**Proceedings of Second Shri Chhatrapati Shivaji Maharaj QIP Conference on Engineering Innovations**
**Organized by Shri Chhatrapati Shivaji Maharaj College of Engineering, Ahmednagar**
***In Association with Novateur Publications JournalNX-ISSN No: 2581-4230***
**February, 22nd and 23rd, 2019**

# Comparative Analysis of FBD,PQ,and CPT current Decomposition:Three Phase Three-Wire Systems

Nemane Priyanka Shivaji
Electrical
GHRIET,Pune
Pune, India
priyankanemane26@gmail.com

Dr.Mittal Shailendra K.
Electrical
GHRIET,Pune
Pune, India
shailendra.mittal@raisoni.net

*Abstract*— **This seminar investigates the main similarities and discrepancies among three important current decompositions proposed for the consideration of unbalanced and/or nonlinearthree-phase three-wire power circuits. The considered approaches were the so called FBD Theory, the pq-Theory and the Conservative Power Theory (CPT), recently presented by Tenti*et al.*. Such decompositions and related definitions may influence the power measurement techniques, revenue metering, instrumentation technology and also power conditioning strategies. The three methods have been summarized, discussed and compared by means of computational simulation. Although the three methods are based on different concepts, the results obtained under ideal conditions are very similar. The main differences appear in the presence of unbalanced and non linear load conditions. Under linear unbalanced conditions, both FBD and pq-Theory suggest that the some current components contain a third-order harmonic. Besides, neither pq-Theory nor FBD method are able to provide accurate information for reactive current under unbalanced and distorted conditions, what can be done by means of the CPT-Theory. The paper tries to explain the causes of these differences in terms of the decomposition's foundations and the resulting waveforms and spectra.**

***Keywords—FBD,CPT,PQ,power theory,instantaneous power.***

## I. Introduction

The worldwide search for a generalized power theory, applicable for power systems under non-sinusoidal and/or unbalanced conditions, has mostly been motivated by the ever increasing of power electronic converters utilization. It point out the major requirement of improvement and adaptation of reactive/harmonic compensators technology and revenue metering techniques under such conditions.

In this sense, numerous new power theories have been defined, and several of them are based on the frequency domain to describe suitable power and current terms under non-sinusoidal and unbalanced conditions. On the other hand, giving special emphasis to instantaneous quantities, other important current decompositions and power definitions has been However, despite of the enormous efforts already spent, there is still no complete agreement on several current decompositions and related power definitions. Most of the misunderstanding is probably caused since several authors usually had presented their contributions directed to a specific application, instead of discussing a general applicable power theory. Thus, considering just the time domain approaches, one could call attention to the proposals of Depenbrock (FBD) ,Akagi*et al.* (*pq*-Theory) and Tenti*et al.* (CPT) ,which are strongly related to power conditioning applications.

**Literature survey**

**Bhende,C.N.,Mishra, S.,&Malla, S.G [1]**. stated a novel algorithm, based on dc link voltage, is proposed for effective energy management of a stand-alone permanent magnet synchronous generator (PMSG)-based variable speed wind energy conversion system consisting of battery, fuel cell, and dump load (i.e., electrolyzer). Moreover, by maintaining the dc link voltage at its reference value, the outpu tac voltage of the inverter can be kept constant irrespective of variations in the wind speed and load

**Kroposki, B., Pink, C., DeBlasio, R., Thomas, H., Simoes, M., &Sen, P [3]** presented the study on Optimization of overall electrical system performance is important for the long-term economic viability of distributed energy (DE) systems. With the increasing use of DE systems in industry and its technological advancement, it is becoming more important to understand the integration of these systems with the electric power systems. New markets and benefits for distributed energy applications include the ability to provide ancillary services, improve energy efficiency, enhance power system reliability, and allow customer choice. Advanced power electronic (PE) interfaces will allow DE systems to provide increased functionality through improved power quality and voltage/VAR support, increase electrical system compatibility by reducing the fault contributions, and flexibility in operations with various other DE sources, while reducing overall interconnection costs. This paper examines the system integration and optimization issues associated with DE systems and show the benefits of using PE interfaces for such application.

## II MAJOR THEORIES

### FBD THEORY

The FBD (Fryze-Buchholz-Depenbrock) method is an extension of the Fryze and Buchholz theories, on which Depenbrock makes use of Fryze's current decomposition and Buchholz's instantaneous and RMS collective values for the definition of new current decompositions. Such currents were also applied to the calculation of novel power components and for the proposition of compensation strategies .With the correct considerations, the FBD method can be applied in any multiphase power circuit, which can be represented by a uniform circuit on which none of the conductors is treated as an especial conductor.

**Active currents ($i_{a\mu}$)**: responsible for the transference of average energy to the load.

**Nonactive currents ($i_{n\mu}$)**: associated to any type of disturbance and oscillations that affect the instantaneous power, but do not transfer average energy to the load.

**Power currents ($i_{p\mu}$)**: responsible for the instantaneous power, including possible oscillations related with harmonic and unbalances.

**Powerless currents ($i_{z\mu}$):** they do not contribute for the energy conveyance and can be compensated instantaneously without the necessity of energy storage elements.

**Variation currents ($i_{v\mu}$):** responsible for the oscillation of the instantaneous equivalent conductance $G_E$ around its average value $G_E$

$$||\mathbf{i}_\mu||^2 = ||\mathbf{i}_{a\mu}||^2 + ||\mathbf{i}_{n\mu}||^2 = ||\mathbf{i}_{a\mu}||^2 + ||\mathbf{i}_{v\mu}||^2 + ||\mathbf{i}_{z\mu}||^2$$

## PQ-THEORY

The instantaneous power theory proposed by Akagi*et al*,is usually known as *pq*-Theory. This theory is based on the Clarke transformation of voltages and currents in three phase systems (*a*,*b*,*c*) into(α,β,0) orthogonal coordinates.
**Zero-sequence power** "$p_0$" (just in case of four-wire system), the **real power** "*p*" and the **imaginary power** "*q*"

$$\begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} = \begin{bmatrix} i_{a0} \\ i_{b0} \\ i_{c0} \end{bmatrix} + \begin{bmatrix} i_{ap} \\ i_{bp} \\ i_{cp} \end{bmatrix} + \begin{bmatrix} i_{aq} \\ i_{bq} \\ i_{cq} \end{bmatrix}$$

$$= \begin{bmatrix} i_{a0} \\ i_{b0} \\ i_{c0} \end{bmatrix} + \begin{bmatrix} i_{a\bar{p}} \\ i_{b\bar{p}} \\ i_{c\bar{p}} \end{bmatrix} + \begin{bmatrix} i_{a\tilde{p}} \\ i_{b\tilde{p}} \\ i_{c\tilde{p}} \end{bmatrix} + \begin{bmatrix} i_{aq} \\ i_{bq} \\ i_{cq} \end{bmatrix}$$

## CPT FRAMEWORK

The third considered approach (Conservative Power Theory, CPT) was recently proposed by Tenti*et al.* and it is based on the definition of instantaneous complex power under non-sinusoidal conditions and it represents an extension of the usual complex power, defined for sinusoidal conditions. Even though detailed discussion has been directed to single phase systems, this theory is also easily extended to multiphase systems.

By definition, all current terms are orthogonal:

$$||\mathbf{i}||^2 = ||\mathbf{i}_a||^2 + ||\mathbf{i}_q||^2 + ||\mathbf{i}_v||^2$$

## III SIMULATION RESULTS

### A. Case I: Unbalanced resistive load – small line impedance

Table 1 – Voltages and impedances for Case I.

| Source | Line | Load (Y) |
|---|---|---|
| $Va = 127\angle 0°$ Vrms | $R_{La} = 1m\Omega$ $L_{La} = 10\ \mu H$ | $Ra = 9{,}3405\Omega$ |
| $Vb = 127\angle -120°$ Vrms | $R_{Lb} = 1m\Omega$ $L_{Lb} = 10\mu H$ | $Rb = 6{,}2270\Omega$ |
| $Vc = 127\angle 120°$ Vrms | $R_{Lc} = 1m\Omega$ $L_{Lc} = 10\mu H$ | $Rc = 3{,}1135\Omega$ |

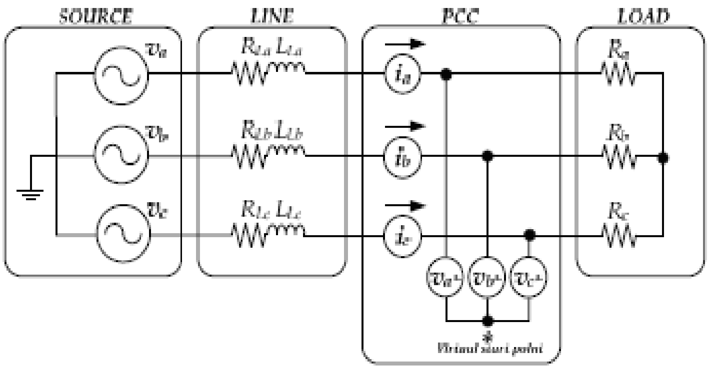



Figure 1: Power circuit for Case I –Unbalanced resistive load

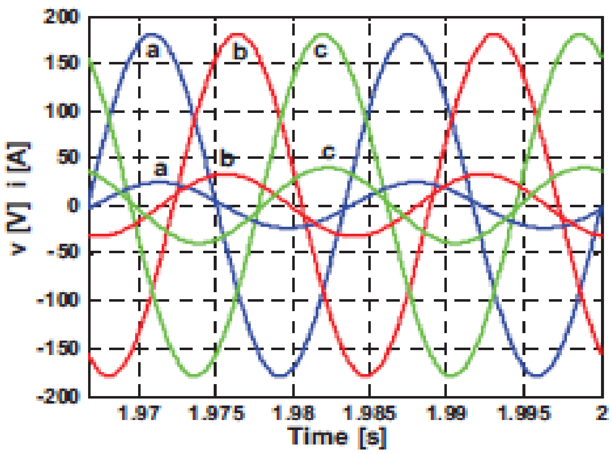
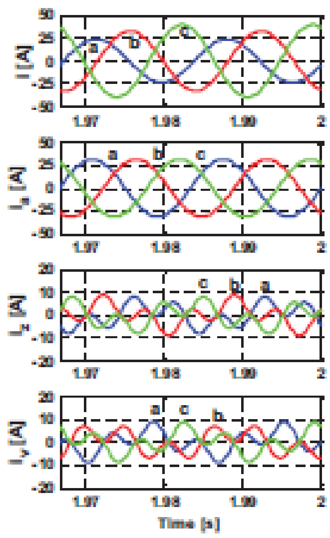
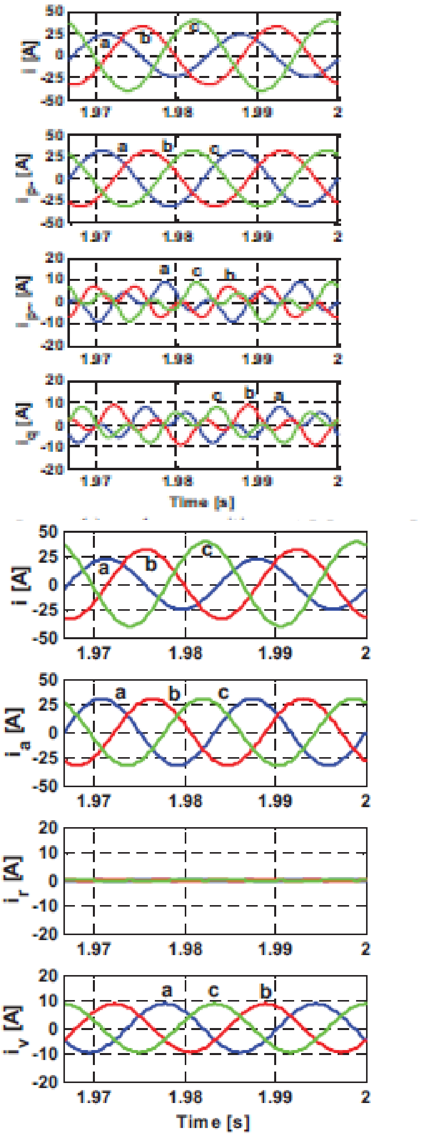



Figure 2: PCC voltages and currents for Case I




a) FBD-decomposition




c) *CPT*-decomposition

Figure3:Current decompositions for Case I.

## IV. APPLICATIONS

1. Power loss is minimized as the number of commutator switches are reduced.
2. The output filter dimensions are reduced which improves the efficiency of the proposed system.
3. Instability and unpredictability will not observe.
4. The optimum solution for hybrid storage system associated with WG and PV systems.
5. The proposed system will supply the constant power to the nonlinear loads.

## V.CONCLUSION

Notwithstanding the basis of the *FBD* method seems to bemore suitable to the understanding of different power phenomena, if compared to the *pq*-Theory, especially because it does not uses any axis transformation and it is based on the extension of well-accepted Fryze's definitions, their results are very similar in the case of three-phase three-wire circuits. The analysis were directed to the instantaneous active and reactive current components from *pq*- Theory. In this seminar, cases I and II show that under some conditions, the interpretation of either the *FBD* and *pq*-Theory can lead to invalid conclusions, e.g., considering a third harmonic content of a linear resistive load circuit. CaseIIIshows that under significant voltage deterioration (week PCC condition), even the average active current from *pq* decomposition is useless for the interpretation of the circuit.

Besides, it has been demonstrated that the active current from FBD and CPT methods match for three-wire circuits. Considering that the current decompositions and related power components could be useful to revenue metering, power conditioning, active filtering, power quality monitoring and so on, the results suggest that the proposal from *Tenti et al*. seems to be a very interesting alternative to the analysis, control and regulation of distinct power circuits, from the case of traditional sinusoidal and balanced voltage and current signals, to nonlinear load circuits with deteriorated voltages.

## II. REFERENCES

[1] M. Depenbrock, "The FBD-Method, a Generally Applicable Tool ForAnalyzing Power Relations", *IEEE Trans. on Power Systems*, vol. 8, n. 2, 381-387, May 1993.

[2] E. Tedeschi and P. Tenti, "Cooperative Design and Control ofDistributed Harmonic and Reactive Compensators", *in Proc. of 2008International School on Nonsinusoidal Currents and Compensation(ISNCC)*.

[3] J. L.Willems, "A New Interpretation of the Akagi-Nabae Power Components for Nonsinusoidal Three-phase Situations," *IEEE Trans. OnInstrumentation and Measurement*, vol. 41, no. 4, pp. 523–527, Aug. 1992.

[4] M. Malengret and C. T. Gaunt, "Decomposition of Currents in Three and Four-Wire Systems", *IEEE Trans. on Instrumentation andMeasurement*, vol. 57, No. 5, pp. 963-972, May 2008.

[5] Harirchi, F., Simões, M.G., Al-Durra, A., &Muyeen, S. (2015).Short transient recovery of low voltage-grid-tied DC distributedgeneration. In Energy Conversion Congress & Expo (ECCE). Vancouver: IEEE.

[6] L. S. Czarnecki, "Instantaneous Reactive Power p-q Theory and Power Properties of Three-phase Systems," *IEEE Trans. Power Delivery*, vol.21, no. 1, pp. 362–367, Jan. 2006.

[7] E. H. Watanabe, R. M. Stephan, and M. Aredes, "New Concept ofInstantaneous Active and Reactive Powers in Electrical Systems with Generic Loads".*IEEE Trans. on Power Delivery* Vol. 8, pp. 697–703,1993.

[8] R. S. Herrera and P. Salmerón, "Instantaneous Reactive Power Theory: A Comparative Evaluation of Different Formulations", *IEEE Trans. OnPower Delivery*, vol. 22, No. 1, pp. 595-604, January 2007.