

# **Design and Analysis of Active Filter based Unbalanced Load Correction**

<sup>1</sup>Dr.C.Nagarajan, <sup>2</sup> R.Srinivasan, <sup>3</sup>M.Suritha

<sup>1</sup>Professor, Department of EEE, Muthayammal College of Engineering, Rasipuram, Tamilnadu, India

<sup>2</sup>Assistant Professor, Department of EEE, Muthayammal College of Engineering, Rasipuram, Tamilnadu, India

<sup>3</sup>PG Scholar, Department of EEE, Muthayammal College of Engineering, Rasipuram, Tamilnadu, India

**ABSTRACT:** Three-phase four-wire distribution systems have been widely used in commercial and industrial installations. The neutral conductor carries the zero sequence current due to the unbalanced loading among the phase conductors. However, as electronic loads increase, their rectifier front-ends reduce significant harmonic current. The triplet harmonic current produced by these loads tends to accumulate in the neutral conductor due to its zero sequence nature, thus resulting in overloading of the neutral conductor and the distribution transformer. Most of the existing harmonic mitigation schemes focus on re-directing zero sequence current harmonics back to the phase conductors. Such schemes can prevent overloading of the distribution transformer, but the neutral conductor is still burdened by the excessive current harmonics.

This paper proposes a new harmonic suppression scheme for the neutral conductors of three-phase four-wire distribution systems. In the proposed scheme, an active filter is connected in series with the neutral conductor. The inverter acts to suppress harmonic current in the neutral conductor to prevent overloading. The active filter operation will not affect the fundamental component due to the unbalanced loading, which the neutral conductor is sized for. The proposed scheme can eliminate current harmonics overloading on both the neutral conductor and the distribution transformer with only one active filter installation.

## **I. INTRODUCTION**

Three-phase four-wire distribution systems have been widely employed to deliver electric power to single-phase or three-phase loads. The neutral conductor usually carries the zero sequence current due to the unbalanced loading among phase conductors. As more and more electronic equipments such as computers, copy machines and adjustable speed drives being used, the harmonic currents drawn by their rectifier front ends also become significant. Especially, the zero sequence triplet ( $3^{rd}$ ,  $9^{th}$ , and  $15^{th}$ ) harmonics accumulate in the neutral conductor, thus result in overloading of the neutral conductor and the distribution transformer. Survey results across sites indicate that 22.6% of the sites have neutral currents exceeding the full-load phase current. Inductive ballasts also inject considerable harmonics in neutral conductors, fire has been reported due to such overloading incident. Several schemes have been proposed to reduce the current harmonics of the neutral conductor, such as zig-zag transformer arrangement, active filter systems based on power electronics components, and the combination of both. The Instantaneous Reactive Power theory has been adopted to calculate the harmonics compensation command for some of the aforementioned schemes. Albeit their different circuit topologies, the above schemes use the active filter systems to provide a path between phase conductors and the neutral conductor, so the zero sequence current can circulate from the loads to the active filter systems via the neutral conductor and then back to the phase conductors. This approach eliminates the undesired current component in the portion of the neutral conductor that lies between the active filter system and the distribution transformer. But the rest of the neutral conductor still carries the excessive current harmonics, thus the danger of overloading still exists. The proposed concept consists of two-levels. A low level controller, which is designed based on the inverter and phase-locked loop (PLL) system, regulates the power output and the terminal voltage. The active filter can be implemented by a hard-switched IGBT inverter operating in pulse width modulation (PWM) mode. The Fuzzy Logic based PI controller is used to control the DC output from the Solar Panel and the Switching Devices a bypass switch is provided in case the active filter is shutdown.

# International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Special Issue 6, May 2015

## II. LC CIRCUIT

An LC circuit, also called a resonant circuit, tank circuit, or tuned circuit, consists of an inductor, represented by the letter L, and a capacitor, represented by the letter C. When connected together, they can act as an electrical resonator, an electrical analogue of a tuning fork, storing energy oscillating at the circuit's resonant frequency. LC circuits are used either for generating signals at a particular frequency, or picking out a signal at a particular frequency from a more complex signal. They are key components in many electronic devices, particularly radio equipment, used in circuits such as oscillators, filters, tuners and frequency mixers.

An LC circuit is an idealized model since it assumes there is no dissipation of energy due to resistance. Any practical implementation of an LC circuit will always include loss resulting from small but non-zero resistance within the components and connecting wires. The purpose of an LC circuit is usually to oscillate with minimal damping, so the resistance is made as low as possible. While no practical circuit is without losses, it is nonetheless instructive to study this ideal form of the circuit to gain understanding and physical intuition. An LC circuit can store electrical energy oscillating at its resonant frequency. See the animation at right. A capacitor stores energy in the electric field( $E$ ) between its plates, depending on the voltage across it, and an inductor stores energy in its magnetic field ( $B$ ), depending on the current through it.

If a charged capacitor is connected across an inductor, charge will start to flow through the inductor, building up a magnetic field around it and reducing the voltage on the capacitor. Eventually all the charge on the capacitor will be gone and the voltage across it will reach zero.

However, the current will continue, because inductors resist changes in current. The energy to keep it flowing is extracted from the magnetic field, which will begin to decline. The current will begin to charge the capacitor with a voltage of opposite polarity to its original charge. When the magnetic field is completely dissipated the current will stop and the charge will again be stored in the capacitor, with the opposite polarity as before.

Then the cycle will begin again, with the current flowing in the opposite direction through the inductor. The charge flows back and forth between the plates of the capacitor, through the inductor. The energy oscillates back and forth between the capacitor and the inductor until (if not replenished by power from an external circuit) internal resistance makes the oscillations die out. Its action, known mathematically as a harmonic oscillator, is similar to a pendulum swinging back and forth, or water sloshing back and forth in a tank. For this reason the circuit is also called a tank circuit. The oscillation frequency is determined by the capacitance and inductance values. In typical tuned circuits in electronic equipment the oscillations are very fast, thousands to millions of times per second

## III. RESONANCE

The resonance effect occurs when inductive and capacitive reactance are equal in magnitude. The frequency at which this equality holds for the particular circuit is called the resonant frequency. The resonant frequency of the LC circuit is

$$\omega_0 = \frac{1}{\sqrt{LC}}$$

Where  $L$  is the inductance in henries, and  $C$  is the capacitance in farads. The angular frequency  $\omega_0$  has units of radians per second. The equivalent frequency in units of hertz is

$$f_0 = \frac{\omega_0}{2\pi} = \frac{1}{2\pi\sqrt{LC}}$$

LC circuits are often used as filters; the  $L/C$  ratio is one of the factors that determine their "Q" and so selectivity. For a series resonant circuit with a given resistance, the higher the inductance and the lower the capacitance, the narrower the filter bandwidth. For a parallel resonant circuit the opposite applies. Positive feedback around the tuned circuit ("regeneration") can also increase selectivity. Stagger tuning can provide an acceptably wide audio bandwidth, yet good selectivity.

# International Journal of Innovative Research in Science, Engineering and Technology

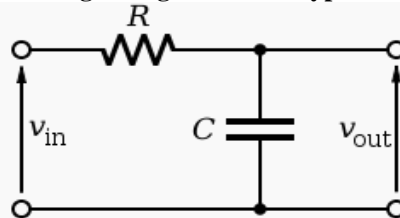
(An ISO 3297: 2007 Certified Organization)

Vol. 4, Special Issue 6, May 2015

## IV. POWER QUALITY AND HARMONICS

The load exerted by harmonics on the power network infrastructure has increased dramatically over the past few years. Harmonic currents are caused by non-linear loads. A non-linear load is a consumer of electricity that draws a non-sinusoidal current from the supply network when supplied with a sinusoidal voltage. These harmonic currents flow in addition to the “active” sine wave, generate additional losses in electrical installations, and can result in thermal overload. Harmonic currents flow through the system impedance, resulting in non-sinusoidal voltage drops that can compromise network voltage quality. Sensitive loads, such as medical devices or IT infrastructure, can have their operation affected if the voltage supply is distorted.

Fig.1.Single elements types



A low-pass electronic filter realized by an RC circuit

The simplest passive filters, RC and RL filters, include only one reactive element, except hybrid LC filter which is characterized by inductance and capacitance integrated in one element.

### L FILTER

An L filter consists of two reactive elements, one in series and one in parallel.

*T and π filters*

FIG.2. CAPACITOR INPUT FILTRR

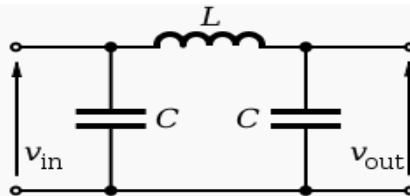
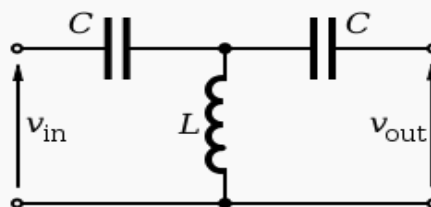


FIG 3.3 LOW PASS π FILTER



## V. DIFFERENT TYPES OF OPERATING MODES

### 1. Voltage control mode

Most applications call for a supply to be used as a voltage source. A voltage source provides a constant output voltage as current is drawn from 0 to full rated current of the supply. In these applications, the power supply runs in voltage mode, maintaining a constant output voltage while providing the required current to the load. A voltage source is generally modeled as providing a low output impedance of the supply. When configured as a **Controlled Voltage** source (voltage amplifier), the amplifier will provide an output voltage that is constant and proportional to the control (input) voltage. If the load's impedance changes, the amplifier will seek to maintain this ratio of input to output

# International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Special Issue 6, May 2015

voltage by increasing or decreasing the current it produces, as long as it is within the amplifier's ability to create the required current. Use this mode if you want the output voltage waveform to be like the input waveform. But whichever design technique is employed, there is a high probability that regulation will employ a PWM technique of (typically) a fixed frequency. (A constant-switching frequency is desirable because it limits electromagnetic interference (EMI) generated by the power supply. In a voltage-mode controlled regulator, the PWM signal is generated by applying a control voltage ( $V_C$ ) to one comparator input and a saw tooth voltage ( $V_{ramp}$ ) (or "PWM ramp") of fixed frequency,(FigureS1).

The duty cycle of the PWM signal is proportional to the control voltage and determines the percentage of the time that the switching element conducts and therefore, in turn, the output voltage (see the Tech Zone article "Using PFM to Improve Switching DC/DC Regulator Efficiency at Low Loads". The control voltage is derived from the difference between the actual-output voltage and the desired-output voltage (or reference voltage). The modulator gain  $F_m$  is defined as the change in control voltage that causes the duty cycle to go from 0 to 100 percent ( $F_m = d/V_C = 1/V_{ramp}$ ).<sup>1</sup>

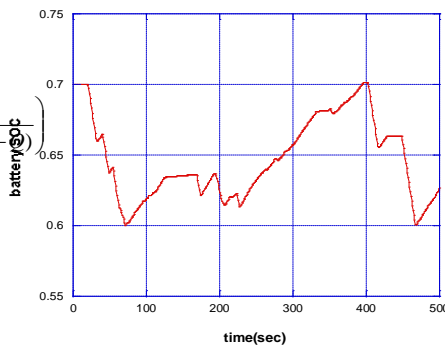
## VI. GENERAL NOTIONS FOR BATTERY

Before a mathematical model for the battery is presented, some fundamental concepts of the battery are briefly reviewed:

**Nominal capacity  $q_{max}$**  - is the number of ampere-hours (Ah) that can maximally be extracted from the battery, under predetermined discharge conditions

$$V(t) = V_c - g_c \left(1 - \frac{Q}{C}\right) + R_c I \left(1 + \frac{M_c Q}{CC_c - Q}\right)$$

$$V(t) = V_d - g_d \frac{C - Q}{C} + R_d I \left(1 + \frac{M_d (C - Q)}{C(1 + C_d) - (C - Q)}\right)$$



## VII. SIMULATION RESULTS

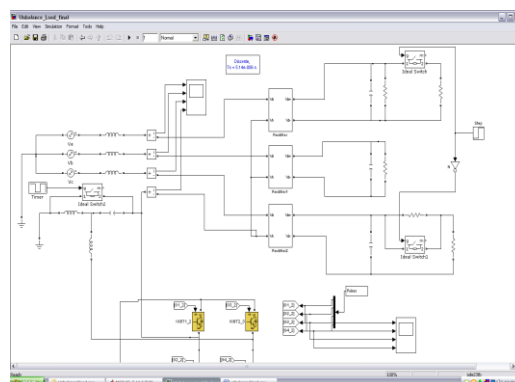


FIG 7.1 SIMULATION DIAGRAM

# International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Special Issue 6, May 2015

OUTPUT:

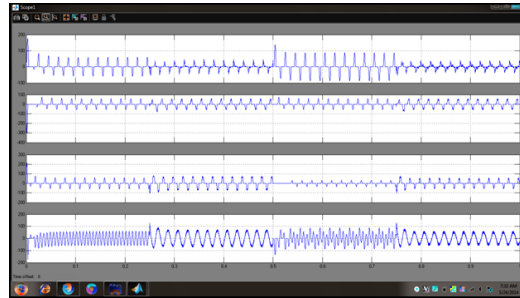


FIG 7.2 OUTPUT

PULSES:

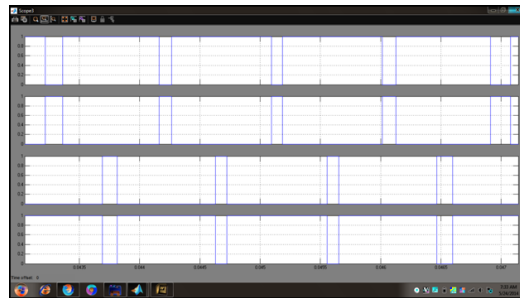


FIG 7.3 PULSES

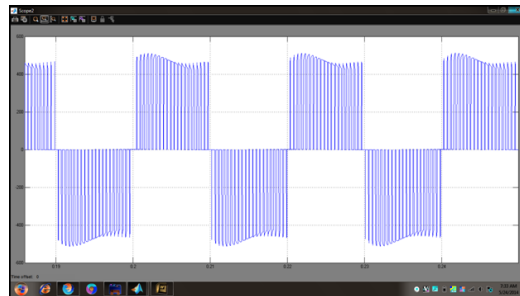


FIG 7.4 OUTPUT

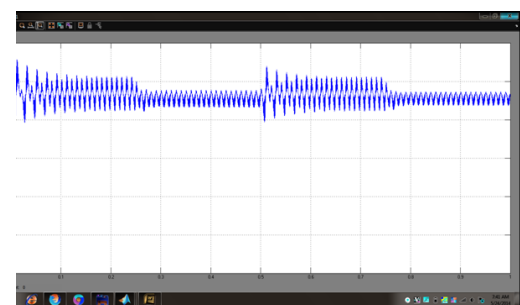


FIG7. 5 OUTPUT

## VIII. CONCLUSION

Micro grids can have significant distribution losses because of their lower voltage levels. They require a voltage control algorithm that works in a plug-and-play way. In this paper, we proposed two decentralized voltage control algorithms that are derived from a cost function that minimizes power losses over the grid network. Computer based simulation

# International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Special Issue 6, May 2015

showed that the algorithm can work reliably without knowledge of the operating conditions and grid structure. When communications are not available, the control algorithm still works well in many cases but the performance deteriorates noticeably compared with the case with communication.

## REFERENCES

- [1] N. G. Hingorani and L. Gyugyi, Understanding FACTS: Concepts and Technology of Flexible AC Transmission Systems. New York, NY, USA: Wiley-IEEE Press, 1999.
- [2] E. Acha, C. R. Fuerte-Esquivel, H. Ambriz-Perez, and C. Angeles-Camacho, FACTS Modeling and Simulation in Power Networks. New York, NY, USA: Wiley, 2005.
- [3] C. Nagarajan and M. Madheswaran - 'Performance Analysis of LCL-T Resonant Converter with Fuzzy/PID Using State Space Analysis'- Springer, Electrical Engineering, Vol.93, March 2011.
- [4] C. Nagarajan and M. Madheswaran, Stability Analysis of Series Parallel Resonant Converter with Fuzzy Logic Controller Using State Space Techniques", Taylor & Francis, Electric Power Components and Systems, Vol.39 (8), pp.780-793, 2011.
- [5] C. Nagarajan and M. Madheswaran - 'Experimental verification and stability state space analysis of CLL-T Series Parallel Resonant Converter' - Journal of ELECTRICAL ENGINEERING, Vol.63 (6), pp.365-372, Dec.2012.
- [6] C. Nagarajan and M. Madheswaran - 'Analysis and Implementation of LLC-T Series Parallel Resonant Converter with Fuzzy controller'- International Journal of Engineering Science and Technology (IJEST), Applied Power Electronics and Intelligent Motion Control. Vol.2 (10), pp 35-43, December 2010
- [7] C. Nagarajan and M. Madheswaran - 'Performance Estimation of LCL-T Resonant Converter with Fuzzy / PID Controller'- International Journal of Computer and Electronic Engineering (IJCEE), Vol.2 (3), pp.534-542, June 2010
- [8] C. Nagarajan, M. Madheswaran and D. Ramasubramanian- 'Development of DSP based Robust Control Method for General Resonant Converter Topologies using Transfer Function Model'- Acta Electrotechnica et Informatica Journal , Vol.13 (2), pp.18-31, April-June.2013
- [9] C. Nagarajan and M. Madheswaran - 'DSP Based Fuzzy Controller for Series Parallel Resonant converter'- Springer, Frontiers of Electrical and Electronic Engineering, Vol. 7(4), pp. 438-446, Dec.12.
- [10] C. Nagarajan and M. Madheswaran - 'Experimental Study and steady state stability analysis of CLL-T Series Parallel Resonant Converter with Fuzzy controller using State Space Analysis'- Iranian Journal of Electrical & Electronic Engineering, Vol.8 (3), pp.259-267, September 2012.
- [11] C. A. Cañizares, "Power flow and transient stability models of FACTS controllers for voltage and angle stability studies," in Proc. IEEE PES Winter Meeting 2000, 2000, vol. 2, pp. 1447-1454.
- [12] E. Barrios-Martinez, C. Angeles-Camacho, E. Acha, and M. A. Olguin-Becerril, "Dynamic phase-domain modelling and simulation of STATCOM in large-scale power systems," in Proc. IEEE Power TechConf. 2009, Bucharest, Romania, 2009, pp. 1-9.
- [13] S. F. Faisal, A. H. M. A. Rahim, and J. M. Bakhshwain, "A robust STATCOM controller for a multi-machine power system using particleswarm optimization and loop-shaping," Int. J. Elect. Commun. Syst. Eng., pp. 64-70, 2007.
- [14] G. Shahgholian, M. Mahdavian, A. Etesami, S. Moalem, and M. Jabbari, "Improvement of dynamic behavior and system stability by using STATCOM," in Proc. IEEE Int. Symp. Industrial Electronics, 2011, pp.1057-1062.
- [15] M. Mahdavian and G. Shahgholian, "Effect of STATCOM on enhancing power system dynamic stability," in Proc. IEEE Int. Conf. Elect. Eng., Comput., Telecomm., and Inf. Technol. (ECTI), 2011, pp.780-783.