased dependability, and cost savings. Such a system is appropriate for the transmission of solar and wind electricity.

S. Yang et al. [13] designed and simulated a transformer-free UPFC system in 2016 and performed its main operations, including modulation and control. This suggested system can be put in place to maximize energy production, optimize energy use in grids, lessen transmission congestion, and greatly increase the penetration of renewable energy sources.

G. Ganga Maheswari et al[14] The introduction of this single-stage CPAT's structure and analysis demonstrates the rationale behind how coupling between transformer windings and boundaries affects CPAT activity. Simulink was used to model the suggested power electronic integrated transformer, and the simulation results were used to evaluate the power quality enhancement.

Vegi Ambika Rani and colleagues [15] In order to address the force quality difficulties, this paper developed a cutting-edge technique using a custom force dynamic transformer (CPAT) in a dispersion framework. The proposed framework had a MATLAB/Simulink conditional structure. According to the recreation findings, the proposed PR regulator in CPAT delivers more profitable execution than other techniques already in use.

3. PROPOSED SYSTEM

i. Wind Farm System

The wind farm shownin Figure 1 is made up of several parallel series-connected/ series-parallel-connected 1.5 MW direct-drive PMSG WTGs that are all the same.

Figure 1 illustrates the assumed UPFC, which consists of a static synchronous compensator (VSC 1) and a series static synchronous compensator (VSC 2) connected by a shared DC link capacitor and capable of bidirectional real power exchanges between the shunt component (VSC 1) and series part (VSC 2). (VSC2).

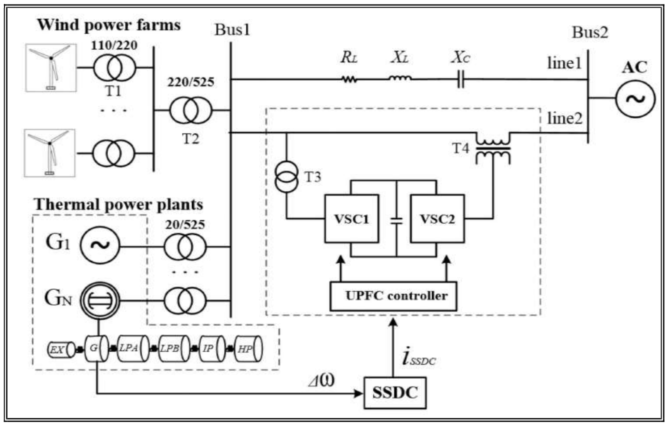


Figure 1Wind farm system using UPFC[16]

The UPFC is a powerful and reasonably adaptable FACTS tool. It has the ability to simultaneously manage a few fundamental components of a power system, including voltage amplitude, phase angle, power flows, and line impedance.

i. ***PV/WT using PMBLDCG***

MGs that rely on a PV system and a WT-powered VSG are appropriate for remote locations with a consistent breeze and sunlight-based potential. Figure 2 shows the PMBLDCG arrangement with PV and WT drive.

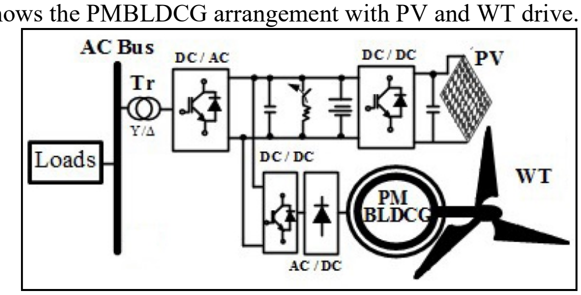


Figure 2 The PV/WT system using PMBLDCG[17]

Until PV power is sufficient to meet load demand, the MG requires sufficient breeze speed to satisfy load interest in the evening, around dusk, and early in the morning; in any case, a sizable BESS is required for this MG to ensure reliable energy.

ii. ***CPAT Based UPFC System***

The CPAT based UPFC system is proposed to mitigate the SSR in series-compensated wind farm system. The key characteristics and benefits of the CPAT system are as follows:

- CPAT makes operating a power system more flexible.
- It allows for lower core sizes and fewer windings
- It magnetically couples series and shunt converter circuits to the primary and secondary winding of transformers.
- Since the transformer core is partially pre-energized by the available converters, it enables the use of a single transformer with controlled flux and lower inrush currents.
- It does not require current-handling or high-voltage windings. In typical applications, shunt and series compensation transformers have high-voltage and high-current windings on the network side.

The Power Electronics Integrated Transformer (PEIT)-based UPFC system that we suggest uses three single-phase CPATs to control power flow between the primary and secondary windings as well as offer reactive power compensation and harmonics removal. The equivalent magnetic circuit of a CPAT's three-phase design, as shown in figure 3, is used to model and evaluate the configuration for power flow control applications.

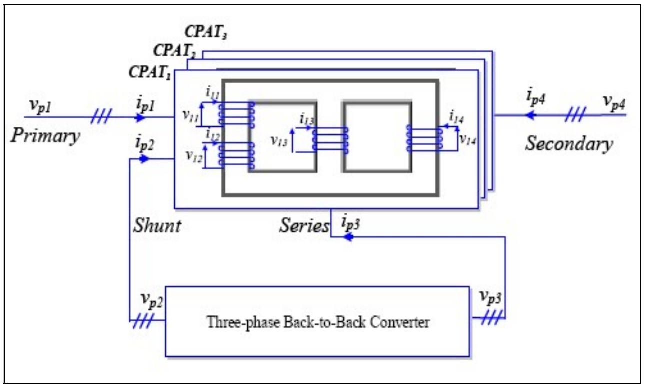


Figure 3 configuration of 3-ϕ CPAT for UPFC system[18]

Power flow regulation between two stiff grids has been studied using simulations and experiments with the CPAT-UPFC. Additionally, the CPAT-UPFC has been modelled as a substation transformer in a 5-bus power system to control power flow and function while under load perturbations. Finally, the results of the experiments and real-time simulations gathered show that a CPAT-UPFC is capable of offering such services successfully.

4. DESIGN OF PROPOSED SYSTEM

Methodology

The usual wind-thermal-bundled power used by this system is transferred through the series-compensated system, which is put at risk by SSR. Investigating the viability of SSR mitigation with a CPAT-based UPFC device is fascinating. Figure 1 depicts the commonly revised wind-thermal-bundled power system with a fixed 41.2% series compensation and UPFC components.

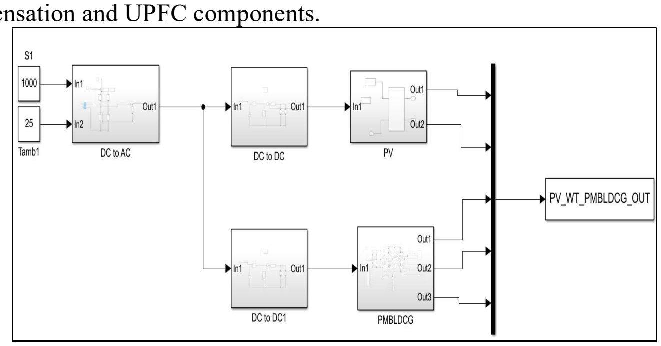


Figure 4 SIMULINK model of PV/WT using PMBLDCG

There are various thermal power facilities and wind farms on the compensated transmission line's sending side.

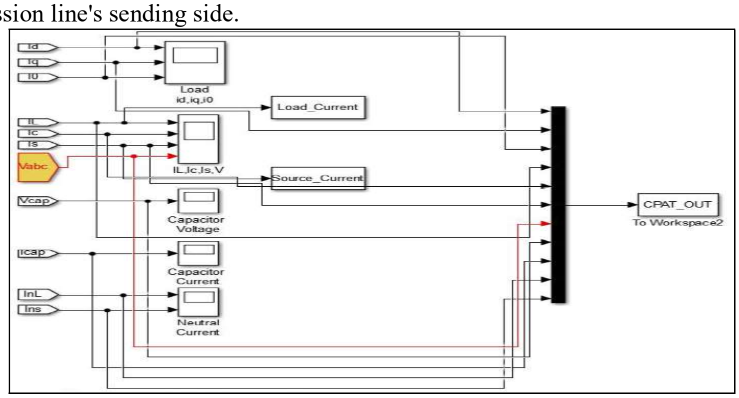


Figure 5 depicts the CPAT design

This research focuses on wind turbine generators (WTGs) based power farms with direct-drive permanent magnetic synchronous generators (PMSGs), which are linked to robust power systems by an ultra-high voltage AC/DC parallel transmission network. Also we investigated the MG configuration using PV and WT driven PMBLDCG for wind farms. First the design of PV/WT using PMBLDCG system is carried out using MATLAB-SIMULINK tool and then the CPAT based UPFC system is designed and simulation is performed.

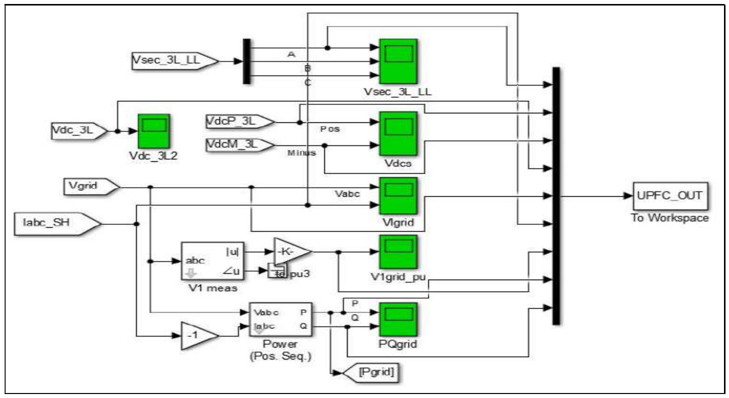


Figure 6 Design of UPFC for power measurements

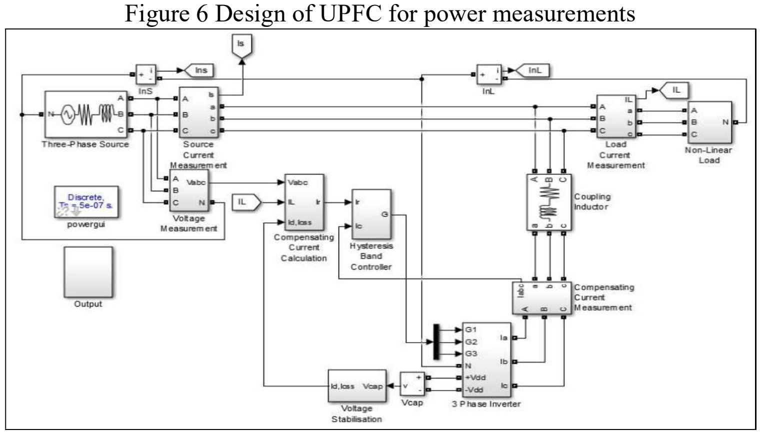


Figure 7 Complete CPAT design

There are various thermal power facilities and wind farms on the compensated transmission line's sending side. This research focuses on wind turbine generators (WTGs) based power farms with direct-drive permanent magnetic synchronous generators (PMSGs), which are linked to robust power systems by an ultra-high voltage AC/DC parallel transmission network.

iii. SIMULATION RESULTS AND ANALYSIS

The simulation analysis was performed on the SIMULINK platform using the system parameters nominal grid voltage of 500KV, normal system frequency of 50kHz, and nominal DC link power of 200MW to validate the effectiveness of the proposed system. Snapshots of the results of the simulation of the designed CPAT system are displayed.

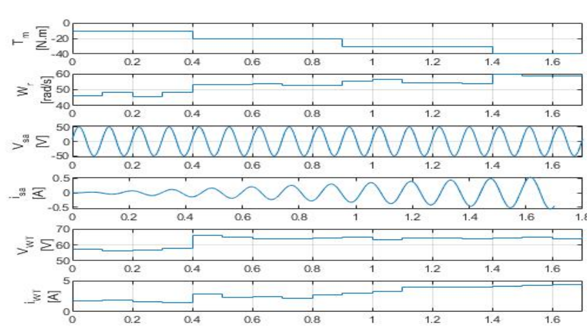
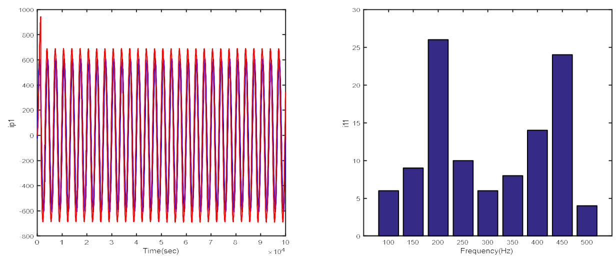


Figure 8 WT and PV performance at change of wind speed

The simulated results shown in figures 5.2 through 5.7 show the primary and secondary current of a shunt converter in enabled and disabled modes. Additionally, it shows the study of the harmonic spectrum.

The following presumptions are made for the simulation's purposes. I All of the generators in a wind farm use the same kind of WTG and run under the same conditions. (ii) A 110 kV line transmits power from a 50 MW wind farm. (iii) A 220 kV line is connected to the local 110 kV grid through step-up transformer T1. A step-up transformer T2 then transmits wind energy to the primary power system. Lines 1 and 2 transmit the electricity from the thermal power plant and wind farm to the main grid.

In Figure 8 various waveforms under the change of wind speed of the mechanical force (Tm), ω_r (rotor speed of the PMBLDCG), Vsa (terminal stator voltage) and i_{sa} current of the stage (a), the DC voltage -V_{WT} and current-(i_{WT} are introduced. It can be seen that more advanced P&O function without detecting speed of rotor during changes in wind speed. The i_{WT} follows variety of i_{sa}, it increments and diminishes with variety of Tm yet the V_{WT} shifts somewhat with this variety, which help to decrease the intricacy and the expense of the framework by utilizing just the detected V_{WT} and i_{WT} to accomplish MPP from WT.

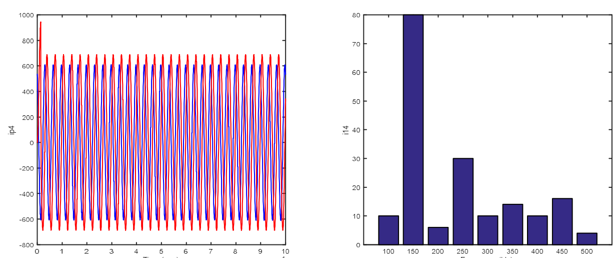


(a) **ip1 current** (b) **Harmonics**

Figure 9 Simulation results of all controllers under enabled mode

The waveform of ip1 current and its harmonics spectrum analysis graph for all controllers operating in enabled mode are shown in the figure 5.6.

Figure 9 shows that the primary current, which is made up of the magnetising current of the CPAT and the DC bus regulation current, is composed of 3rd, 5th, and 7th-order harmonics because there is no power flow in this situation.



(a) ip4 current (b) Harmonics

Figure 10 simulation results of all controller under enabled mode

The waveform of ip1 current and associated harmonics spectrum analysis for all controllers operating in enabled mode are shown in the figure 10.

From the simulation results we seen that the CPAT based UPFC systems offers benefits and reduces the drawbacks of conventional UPFC system The results also demonstrated that UPFC may use subsynchronous damping controllers in conjunction with UPFC's primary controllers to reduce SSR in wind farm installations.

CONCLUSION

We have investigated issues and challenges of wind farm system and proposed the CPAT based UPFC system to overcome the drawbacks and offer benefits. The proposed system was designed with Simulink tool and simulation analysis were carried out for capability of

CPAT as UPFC for wind farm applications. The analysis, simulation results confirm the CPAT-UPFC ability to mitigate SSR and offers efficient services.

REFERENCES

[1]. Narain G. Hingorani, Laszlo Gyugyi "Understanding FACTS: Concepts and Technology of Flexible AC Transmission Systems", Wiley-IEEE Press, December 1999. ISBN 978-0-7803-3455-7. pp 90

[2] H. Liao and J. V. Milanović, "On capability of different FACTS devices to mitigate a range of power quality phenomena," IET Generation, Transmission & Distribution, vol. 11, no. 5, pp. 1202-1211, Mar. 2017.

[3] H. Wang, "A unified model for the analysis of FACTS devices in damping power system oscillations—UPFC," IEEE Trans. Power Del., vol. 15, no. 3, pp. 978–983, Jul. 2000.

[4] M. Noroozian et al., "Improving power system dynamics by series connected FACTS devices," IEEE Trans. Power Del., vol. 12, no. 4, pp. 1635–1641, Oct. 1997.

[5] Sandeep Sharma and Shelly Vadhera, "Enhancement Of Power Transfer Capability Of Interconnected System By Using (UPFC) " IEEE Vol. 4, No. 3, June 2016

[6] S. Yang, Y. Liu, X. Wang, D. Gunasekaran, U. Karki and F. Z. Peng, "Modulation and Control of Transformerless UPFC," IEEE Trans. Power Electron., vol. 31, no. 2, pp. 1050-1063, Feb. 2016.

[7] M.A. Elsaharty, J. Rocabert, I. Candela and P. Rodriguez, "Three-Phase Custom Power Active Transformer for Power Flow Control Applications," IEEE Trans. Power Electron., Early Access, June 2018.

[8] M.A. Elsaharty, J.I. Candela and P. Rodriguez, "Power System Compensation Using a Power Electronics Integrated Transformer", IEEE Trans. Power Del., vol. 33, no. 4, pp. 1744-1754, Aug. 2018.

[9] F. Z. Peng, Y. Liu, S. Yang, S. Zhang, D. Gunasekaran and U. Karki, "Transformer-Less Unified Power-Flow Controller Using the Cascade Multilevel Inverter," IEEE Trans. Power Electron., vol. 31, no. 8, pp. 5461-5472, Aug. 2016.

[10] S. Yang, Y. Liu, X. Wang, D. Gunasekaran, U. Karki and F. Z. Peng, "Modulation and Control of Transformerless UPFC," IEEE Trans. Power Electron., vol. 31, no. 2, pp. 1050-1063, Feb. 2016.

[11] Y. Liu, S. Yang, X. Wang, D. Gunasekaran, U. Karki and F. Z. Peng, "Application of Transformer-Less UPFC for Interconnecting Two Synchronous AC Grids With Large Phase Difference," IEEE Trans. Power Electron., vol. 31, no. 9, pp. 6092-6103, 2016.

[12] P. Wang, Feng and J. Lin, "Application of MMC-UPFC in the 500kV power grid of Suzhou," The Journal of Engineering, vol. 2017, no. 13

[13] M. Andresen, K. Ma, G. De Carne, G. Buticchi, F. Blaabjerg and M. Liserre, "Thermal Stress Analysis of Medium-Voltage Converters for Smart Transformers," IEEE Trans. Power Electron., vol. 32, no. 6, pp. 4753-4765, Jun. 2017.

[14] G.Ganga Maheswari, Shaik Hussain Vali, "Power System Compensation using A Custom Power Active Transformer", Journal of engineering sciences, Vol 10, 2019

[15] Vegi Ambika Rani, Senapati Varaprasad "Design and control of custom power active transformer for sag/swell compensation with PR based controller" Journal of Science, Technology and Development, Volume VIII Issue XI Page No : 307-315, 2019

[16] Hongli Jiang1, Ruihua Song, Ning Du, Peipeng Zhou, Bin Zheng, Yanan Han1, Daye Yang, "Application of UPFC to mitigate SSR in series compensated wind farms" The Journal of Engineering, Vol. 2019 Iss. 16, pp. 2505-2509

[17] Rezkallah, A. Chandra, B. Singh and Singh, "Microgrid: Configurations, Control and Applns ," in *IEEE Transactions on Smart Grid*, vol. 10, no. 2, pp.1290-1302, 2019,

[18] M.A. Elsaharty, A. Luna, J. I. Candela, Pedro Rodriguez, (2018) A unified power flow controller using a power electronics integrated transformer.IEEE transactions on power delivery . Vol. 34, iss. 3, Pp. 828-839