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A CUSTOM POWER ACTIVE TRANSFORMER BASED UNIFIED POWER FLOW CONTROLLER WITH VOLTAGE STABILITY

[1] P.SRILAKSHMI, [2]MANJULA SWETHA, [3]S. SUMALATHA
[1]Assistant Professor, Department of EEE, Sanskrithi School Of Engineering Prasanthigram, Puttaparthi, Anantapur Dist., Andhra Pradesh, India
[2] Assistant Professor, Department of EEE, Sanskrithi School Of Engineering Prasanthigram, Puttaparthi, Anantapur Dist., Andhra Pradesh, India
[3]Assistant Professor, Department of EEE, Sanskrithi School Of Engineering Prasanthigram, Puttaparthi, Anantapur Dist., Andhra Pradesh, India

ABSTRACT: The reliability, power quality, line congestion, lines capacity and stability are major issues in transmission and distribution systems for efficient power transmission. The UPFC will provide solutions for these issues. In this paper, a Custom Power Active Transformer (CPAT) based unified power flow controller (UPFC) for enhanced voltage stability margin is proposed in power system network by analyzing dynamic voltage stability for power flow control and compensation. CPAT is a power electronics integrated transformer which provides services to the grid through its auxiliary windings. The CPAT structure wires three single-stage transformers into one shunt-strategy mixing transformer. Voltage stability indices and voltage collapse point indicators (VCPI) indices are used to determine the weakest line for UPFC by dynamic load variation. The controllers of the shunt and series converters of the UPFC are developed using fuzzy logic (FL) and proportional integral (PI) controllers respectively to enhance the dynamic voltage stability of the power system network. This proposed system can be design using MATLAB SIMULINK tool. The results obtained through simulations have ensured the effectiveness of the proposed placement method since fuzzy based UPFC's placement in the obtained locations resulted in significant improvement in voltage stability

KEY WORDS: Custom Power Active Transformer (CPAT), Unified Power Flow Controller (UPFC)

I. INTRODUCTION

In the last few years, significant increase of power demand has been observed all over the world. This increase however does not followed by increasing in power generation and transmission capacity. Hence, in order to meet the increasing electrical power demand power generating plants as well astransmission lines are always operating closer to their maximum stability limit. As a result, the power system networks are becoming less secure and always expecting the risk of voltage instability [1]. Different preventive measures using conventional electromechanical devices had been adopted to overcome voltage instability issue [2]. However, most of these devices have the drawbacks like slowness and wear. a better solution, keen attention has been paid to Flexible Alternating Current Transmission System (FACTS) devices which are driven from modern power electronics components. Among different types of FACTS devices UPFC has got the epic popularity [3]. Since, it is capable of voltage regulation, series compensation, and phase angle regulation simultaneously, lead to the discrete control of active and reactive power transmitted through the line [4]. However, due to high cost and the voltage stability problem, it is highly preferred to place UPFC at appropriate locations in the power system network. In previous studies, optimization techniques have been used to determine the location of FACTS controller based on steady state voltage stability analysis.

Among the FACT devices, the Unified Power Flow Controller (UPFC) is the most versatile and powerful device in reduction of line congestion and increasing existing lines capacity [5]. The high-power transformers are an essential element in a power system to match the voltage level between different buses, it would be interesting to integrate in such a transformer series and shunt auxiliary connection to power electronics converters. Integration of both series and shunt transformers in a single power transformer would facilitate areas of the power system and the transformer itself with services in a single structure. The CPAT is a monolithic transformer core structure that integrates series and shunt power electronics converters to a distribution transformer. A CPAT is comparable to a Sen Transformer in the case of combining multiple transformers into a single unit. However, the CPAT carries several advantages over a Sen Transformer which is mainly due to the presence of power electronics converters in a CPAT as opposed to the step response of a Sen Transformer. The CPAT has been presented to provide shunt services such as reactive power compensation, harmonics elimination and inrush current mitigation.

II. LITERATURE SURVEY

There were many obstacles, and technological issues posed by the growing demand for distributed generation to enable substantial grid contributions [6]. Since of the erratic conduct of renewable generation and the ever-increasing need for electrical energy, substation building and operation has undergone many innovations to overcome these challenges [7]. To ensure a efficient, sustainable and smart electric network, integration of monitoring and control functionalities across the power grid, has evolved to meet these demand. Such functionalities were commissioned via power electronic converters which proved to have several beneficial impacts on the distribution network and the transmission network. Flexible AC Transmission Systems (FACTS) have demonstrated their ability to provide services to support power transmission and power distribution systems effectively and to improve their power system efficiency, consistency and its stability [8]. Of these power systems, the UPFC system is considered to be the most flexible tool for reducing line congestion and increasing the efficiency of existing transmission lines. Connection of power electronics converters system to offer UPFC services has been achieved either through large isolation transformer system, complex multilevel topologies or back to back converters system that handle the rated line power [9].

Transformer-less solution involving multilevel topologies emerge from the need to remove bulky isolation transformers system requirement. However, the full rated voltage is needed for multilevel topologies and for this a complex system configuration is required. The transformers system provides isolation and they can be used to connect both shunt and series power devices to power system very efficiently. However, when considering high power compensation systems, size, cost and footprint are a further concern. To resolve these concerns, the incorporation of electronic control devices into a traditional transformer system has been observed in recent literature aimed at the use of off-the-shelf converters system or the development of a transformer system based on control electronics.

Other indices like line security margin index], voltage security index, security index, controllability index were also used to find the location of UPFC to fix voltage instability problems. The shortcoming of both optimization and index based methods is the exploration FACTS devices locations are conducted by analyzing steady state voltage stability [10]. This steady state analysis is suitable for the planning and designing stage of the power system network. However, during real time operations of power system networks, the problem of voltage instability occurs due to disturbances like load demand increment, line trip or generator outage which are dynamic phenomena. As a consequence, the need for a dynamic approach to determine the location of the FACTS controllers has become essential.

III. PROPOSED SYSTEM

A three phase CPAT called Power Electronics Integrated Transformer based UPFC system is proposed in this paper. This system can be used to regulate the power flow between primary winding and secondary winding. Also it can be used to compensate the reactive power and for elimination of harmonics in the grid. The figure 1 illustrates the configuration of 3-phase CPAT system and this useful in power transmission system applications. This configuration is constructed using 3-single phase CPATs with grid connected to its primary and secondary windings and 3-phase converter (back to back) is connected to shunt and series windings. This converter will control the shunt winding current and series winding voltage. The function of shunt converter is to eliminate the harmonic and compensates the reactive power to primary windings. Further, the function of series converter is to control the active and reactive powers through secondary winding. This proposed system is useful in controlling the flow of power among two striff grids. This CPAT system can be designed and analyzed to investigate its performance.

3.1 Configuration

The center development of a solitary stage CPAT that consolidates arrangement and shunt windings in a transformer has been introduced. The activity rule of the CPAT depends on the hypothesis that windings twisted over regular appendages are proportional to shunt electric circuits and that windings twisted over equal appendages are proportionate to arrangement electric circuits. Considering these standards, the setup in Fig.1 addresses a three-stage $CPAT$ in a transmission application. The strategy contains three single-stage CPATs furnished with a three-phase dynamic converter. Each CPAT is named $CPAT_p$, where p keeps an eye on the stage number. Winding voltages and floods of each CPAT are tended to by vpk and ipk where k watches out for the winding number. The essential and associate windings of a $CPAT$ (k=1, k=4) are associated with the system as in a run of the mill transformer. A three-phase dynamic converter is associated with the shunt and procedure windings (k=2, k=3) to control the shunt winding current and strategy winding voltage. The shunt converter offers types of assistance to the essential twisting, for example, consonant disposal and responsive force pay; it additionally directs the DC transport voltage. The arrangement converter controls dynamic and receptive force through the optional twisting to work as an UPFC.

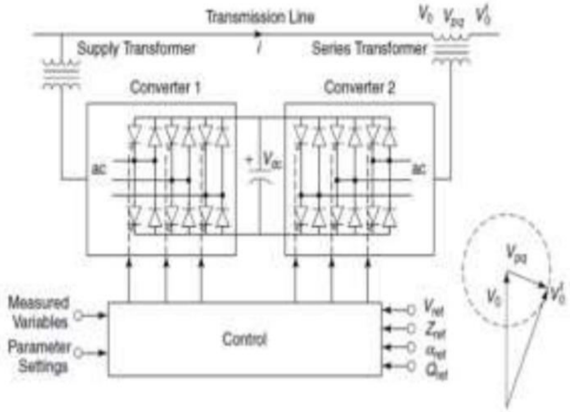

Fig. 1: THREE-PHASE CPAT CONFIGURATION

3.2 Control of Three-Phase CPAT-UPFC

The control plan of the CPAT-UPFC is appeared in Fig.2 and Fig. 3 containing two free controllers. As discussed previously, the objectives of the shunt converter controller showed up in Fig.2 are according to the accompanying: to keep up a reliable DC transport voltage subject to the reference DC transport voltage ($Vdc*$), to manage receptive force through the essential dependent on the reference responsive force ($Q1*$), and to take out consonant parts present in the essential current. The deliberate qualities for these targets are essential framework voltage ($vp1$), essential matrix current ($ip1$), shunt converter current ($ip2$) and DC transport voltages ($vdc1\ and\ vdc2$). The arrangement converter controller appeared in Fig. 3at the same time controls the dynamic and receptive force course through the optional twisting of the CPAT, in view of the reference dynamic ($P4*$) and responsive ($Q4*$) power. Additionally, $Q4*$ can be set through a controller that directs a heap transport voltage ($Vload$). The deliberate factors for these control destinations are auxiliary matrix voltage ($vp4$), optional lattice current ($ip4$) and load transport voltage ($vload$). Both $ip2$ and arrangement converter current ($ip3$) are additionally utilized for over-current security in every converter. Estimations from every engineering were examined through the Sample and Hold to acquire the n test estimation of each deliberate variable. The synchronization framework utilizes the deliberate voltages to decide their proportional recurrence (ω), synchronizing signals $sin\, f0\ (\omega t)$, $cos\, f0\ (\omega t)$ size (V) and simultaneous reference-outline parts ($v\alpha$, $v\beta$). These signs, alongside the deliberate factors and reference factors, were passed to the indistinct controller, which picked the huge leveling of the converter (M). Finally, the PWM module picked the looking at trading state of each switch (g) to achieve the basic control targets.

The shunt controller showed up in Fig.2 has been achieving the huge control objectives. A Proportional Resonant (PR) controller sorts out the shunt converter current as demonstrated by the principal reference shunt current ($ip2*$). The reference contains a head part ($ip2f*$) which is utilized to manage the DC transport voltage and responsive force through the essential just as a sounds segment ($ip2h*$) which is utilized to direct the consonant flows present in ip1. Symphonious sections infused through the shunt converter are settled through a Resonant Controller tuned to the essential weakening frequencies of the principal current ($ip1$). The DC transport voltage is facilitated through two Proportional Integral (PI) controllers that manage the run of the mill DC transport voltage (vdc) and the concordance between both upper and lower DC voltages ($vdc1\ and\ vdc2$). Responsive force through the central is composed through a PI controller that picks the fundamental open current to be embedded through the shunt converter to get the essential reference $Q1*$. The input receptive force ($Q1$) is determined utilizing (1).

$$Q_1 = \frac{1}{\sqrt{3}}[V_{11}V_{21}V_{31}][0-11101-110][i_{11}i_{21}i_{31}] \text{ --- (1)}$$

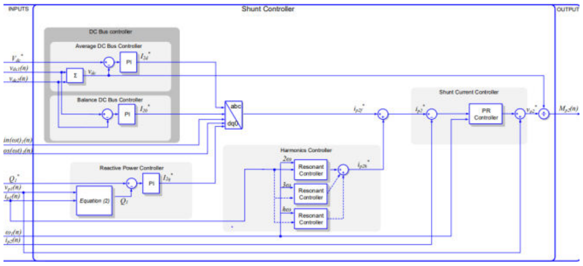

Fig 2: SHUNT CONTROLLER BLOCK STRUCTURE

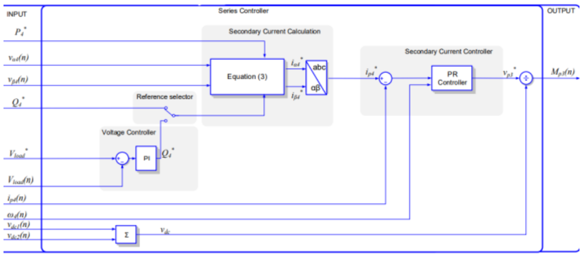

Fig 3: SERIES CONTROLLER BLOCK STRUCTURE

The arrangement controller appeared in Fig.3 comprises of three phases: reference receptive force computation, optional current figuring and auxiliary current controller. The reference receptive force ($Q4*$) is set either physically or through an optional voltage controller that decides the necessary responsive capacity to keep up the reference load voltage ($Vload*$). The auxiliary current estimation decides the comparable fixed reference-outline optional current ($i\alpha4$, $i\beta4$), in view of the reference dynamic and responsive force ($P4*$, $Q4*$) utilizing the fixed reference-outline optional voltage ($v\alpha4$, $v\beta4$). Condition (6) sums up the estimations. Utilizing the auxiliary synchronizing signals ($(sin\ f0(\omega t))$_4, $(cos$ f0 $f0\ (\omega t))$_4 the $i\alpha4$ and $i\beta4$ are changed to their ill-defined three-phase wholes ($ip4*$). A PR controller tuned to the dire repeat ($\omega4$) controls the associate current ($ip4$) to orchestrate the reference $ip4*$. The resultant reference approach voltage ($vp3*$) is isolated by the DC transport voltage (vdc) to pick the equality archive of the course of action converter (Mp3).

$$[i_{\alpha4}i_{\beta4}] = \frac{1}{V_{\alpha4}^2+V_{\beta4}^2}[P_4^* Q_4^*][V_{\alpha4}-V_{\beta4}V_{\beta4}V_{\alpha4}] \text{------ (6)}$$

3.3 Fuzzy logic controller

Fuzzy logic controller predominantly relies upon the principles based. It is the type of information and yield. The fuzzy logic controller input has two qualities like mistake worth and change in blunder esteem. The yield esteem relies on the info esteems and rules setup. The restrictions of variable between - 1 to 1. Reality estimation of Boolean rationale the factors might be 0 or 1. The fuzzy logic controller has grouped into following kinds as Fuzzification, rule network, Defuzzification. The beneath circuit chart clarifies the relations between three controllers. Fluffy principles are ordered relies on information and yield participation capacities.

IV. RESULTS

The complete CPAT UPFC were designed using MATLAB-SIMULINK is as shown in figure 4. Its circuits were design using the blocks available in SIMULINK tool. Every block of diagram is taken from libraries and drawn the complete diagram and interconnections are made with the specification. Then the design is saved and it has been further simulated to find out flow of various current, voltage and power. The figure 4 indicates the design of configuration of CPAT and design of UPFC power measurement is shown in figure 5. Further the figure 4 shows the circuit design of power flow control.

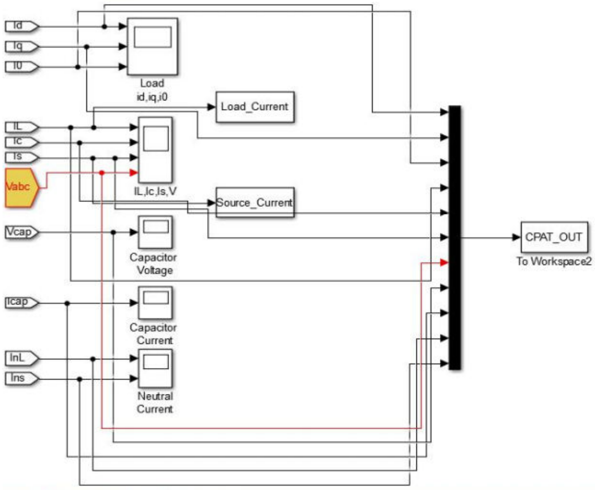

Fig. 4: CPAT CONFIGURATION

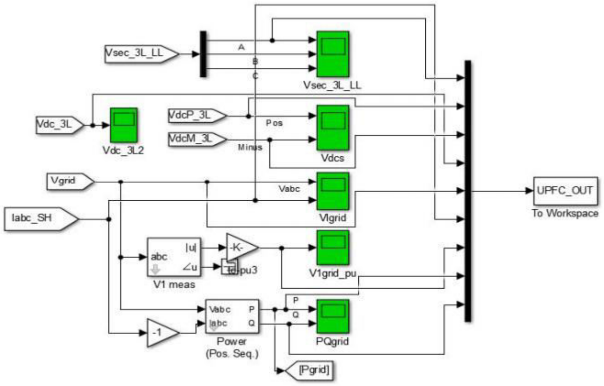

Fig. 5: UPFC POWER MEASUREMENT

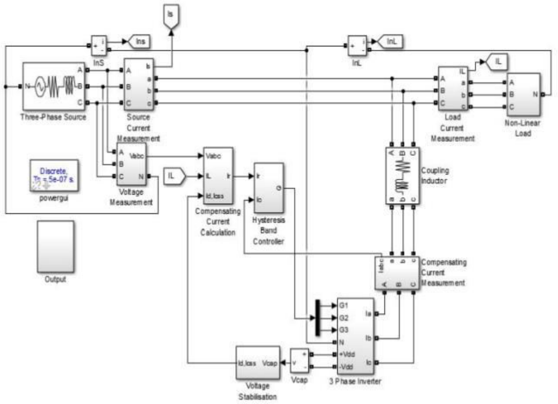

Fig. 6: POWER FLOW CONTROL

The mentioned voltage stability indices are formulated based on the power transmission concept in a single line. From (2) a single line in an interconnected network is illustrated by considering V_s and V_r of the sending end and receiving end voltages, respectively, δ_s and δ_r of the phase angle at the sending and receiving buses, Z of the line impedance, R of the line resistance, X of the line reactance, θ of the line impedance angle, Q_r is the reactive power at the receiving end and P_r is the active power at the receiving end.

$$S_1 = P_r + jQ_r \text{ --- } (2)$$

LQP Index: This index can be defined in (3) which has been derived as following:

$$LPQ = 4\left(\frac{V_s^2}{X}\right)\left(\frac{V_s^2}{X}P_s^2 + Q_r\right) \text{ --- } (3)$$

Voltage Collapse Point Indicators (VCPI): The Voltage Collapse Point Indicators (VCPI) is based on the concept of maximum power transferred through a line.

$$VCPI(P) = \frac{P_{\mathrm{r}}}{P_{\mathrm{r(max)}}} \text{ ---- } (4)$$

The numerator is the real power transferred to the receiving end and denominator is the maximum power that can be transferred to the receiving end at a particular instant. It can be calculated in the following way:

$$P_{\mathrm{r(max)}} = \frac{V_s^2}{X} - \frac{\cos\emptyset}{4\cos^2\left(\frac{\theta-\emptyset}{2}\right)} \text{ --- } (5)$$

where, $\emptyset$ is the load impedance $\emptyset = \tan^{-1}\frac{Q_r}{P_r}$

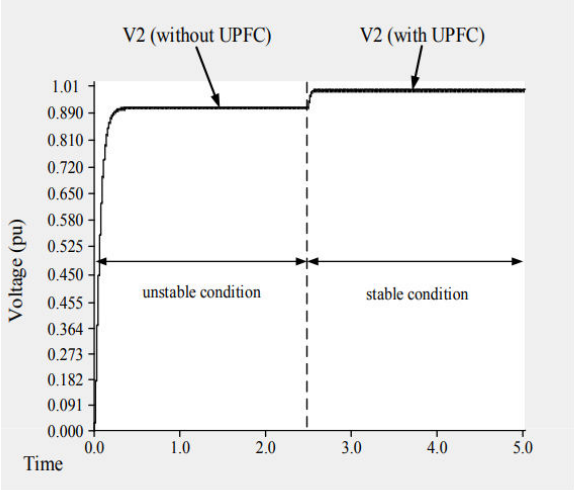

Fig. 7: VOLTAGE ACROSS PRIMARY BUS CONTROL SYSTEM

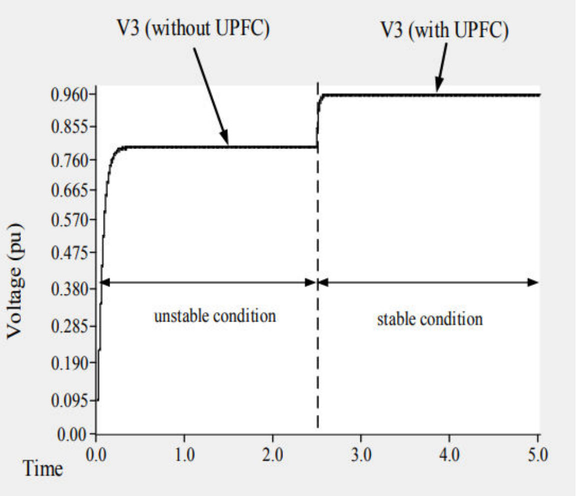

Fig. 8: VOLTAGE ACROSS SECONDAY BUS CONTROL SYSTEM

From Figs. 7 and 8, it has been observed that at unstable condition the voltages across primary and secondary buses are found 0.8851 pu and 0.776 pu respectively. At 2.4s when UPFC has connected across line 2-3 the voltages have improved to 1.001 pu and 0.962 pu across primary and secondary buses respectively.

V. CONCLUSION

This paper has introduced the CPAT-UPFC comprising of three single-stage CPATs outfitted with a consecutive converter with fuzzy logic controller. The CPAT-UPFC system has been successfully modeled, analyzed and simulated using SIMULINK tool and the control architecture has been evaluated to investigate the CPAT system ability to be function as a UPFC for power distribution systems. The performance analysis and simulation results have been confirmed the effectiveness of CPAT-UPFC system in eliminating grid system harmonic currents and compensation of reactive power of distribution system. Also, it has been verified and validated the control of power flow between two stiff grids system. Hence, this system is efficient for power distribution system application.

VI. REFERENCES

[1] Nasser Hosseinzadeh , Asma Aziz, Apel Mahmud, Ameen Gargoom and Mahbub Rabbani "Voltage Stability of Power Systems with Renewable-Energy Inverter-Based Generators: A Review", Electronics, 10, 115, 202.

[2] Hyun-Jun Lee, Dae-Shik Lee and Young-Doo Yoon "Unified Power Flow Controller Based on Autotransformer Structure," ectronics 2019, 8, 1542; pp:1-15

[3] 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

[4] 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.

[5] P. Li, Y. Wang, C. Feng and J. Lin, "Application of MMC-UPFC in the 500 kV power grid of Suzhou," The Journal of Engineering, vol. 2017, no. 13, pp. 2514-2518, 2017.

[6] M. Shahparasti, M. Mohamadian, P. T. Baboli and A. Yazdianp, "Toward Power Quality Management in Hybrid AC–DC Microgrid Using LTC-L Utility Interactive Inverter: Load Voltage–Grid Current Tradeoff," IEEE Trans. Smart Grid, vol. 8, no. 2, pp. 857-867, Mar. 2017.

[7] Q. Huang, S. Jing, J. Li, D. Cai, J. Wu and W. Zhen, "Smart Substation: State of the Art and Future Development," IEEE Trans. Power Del., vol. 32, no. 2, pp. 1098-1105, Apr. 2017.

[8] W. Litzenberger, K. Mitsch and M. Bhuiyan, “When It's Time to Upgrade: HVdc and FACTS Renovation in the Western Power System,” IEEE Power Energy Mag., vol. 14, no. 2, pp. 32-41, Mar. 2016

[9] C. Wang, X. Yin, Z. Zhang and M. Wen, “A Novel Compensation Technology of Static Synchronous Compensator Integrated With Distribution Transformer,” IEEE Trans. Power Del., vol. 28, no. 2, pp. 1032-1039, Apr. 2013

[10] H. Baghaee, et al., "Improvement of voltage stability and reduce power system losses by optimal GAbased allocation of multi-type FACTS devices," in 11th International Conference on Optimization of Electrical and Electronic Equipment, OPTIM, 2008, pp. 209-214.