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Reactive Power Management in Distribution System using UPFC

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ABSTRACT: In the present era, the quality of the power system should be more specific when it reaches customer ends. Key industrial loads need reactive power for nutritious magnetic field, for example, transformers, furnaces, induction motors etc. Reactive Power Compensation (RPC), a chief power quality issue in the distribution system, which affects the performance of the power system. The core fact behind reactive power compensation is the amplified system stability, better utilization of gadgets connected to the systems voltage regulation, dropping system losses associated with the system. The complete pillar of the compensating strategies and power electronic application in compensating devices is depicted in this paper. FACTS devices are energetic reactive power compensator capable of contributing reactive power to the grid and consuming reactive power from the grid. This paper proposes the UPFC, a FACTS device for the remuneration of reactive power. The compensation using the UPFC modeling is also discussed in this work. The UPFC normally mounted between source voltage and critical or sensitive load. The configuration of UPFC has been scheduled for improving voltage profile management and power factor performance for different sorts of loads in distribution system. UPFC is an effective degree to sustain voltage stability and improve power quality events of distribution system. The simulation is performed in MATLAB for UPFC and voltage source converter (VSC).

KEYWORDS: Reactive Power Management, UPFC, Distribution System, Power Quality, Power Factor, Voltage Stability.

I. INTRODUCTION

In power system, stability is one of the imperative features for consistent power supply. The reactive power compensation can be accomplished by using Flexible AC Transmission Systems devices (FACTS), which offers virtuous flexibility to control the active and reactive power flow and bus voltages in the power system. In India, there are still several villages or isolated areas which are not electrically coupled but to empower those deserted or isolated areas, the apt keys are microgrids. These microgrids can deliver continuous and lucrative electric power to such areas. For such microgrids, the hybrid grouping of non-conventional and conventional energy sources are sensible solutions because it crops cost-effective and eco-friendly power. But power quality is the vital tackle in such type of microgrids and an archetypal disadvantage is the voltage profile [1].

Even though every Distributed Generation (DG) unit amid the microgrid try to enact a stable voltage in the system, the existence of non-conventional energy sources conveys lot of voltage disparities in the system. Hence, power electronic-based convertor management tactics are implemented in the power system to sustain the output voltage stability. The compensation is usually accomplished for such hybrid power systems because the voltage disparity is quite evocable in the Renewable Energy System (RES) determined microgrids caused by the distinction in unbalanced load currents discussed in (Rodriguez et al., 2006) [2]. This request of reactive power to sustain the voltage stability is usually granted provincially at load centres. The presented compensation tactic depends on the inoculation of synchronous voltage base to the bus terminal depicted in (Azevedo et al., 2009) [3].

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In this paper, following sections designate a brief discussion of the matter and a simulation model that attests the event of voltage stability due to unbalanced loads are presented. An authoritative reactive power compensation approach has been implemented to fix it.

II. UNIFIED POWER FLOW CONTROLLER

The UPFC is a device which can regulate simultaneously all three parameters of line power flow (line impedance, phase angle and voltage). It is one of the FACTS family that used to optimum power flow in transmission. A Unified Power Flow Controller (UPFC) provides fast acting reactive power compensation on high voltage electricity transmission networks. The UPFC is a combination of static synchronous compensator (STATCOM) and static synchronous compensator (SSSC). The key factor for the wide spreads of UPFC are its ability to power flow bidirectional maintaining well-delimited DC voltage, workability in the wide range of effective conditions.

Apparently, the UPFC could be supporting Instantaneous governor of all essential power system parameters i.e. transmission voltage, phase angle and impedance. The controller can be rewarding functions of reactive series compensation, shunt compensation, and phase shifting meeting multiple control objects. From a practical perspective, the purposes are met by applying a boosting transformer inoculated voltage also an exciting transformer reactive current. The inoculated voltage is interleaved done by a series transformer [4]. In addition to this, transformers, the general edifice of Unified Power Flow Controller (UPFC) encompasses besides a "back to back" AC to DC voltage source converters functioned from a shared DC Link capacitor.

The UPFC is lately introduced FACTS controller, it is having the competence to control all the distribution parameters. UPFC achieves the functions of diverse FACTS devices like SVC, TCSC, STATCOM, D-STATCOM and the phase angle regulator and it also offers additional flexibility by merging some of the functions of these controllers. It enhances voltage stability and active and reactive power flow in distribution system [6]. Thus, sheltered loading can be done, hence it also rises and alleviates the stability in the power systems. UPFC entails of two voltage-sourced converters (VSCs) which are coupled to each other with a common dc link. Its series converter enclosures controllable magnitude and controllable phase angle of ac voltage in series with our distribution system [7].

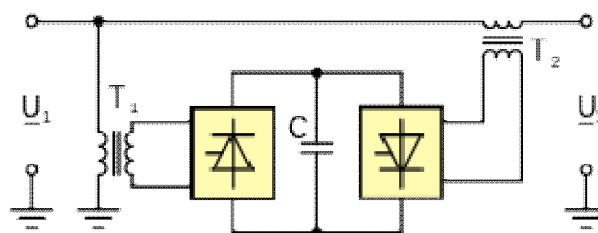


Fig.1 Basic Structure of UPFC

The configuration of UPFC can be considered as a compound system of STATCOM and SSSC sharing a common dc link capacitor. However, UPFC has direct control capability of the real and reactive powers through transmission line [8]. Fig. 1 depicts the basic structure of UPFC and it consists of two converters namely, STATCOM and SSSC. Both perform the optimal power flow of the UPFC. Moreover, UPFC works only at balanced load. If any disturbance occurred it restricted work.

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Fig. 2 Power exchange of the Shunt Converter

Fig. 2 explains the Power exchange of the Shunt Converter. Fig. 2 shows the transfer of the reactive power between the UPFC and the electrical system. The shunt converter produces a voltage V_{s1} in phase with VA but with variable magnitude. If $V_s = V_{s1}$. The UPFC injects some reactive power, if $V_s = V_{s2}$ the UPFC fascinates some reactive power and no reactive power is transferred for $V_s = VA$ [9].

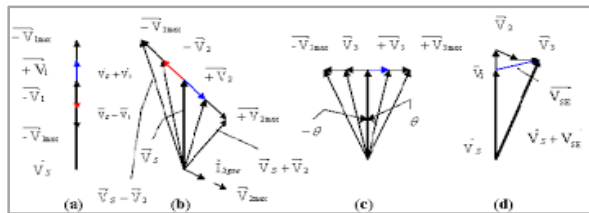


Fig. 3 Series Voltage Injected Phasor diagrams.

As demonstrate in figure 3, by the appropriate control of phasor V_{se} , the three regular power flow control functions:

- 1) Voltage regulation
- 2) Phase Shift.
- 3) Series reactive compensation.

Simultaneous control of terminal voltage, line impedance and phase angle consent the UPFC to accomplish multifunctional power flow control.

III. MATHEMATICAL MODELLING OF UPFC

A. MODELING OF SERIES CONVERTER

To advance the series converter model, Kirchhoff's voltage equations (KVL) for the phase 'a' of the series branch can be written as

$$L_{se} \frac{di_{a1}}{dt} + i_{a1} r_{se} = V_{ta} - V_{ra} + V_{sa} \tag{1}$$

Likewise, the KVL equations can be written for phases 'b' and 'c'. The KVL equations for three phases in matrix form can be written as follows.

$$\frac{d}{dt} \begin{bmatrix} i_{a1} \\ i_{b1} \\ i_{c1} \end{bmatrix} = \begin{bmatrix} \frac{-r_{se}}{L_{se}} & 0 & 0 \\ 0 & \frac{-r_{se}}{L_{se}} & 0 \\ 0 & 0 & \frac{-r_{se}}{L_{se}} \end{bmatrix} \begin{bmatrix} i_{a1} \\ i_{b1} \\ i_{c1} \end{bmatrix} + \frac{1}{L_{se}} \begin{bmatrix} v_{ta} & -v_{ra} & +v_{ca} \\ v_{tb} & -v_{rb} & +v_{cb} \\ v_{tc} & -v_{rc} & +v_{cc} \end{bmatrix} \tag{2}$$

Equation (2) affects to a-b-c reference frame. To comfort the complexity, these equations are malformed from a-b-c reference frame to synchronous d-q reference frame keeping V_t as reference ($V_{td}=V_t$, $V_{tq}=0$). The differential equations for d-q components of series branch current can be inscribed as

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$$\frac{di_{d1}}{dt} = \frac{-r_{se}}{l_{se}} i_{d1} + \omega i_{q1} + \frac{1}{l_{se}} (v_{td} - v_{rd} - v_{cd}) \quad (3)$$

B. MODELING OF SHUNT CONVERTER

Scheduled in a similar way, the differential equations for the shunt converter currents are given by

$$\frac{di_{d2}}{dt} = \frac{-r_{sh}}{l_{sh}} i_{d2} - \omega i_{q2} + \frac{1}{l_{sh}} (v_{td} - v_{pd}) \quad (4)$$

$$\frac{di_{q2}}{dt} = \frac{-r_{sh}}{l_{sh}} i_{q2} - \omega i_{d2} + \frac{1}{l_{sh}} (v_{pq} - v_{tq}) \quad (5)$$

C. MODELING OF DC LINK CAPACITOR VOLTAGE

In general, the triumph of UPFC rest on the stability of the dc link voltage among the series and shunt converters. Even though, during active conditions, the input power to the shunt converter should be equal to the sum of series injected power and the rate of change of stored energy in the capacitor on an instantaneous basis. Consequently, by power balance we obtain the equation below [10].

$$P = \frac{3}{2} (-v_{dp} i_{d2} - v_{pq} i_{q2} - v_{cd} i_{d1} - v_{cq} i_{q1}) = C v_{dc} \frac{dv_{dc}}{dt} + \frac{v_{dc}^2}{r_{dc}} \quad (6)$$

$$v_{dc} = \frac{2}{3v_{dc}} [-v_{dp} i_{d2} - v_{pq} i_{q2} - v_{cd} i_{d1} - v_{cq} i_{q1}] - \frac{v_{dc}}{cr_{dc}} \quad (7)$$

Henceforth above equation (7) and (8) directs the dc-link capacitor voltage of UPFC.

IV.SIMULATION AND RESULTS

The analysis is done on single phase basis. The simple power system encompasses of a single-phase voltage source, transmission line and an impedance load. The real and the reactive power flow are attained from the simulation with and without compensation. The Simulink archetypal for the uncompensated system is shown in Fig. 4. Moreover, Fig.5 to 10 depicts the simulation results [11,12].

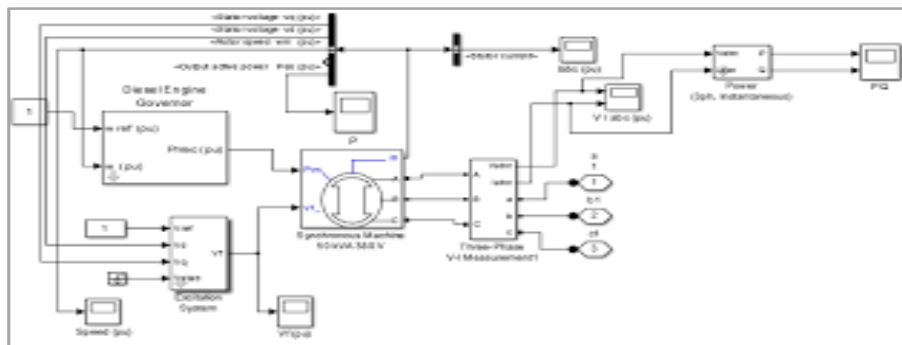


Fig. 4 Simulink Model of UPFC



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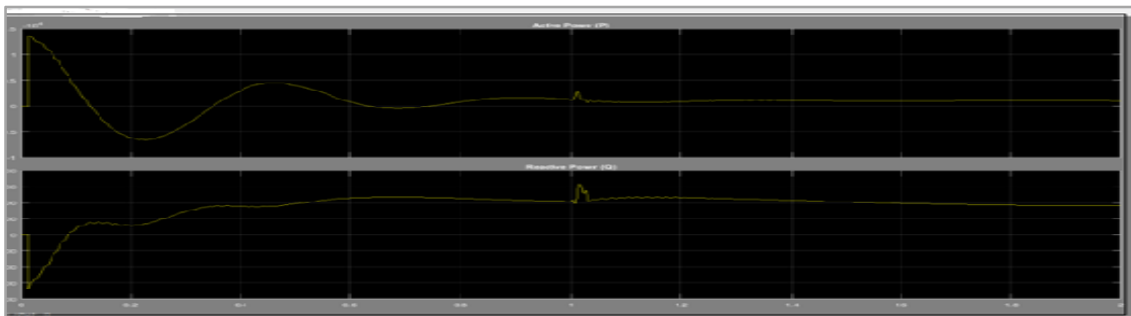


Fig. 5 Active and Reactive Power without UPFC

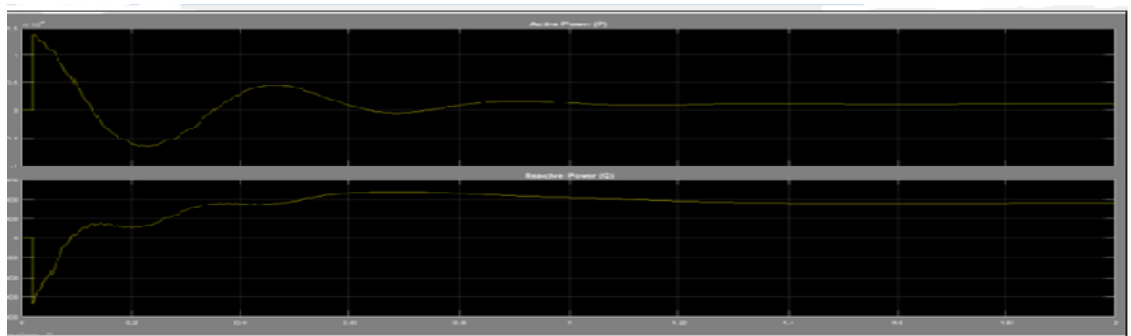


Fig. 6 Active and Reactive Power With UPFC

In general, Fig.5 and Fig. 6 shows the active and reactive power flow. To clarify, without UPFC the real and reactive power varies slowly with harmonics. After addition of UPFC it become harmonic free and also et more precise real and reactive power.

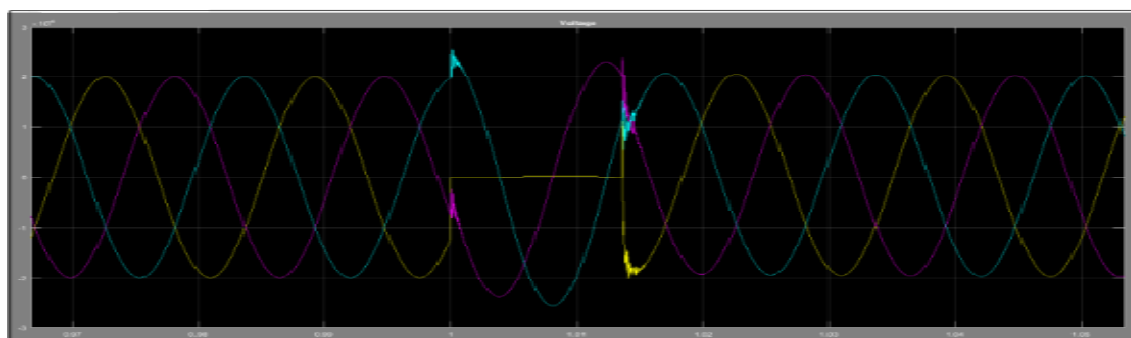


Fig. 7 Grid Voltage Without UPFC

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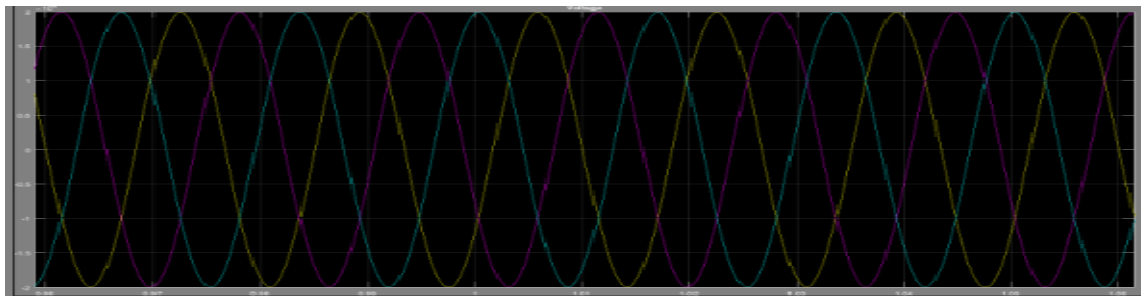


Fig. 8 Grid Voltage With UPFC

To enumerate, both Fig.7 and 8 illustrates the grid voltage through fault condition without andwith UPFC. In fact, the grid voltage without using UPFC is 25.84% and with UPFC it compacts to 5.13%. Subsequently by adding UPFC the grid voltage become more accurate than without UPFC. The output become sine wave without any disturbances.

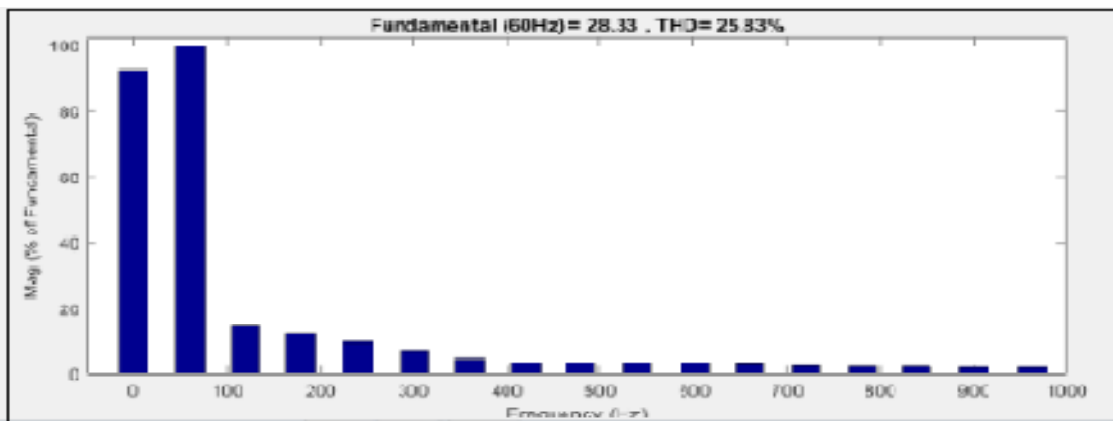


Fig.9 THD without UPFC

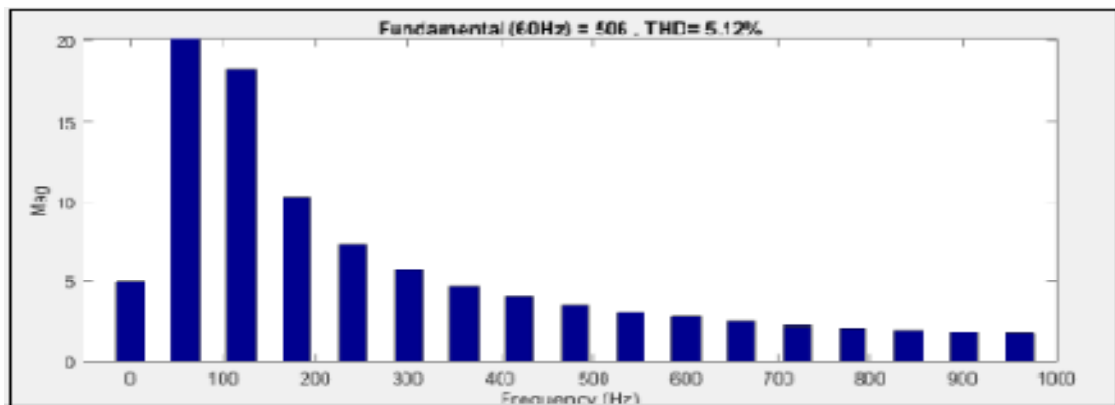


Fig.10THD with UPFC



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The THD of line voltage without UPFC and with UPFC is shown in fig.9 and fig.10 respectively. THD without UPFC the number of harmonics less than that of with UPFC. Thus, the value of THD reduced from 25.33% to 5.12%.

V. CONCLUSION

In brief, the simulation and modeling of UPFC in MATLAB SIMULINK toolbox and its detailed simulation analysis directs D-STATCOM as an active decision for overall compensation. The UPFC can be hence used to tackle problems associated to the Power Quality events. Moreover, this has been authorized by extensive computer simulation. The concert of UPFC is found to be satisfactory under nonlinear. In a nutshell, UPFC can regulate reactive power and also adjust the bus voltage. In addition to this, THD level also improved by using UPFC. In a nutshell, UPFC is one of the most versatile devices based on concept collective series-shunt FACTS controllers. By using UPFC we can increase the transient and stability of the grid system.

UPFC provides better utilization of existing distribution system.

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