Power Oscillations Damping Using UPFC

K.Dhayalini, Kirthika.S, Merlin Diyana.S, Gayathri.D, Kalpana.K

Abstract—This paper uses a FACTS device, UPFC for damping power oscillation in transmission systems as the power oscillations might increase risk of instability in the system and may also reduce power quality when the power system is being exposed to any disturbance. FACTS controllers permit newer approaches to system stabilization. In the proposed system, whenever power oscillations are detected due to any system disturbance the UPFC provides voltage support and improves the power system stability. The proposed system improves damping performance when compared with other methods. Harmonics is reduced in this proposed system. The quicker power oscillation damping using UPFC ensures smooth and reliable flow of the power through transmission line. This paper implements the control scheme and result is thus obtained for oscillations damping using Unified Power Flow Controller (UPFC) based on the computer simulations using the MATLAB software.

Keywords—Unified Power Flow Controller(UPFC), stabilization, Flexible AC Transmission System(FACTS), Power Oscillation Damping (POD

1. INTRODUCTION

The Electrical power systems are among the biggest basic accomplishments of man. The generators inside an interconnected system generally produce alternating current, which are synchronized to operate at similar frequency. In properly synchronized systems, the power is normally shared among all generators in the proportion of the rating of various generators, yet this can sometimes be adjusted by the administrator. With the help of frequency converters or current ties, the systems which are operating at different frequencies can also be interconnected [1]. For an efficient operation of interconnected system proper control mechanisms are essential. This can be achieved by combined operation of manual operators and automatic controllers. The power supplied by the generators under normal operating conditions can be controlled manually whereas adjustments needed in order to maintain voltage and frequency during violation of design limits is done by automatic controllers [2]. For this purpose speed governing mechanism are installed for automatic adjustment of prime mover which drives the generator in order to maintain the generator speed as constant. In order to maintain generator voltage as constant, voltage regulating system is used to adjust the generator's excitation[3]. These controls are fundamental for all interconnected power system to supply demanded power of the quality requested by the clients. Nonetheless, most programmed controls utilize negative feedback of higher gain, which, by its dynamic nature, can make oscillations develop rapidly with increase in time[4]. The programmed controls in power systems must, like other programmed input controls, be planned so that oscillations gets reduced rather than being increased. Electromechanical oscillations cause oscillation of power. There are several types of power oscillations. For example, interplant mode oscillations occur on rotational electric generators on that generator site itself [5]. Local plant mode oscillation occurs whenever the generators may swing against the remaining power system. Control mode oscillations occurs in generators when exciters, some of the governors, converters of HVDC and SVC are ill tuned [6].Power oscillations in power transmission systems, mainly in terms of local plant mode oscillations and inter-area power oscillations, are common phenomena in power transmission system with rotational electric generators [7]. The main causes of the power swings occurring transmission system are electromechanical oscillations of rotational generators due to fault of systems, transmission line switching, sudden change of output of generators and sudden change of critical loads. The oscillation can last for 20 seconds with low frequency which is lower than 2Hz [8]. Due to very low line resistive characteristic, transmission system's ability of oscillation damping of the transmission system internally maybe very low.

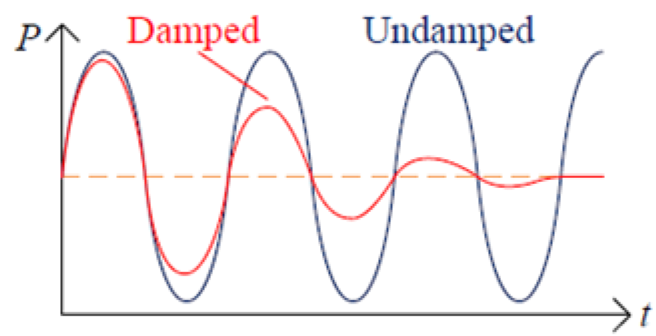

Fig.1. Oscillation damping

2. FACTS DEVICES

Flexible Alternating Current Transmission System (FACTS) is an recent advancement in which an equipment which is static is used for the electric power transmission. It can be used for the purpose of enhancing controllability and it increases the capability of power transmission in any of the networks[9]. This is based on power electronics control system. According to IEEE FACTS can be defined as "power electronics system along with any of the static equipments which provides required control of some of the parameters of AC transmission in in aim of improving the controllability and this may lead to increase of the capacity of power transmission[10].

Hence these devices finds wide range application for control of electric power transfer.

2.1. Shunt compensation:

This is a type of compensation, in which the FACTS device is to be connected parallel to power system. This can be classified into two categories:

2.1.1. Shunt capacitive compensation:

It is a kind of compensation which can be mainly used for power factor enhancement. Sometimes during the connection of inductive load in the transmission line, there may be a small lag in the power factor as there will be an lagging load current. For the purpose of compensating this, we are in an need of connecting an shunt capacitor in order for drawing leading current. As a result power factor will be improved[11].

2.1.2. Shunt inductive compensation:

Sometimes in receiving side whenever there is lower load is the main reason due to which a only less amount of load current flows across the transmission line. This may also happen when the line is being charged[12]. In order to amplify the voltage shunt capacitance can be used. At the receiving end of an long transmission line this may increase the voltage. For maintenance of these issues the use of shunt inductors are encouraged which may lead to overall increase in the capacity of the power transmission line. Thus it can be concluded that the usage of the shunt compensators will always result in improvement of the power factor which will finally result in enhancement of the much needed transmission line's power transfer capability.

2.2. STATCOM for power oscillation damping

STATCOM which is commonly called as Static Synchronous Condenser (STATCOM), can be commonly used as a device for regulation in power systems. STATCOM is generally a power electronics based VSC which may operated as reactive power source reactive power sink of reactive in the power system[13]. In some cases whenever it may be connected as a source it's main objective will be to provide active power to the system. This comes under FACTS device family. Since these devices can be used for the purpose of reduction in the voltage fluctuations this device can also be said as a device with inherent modularity. STATCOM which is generally a VSC device, in which the presence of voltage source is behind the reactor [14]. But in this case the STATCOM's active power capability is of lower range because the voltage we needed is created by the use of a DC capacitor. However, this can be overcome by connecting a suitable energy storage device across the DC capacitor which will thereby result in an increased active power capability. In this case the reactive power that is going to be present at the STATCOM terminals is to be determined by the amplitude of this voltage source. For example, in the event when VSC's voltage that is available at the terminal end is greater than that of the connection point's AC voltage, then in that case the STATCOM will produce certain amount of reactive current; on the other hand, absorption of reactive power will take place if the magnitude of the voltage source is lesser than that of the AC voltage[15]. The reaction time of a STATCOM is much shorter than the response time of a static VAR compensator (SVC), mostly because of the fact that the fast switching times of the IGBTs of the VSC[16]. STATCOM likewise gives a much better support of reactive power at even in case of very low voltages which is better than that of a SVC, because the reactive power output of a STATCOM will be starting to diminish directly with the AC voltage (as the current can be kept up at the evaluated esteem even in case of low voltages[17].

2.3. UPFC for power oscillation damping

In the proposed system UPFC based control scheme is implemented for power oscillation damping. UPFC is one among the most flexible FACTS equipments[18]. UPFC as a whole performs the functions of many devices like the static synchronous compensator (STATCOM), thyristor switched capacitor, thyristor controlled reactor and phase angle regulator which offers flexibility for both static and the dynamic operations of the power network[19]. All the electrical variables of the transmission network can be controlled by this device. FACTS devices always has various applications related to the operation and the control of power system, such as power oscillation damping, scheduling power flow, and improving transient stability of the system. Recently various studies on these FACTS devices and the impact they make on power system like power flow control, improving transient stability and small signal stability and oscillation damping are being carried out. Since UPFC has the most flexible characteristics among all FACTS devices, it is used for this purpose. It generally consists of a gain, signal washout block and many phase compensator blocks. By using the phase compensation techniques the parameters for the damping controller is obtained[20]. Signal washout is nothing but a high pass filter which has the tendency to prevent the steady changes in speed by the modification of the various parameters of the UPFC input. The representation of value of washout time constant is Tw which should always be higher enough in order to allow signals that are associated with oscillations in rotor speed to be unchanged. From washout function viewpoint, Tw value is not that much critical and it can also be in the range of 1 to 20s [21]. Unified Power Flow Controller (UPFC), which is a third generation representative of FACTS devices, is considered to be the most comprehensive device among the FACTS family since it exhibits better operation in power flow regulation, by controlling the line active and the reactive power reasonably and moreover, it has the tendency to improve the damping thus improving power angle stability [22]. This FACTS device named UPFC is made of solid state devices, due to this it is able to provide the essential functional flexibility that cannot be provided by the conventional thyristor using systems [23]. The UPFC used here will be the combined form of static synchronous compensator (STATCOM) and SSSC which are coupled via a link commonly a DC link [24]. A major application of the UPFC in a transmission line is the effective control of parameters like active and reactive power. UPFC will not operate during any disturbance or faults at the source side. The operation of UPFC is restricted only to a balanced sine wave source. The parameters such as phase angle, line reactance, and voltage can be controlled [25].

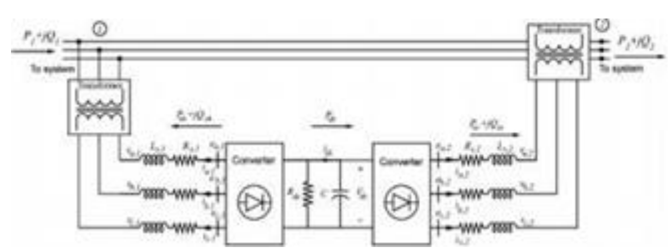

Fig.2 Control structure of UPFC

3.SIMULATION RESULTS

The oscillations are damped and the voltage and current waveform after damping is shown below:

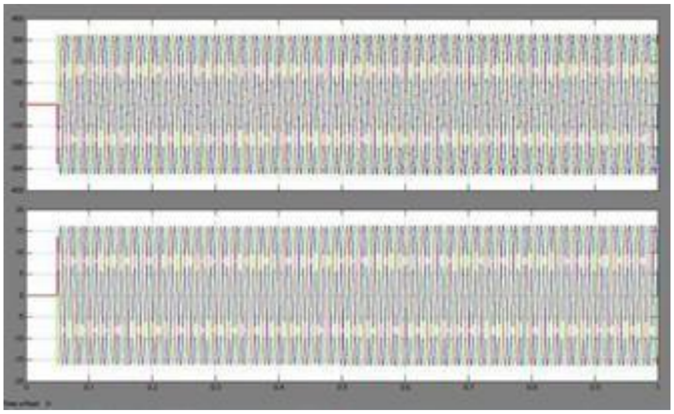

Fig.3 Voltage and current after damping

It is observed from the result that as soon as the oscillation occurs in the system, the UPFC connected across the system starts operating and it can also restore back the normal operating conditions. This will also result in improvement of system stability and thus paves way for efficient operation. The current waveform during this time is shown below:

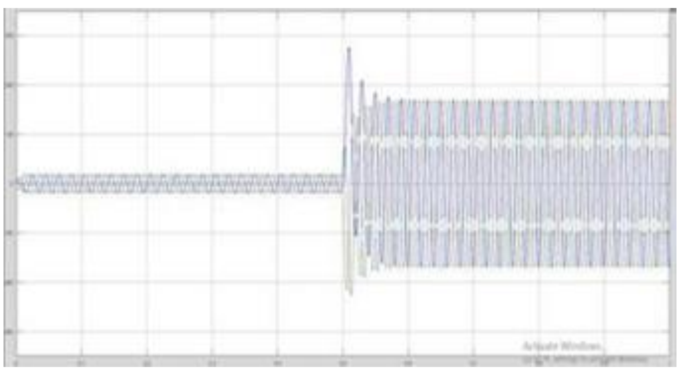

Fig.4 *Output current waveform*

From the above output waveform it can be inferred that as soon as an oscillation occurs in a system there is a sudden rise in current. The UPFC functions in order to reduce this rise and bring back the system to normal operating conditions. The UPFC hence is observed as an effective FACTS device in oscillation damping.

3.1. TOTAL HARMONIC DISTORTION

THD which is nothing but the total harmonic distortion can be defined as measurement of harmonic distortion that are found to be present in the signal and it can theoretically be defined as ratio of sum of the powers of all harmonic components to the power of the fundamental frequency.THD is an very important factor that is to be considered in any of the efficient power system and has to be always kept as lower as possible. Higher power factor which is to be required in a power system can also be achieved by maintaining lower value of THD and peak current value will be lower thus improving the overall efficiency. the nature of current and the nature of power factor is generally determined by the load. If these harmonics are allowed to exist in the system it may lead to various kinds of problem in the power system such as sudden rise in temperature of other equipments, reduction in the performance of other electrical components, change in behavior of protective elements, occurrence of resonance in other electrical equipments which may sometimes result in equipment failure, possibility of interference with communication lines, production of vibrations in electrical motors, occurrence of noise etc., Above all, one of the characteristic of harmonic current is it not only stays near the source but also start to spread throughout electrical distribution system by penetrating into them. This will automatically result in distortion of electric voltages for the end users which results in accumulation of harmonic effects.

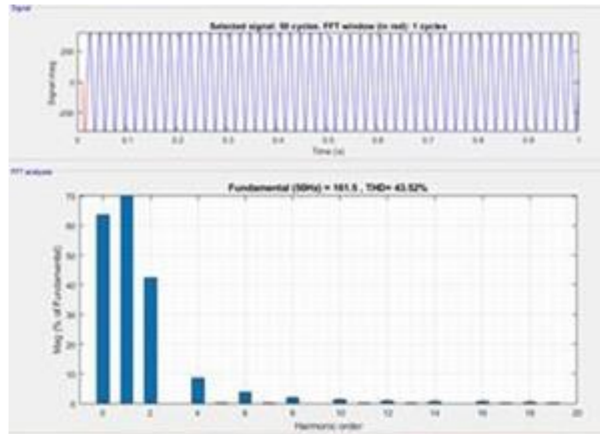

Fig.5 THD before operation of UPFC

The value of THD before the operation of UPFC is shown above. Similarly once the oscillations occur UPFC start operating which eventually reduce the value the THD. The value of THD after the operation of UPFC is shown below:

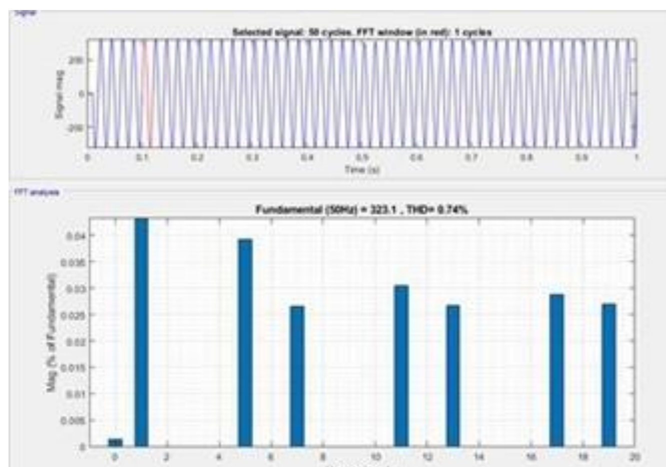

Fig.6 THD after the operation of UPFC

From the above THD results, it can be seen that the value of THD before the operation of UPFC is 43.525 and after the operation of UPFC it is only 0.74% only. Hence its is evident that UPFC plays a major role in damping of oscillations that are being produced in power system.

4. CONCLUSION

The UPFC is one of the FACTS device that can be used alternatively and it can also be expected to enhance the profit by providing savings for utilities who are in an motive to improve the capacity of power transmission. Implying this technology will require necessary agreements between utilities and other system regulators, inverter manufacturing companies and other solar farm developers. The proposed system explains that, whenever power oscillations that are caused due to any one of the system disturbances have been detected, then UPFC provides voltage support and improves the power system stability. The proposed system improves damping performance when compared with other methods. Harmonics is reduced in this proposed system. The THD value before the operation of UPFC was 43.52% and after the operation of UPFC the value of THD is 0.74%.

REFERENCES

[1] Arabi.S,Hamadanizadeh.H,andFardanesh.B.B.(2002),“ Convertible static compensator performance studies on the NY state transmission system”IEEE Trans. Power Systems, vol. 17, pp. 701-706.

[2] Bian.X.Y, Geng.Y, Lo.K.L, Fu.Y, and Zhou.Q.B.(2016), “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.

[3] Dhayalini.K & Mukesh .R, 2017, Optimal tracing based real power loss in transmission lines published in IEEE Xplore Digital Library, pp: 20-25.

[4] Eftekharnejad.S, Vittal.V, Heydt.G.T, Keel.B, and Loehr.J.(2013), “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.

[5] R. Manivasagam and V. Dharmalingam, "Power quality problem mitigation by unified power quality conditioner: An adaptive hysteresis control technique," *International Journal of Power Electronics,* vol. 6, pp. 403-425, 2014. Available at: https://doi.org/10.1504/ijpelec.2014.067442.

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

[7] Dhayalini. K, 2017, ‘Hybrid Particle Swarm Optimization - Genetic Algorithm Based Optimal Dispatch of Wind and Thermal System, Asian Journal of Research in Social Sciences and Humanities, vol. 7, no.1, pp 364 - 383.

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

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

[10] R. Manivasagam and D. Aarthi, "Design of UPFC using ten switch converter with switch reduction," *International Journal for Scientific Research & Evelopment,* vol. 5, pp. 490-493, 2017.

[11] Li.Y, Rehtanz.C, Ruberg.S, Luo.L, and Cao.Y.(2012), “Wide-Area Robust Coordination Approach of HVDC and FACTS Controllers for Damping Multiple Interarea Oscillations” IEEE Trans. Pwr Del., p1096-1105.

[12] Mathur.R.M and Varma.R.K.(2002),“Thyristor-based FACTS controllers for electrical transmission systems”John Wiley & Sons.

[13] Dhayalini. K, 2016, Optimization Of Wind-Thermal Coordination Dispatch Using Flower Pollination Algorithm, International Journal of Advancement in Chemistry, vol. 12, no.16, pp. 4963 – 4970.

[14] Mithulananthan.N, Canizares.C.A, Reeve.J, and Rogers.C.J.(2003), "Comparison of PSS, SVC, and STATCOM controllers for damping power system oscillations," IEEE Trans. Power Systems, pp. 786-792.

[15] Morjaria.M, Anichkov.D, Chadliev.V, and Soni.S.(2014), “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.

[16] R.Manivasagam & D Aarthi “Design and Implementation of UPFC Using Ten Switch Converter With Switch Reduction”, International Journal Of Engineering And Computer Science, vol.6,Issue.6, 2017 ,Page no. 21861-21869.

[17] Padiyar.K.R and Varma.R.K.(1991), “Damping torque analysis of static VAR system controllers” IEEE Trans. Power Systems, vol. 6, pp. 458-465, 1991.

[18] Raghavi, R ,Manivasagam.R, “Modeling of a Grid Connected New Energy Vehicle Charging Station” International Journal of Applied Engineering Research (IJAER), Volume 10, Number 20 (2015), Special Issues, pp. 15870- 15875.

[19] Sanchez-GascaJ.J.(1998),“Coordinated Control of Two FACTS Devices for Damping Inter-Area Oscillations,” IEEE Trans.Power Sys., Vol. 13, No. 2, pp. 428–434.

[20] R. Manivasagam, P. Parthasarathy, and R. Anbumozhi, "Robust analysis of T-S fuzzy controller for nonlinear system using H-infinity," *Advances in Intelligent Systems and Computing,* vol. 949, pp. 643-651, 2019. Available at: https://doi.org/10.1007/978-981-13-8196-6_56.

[21] Simoes.A.M, Savelli.D.C, Pellanda.P.C, Martins.N, and Apkarian.P.(2009), “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.

[22] Tamimi.B, Canizares.C, and Bhattacharya.K.(2013), “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.

[23] Tiba.C and Ricardo.E.D.(2012), “Siting PV plant focusing on the effect of local climate variables on electric energy production–Case study for araipina recife,” Renewable energy,vol 48

[24] Varma.R.K, Khadkikar.V, and Seethapathy.R, “Nighttime Application of PV Solar Farm as STATCOM to Regulate Grid Voltage," IEEE Trans. Energy Conversion, vol. 24, pp. 983-985, 2009.

[25] Xiao.Y, Song.Y, Liu.C, and Sun.Y.(2003),“Available transfer capability enhancement using FACTS devices” IEEE Trans. Power systems,vol.18.