An Integration of Dual UPQC Controller for Power Quality Compensation by Extending its Voltage Regulation at Grid Side as a STATCOM

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Abstract: This paper presents a modified controller by integrating dual unified power quality conditioners: iUPQC controller with its utilization in microgrid and power-quality applications. By utilizing this controller it extends the power quality characteristics just like the UPQC controller it offers reactive power regulation both at load-side bus voltage and at grid-side bus voltage, which also compensates voltage swell & sag. At grid- side iUPQC controller will work as a STATCOM, by providing all the conventional UPQC applications both at the grid-side and load-side. Simulink results are providing to validate the latest functionality of the apparatus.

Index Terms: Dual topology: iUPQC, micro grids, unified power quality conditioner (UPQC), STATCOM- static synchronous compensator, power quality.

1. INTRODUCTION

Undoubtedly, power electronics devices caused enormous technological improvements. These increasing applications of power electronic devices generally used in industries will create unusual power quality issues. These power electronic devised loads needs perfect sinusoidal supply voltage to perform suitably, which are generally responsible for harmonic imbalances in the electrical system. At this context, to mitigate these disorders some controllers been developed. Few among the solutions will engage the Facts Controllers, called as unified power quality conditioner controller (UPQC) [1]-[3] and STATCOM i.e., static synchronous compensator [4]-[6]. The UPQC controller consists of compound of a series and shunt active filter connected in back-end to back-end arrangement. This arrangement validates both the compensations at the supply voltage and load current, should be in order to compensate supply voltage given to load and current drawn should keep in sinusoidal and balanced.

In the double topology of unified power quality conditioner controller (UPQC), i.e., iUPQC the series active filter performs as AC current source & shunt active filter as AC voltage source, both of them at fundamental frequency. This extends its capability in designing the control gains and LCL filter for power converters, which permits in increasing the whole performance of the iUPQC compensator. For dynamic reactive power compensation STATCOMs are extensively used in transmission for voltage regulation, but iUPQC is opted as solution for many particular applications. In addition these last applications generally used in specific cases, where high costs are acceptable for power quality compensations, those will be unachievable by traditional methods.

By having the additional utilization like STATCOM in the proposed double topology UPQC i.e., IUPQC controller, many number of applications can be achieved, specifically in distributed smart grids and grid tied microgrids. In UPQC series converter regulated as a non-sinusoidal voltage source and shunt converter regulated as a non-sinusoidal current source and to determine the harmonics in currents and voltages.

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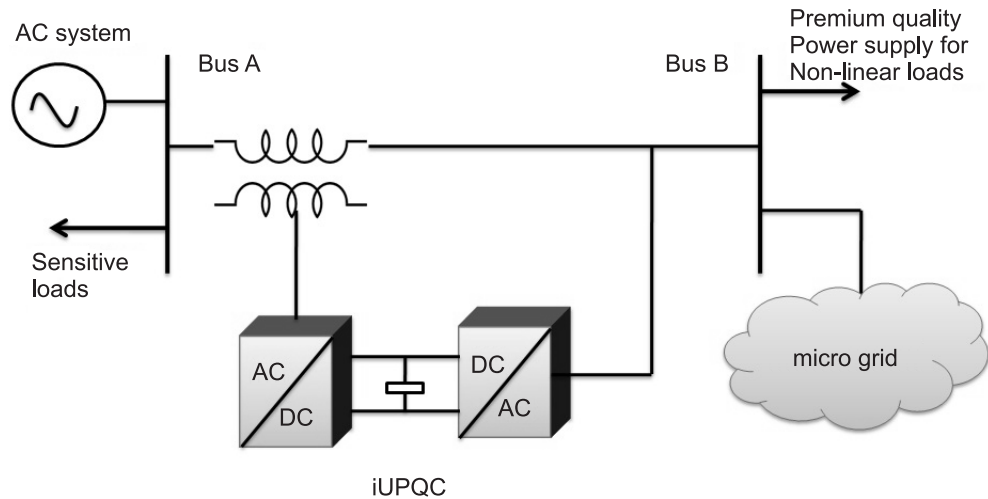
Figure 1: Example for utilization of iUPQC

By this it is not essential to find the harmonics in currents and voltages to be mitigated because harmonic currents enters into shunt voltage source and harmonic voltages found at series current source naturally. In generally power regulators, if the switching frequency raises then the power rating capability decreases. So IUPQC proposes better solution evaluated with UPQC in high power utilizations.

This paper proposes modified IUPQC controller functionalities which includes all the previous applications in addition to the voltage regulation towards the grid side bus & load side bus, just as a STATCOM at the grid side.

In this paper section II is applicability of IUPQC and features of proposed controllers are explained. Section III is for proposed controller with the analysis of power flow is explained. Section IV with the simulink results and section V for conclusion.

2. IUPQC APPLICABILITY

For understanding the utilization of the modified iUPQC controller, from Figure 1 it represents an distribution system with bus A and bus B, at bus A supplies sensitive loads as joining of a micro grid, at bus B nonlinear loads are connected, so it needs best quality supplying power. At respective buses A and B voltages should be controlled to suitably supply the nonlinear and sensitive loads.

By using a STATCOM at bus A the voltage regulation will not reduce harmonics in currents which is drawn from the non-linear loads, and by placing UPQC in between buses A and B then it only mitigates harmonics in currents in non-linear loads and compensates voltage at bus B, but it won't control the voltage at bus A. Therefore, to achieve all the expected results, STATCOM should be employed at bus A, but the UPQC should be placed between bus A and B, but by this solution it costs extensively high.

From these the best solution would be by employing improved iUPQC controller which also provides reactive power at bus A, in extension to all the previous utilizations provided to the apparatus. This modified iUPQC controller performs as a bridge between buses A and B.

The improved iUPQC controller will perform the following:

i)   It Regulates the power flow and energy between microgrid and grid

ii) It supports to provide reactive power at bus A.

iii) It allows current isolation and harmonic voltage between buses A and B

iv) It compensates current and voltage imbalances

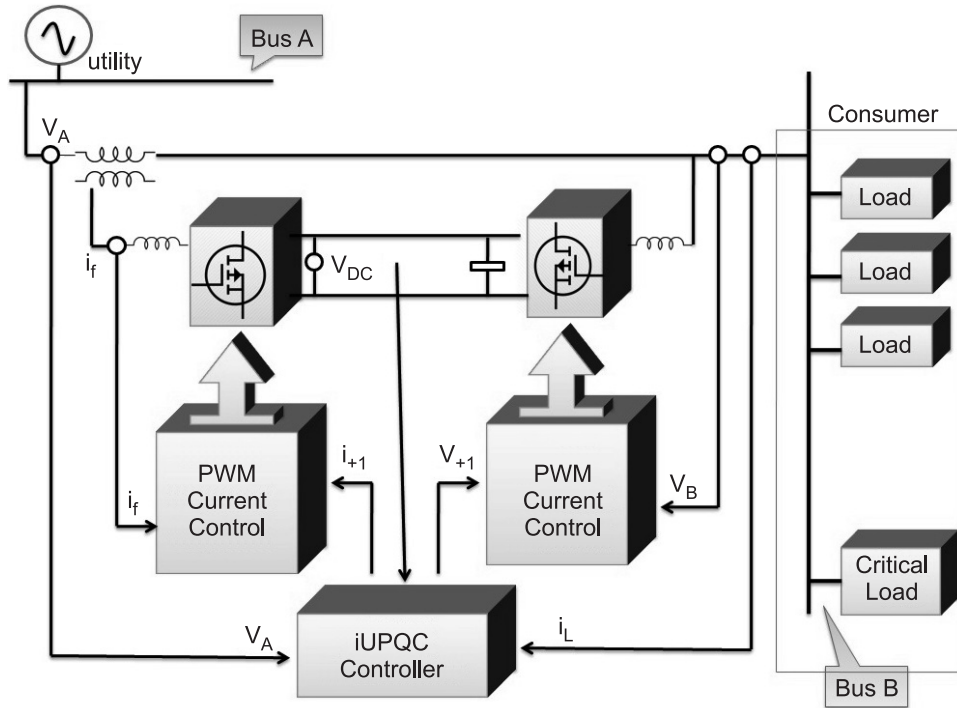v)   It acts as smart circuit breaker between grid and microgrid

Figure 2: Improved iUPQC arrangement

It also allows voltage/frequency compensations at micro grid of bus B Figure 2 shows all the connections of iUPQC controller between buses A and B. Generally in conventional IUPQC the shunt converter provides only regulated sinusoidal voltage to provide voltage/frequency functionality and does not compensate active or reactive power variables.

If *dc* link doesn't has much energy storage system in iUPQC the variable *p* provides an extra active power ref to series converter for keeping the energy within the *dc* link as balanced in iUPQC. The iUPQC controller serves the above first and fifth functionalities by compensating active power and reactive power indications for the series converter. In this regard it is required to provide huge energy storage to *dc* link. Thus the iUPQC will compensate reactive power just as a STATCOM at bus A. This is an additional functionality added to the iUPQC controller including all other previous utilities in the iUPQC controller.

3. IUPQC MODIFIED CONTROLLER

Improved Controller

Figure 3 depicts the proposed improved iUPQC controller, input voltages at bus A and bus B, the current flow at bus B, and the voltage common at *dc* link. Shunt voltage and series current references are the outputs for the pulse width modulation: PWM controllers. Clark transformation should be applied for measured variables and to find grid voltage in αβ-reference by using clark transformation

$$\begin{bmatrix} V_{A\_\alpha} \\ V_{A\_\beta} \end{bmatrix} = \begin{bmatrix} 1 & 1/2 \\ 0 & \sqrt{3}/2 \end{bmatrix} \begin{bmatrix} V_{A\_ab} \\ V_{A\_bc} \end{bmatrix} \tag{1}$$

The sinusoidal voltages with normal frequency and amplitude are applied, and accordingly signals given to PWM are the phase locked loop (PLL) with 1pu equivalent amplitude. In the iUPQC model suggested in [7], shunt converter output voltage reference may be PLL outputs or positive sequence component called VA+1, by this voltage it can be feasible to minimize circulating power in shunt and series converters under normal conditions. Here both the buses will controlled independently to estimate their reference values.
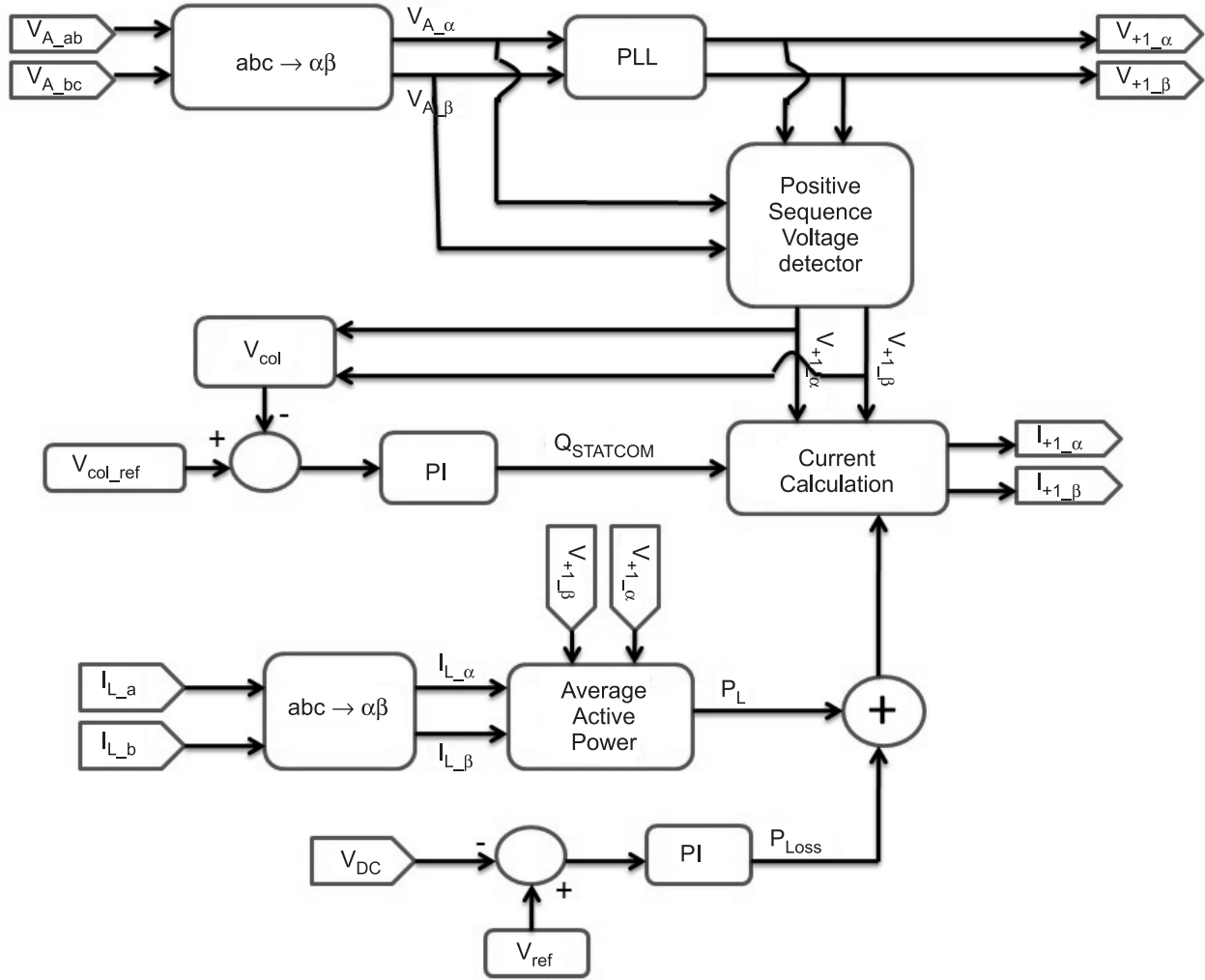
Figure 3: Proposed iUQPC Controller

In original iUQPC model current is calculated by active power required by loadsof power PL plus power Ploss. The load active power is calculated by

$$P_L = V_{+1\_\alpha} \times i_{L\_\alpha} + V_{+1\_\beta} \times i_{L\_\beta} \qquad (2)$$

Where, $i_{L\_\alpha}, i_{L\_\beta} \rightarrow$ load currents

$V_{+1\_\alpha}, V_{+1\_\beta}$ are voltage references at shunt converter

To get the active power (PL) low pass filter should be used, to get the power losses in the converters and for providing balanced energy inside to the iUPQC are indirectly measured by the *dc* link voltage. In another way, Ploss is calculated by PI controller by comparing calculated VDC with its references, an extended control loop is used to supply voltage regulation just like STATCOM to the grid bus, is denoted with QSTATCOM, this will be attained by a PI controller. The current references of series converter are given by

$$\begin{bmatrix} V_{A\_\alpha} \\ V_{A\_\beta} \end{bmatrix} = \frac{1}{V_{A+1\_\alpha}^2 + V_{A+1\_\beta}^2} \begin{bmatrix} V_{A+1\_\alpha} & V_{A+1\_\beta} \\ V_{A+1\_\beta} & -V_{A+1\_\alpha} \end{bmatrix} \begin{bmatrix} P_L + P_{Loss} \\ Q_{STATCOM} \end{bmatrix} \qquad (3)$$

4. SIMULATION RESULTS

The below shown graphs shows simulink results for the input & output voltages, controller signals and load currents of an improved iUPQC controller
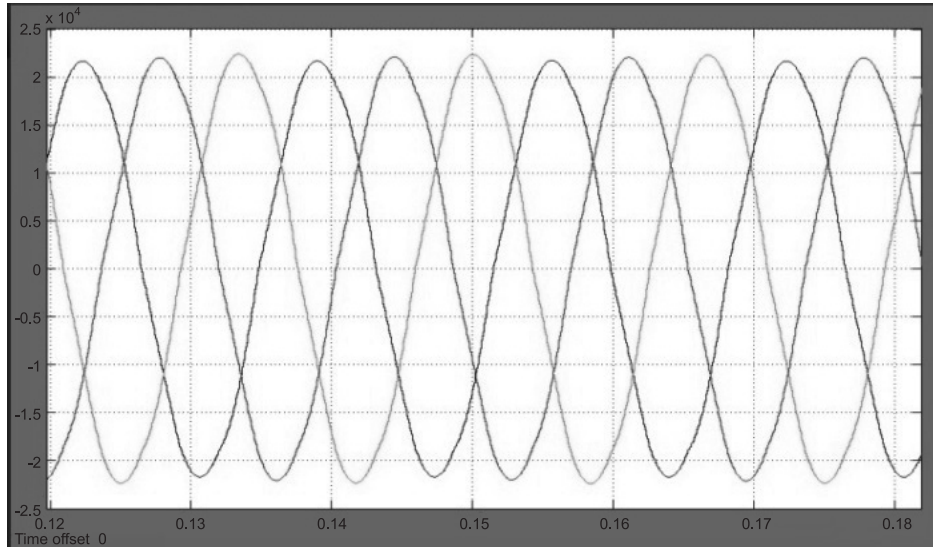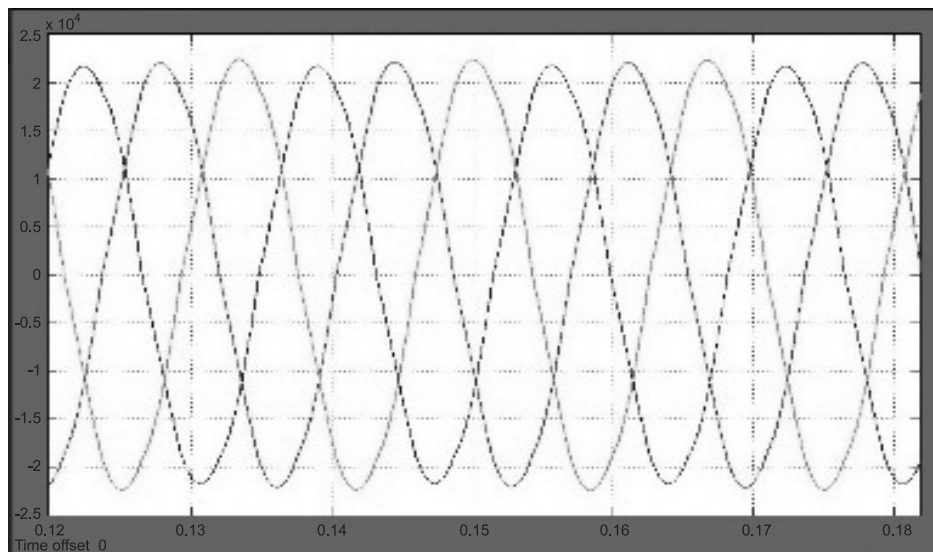
Figure 4: Grid voltages
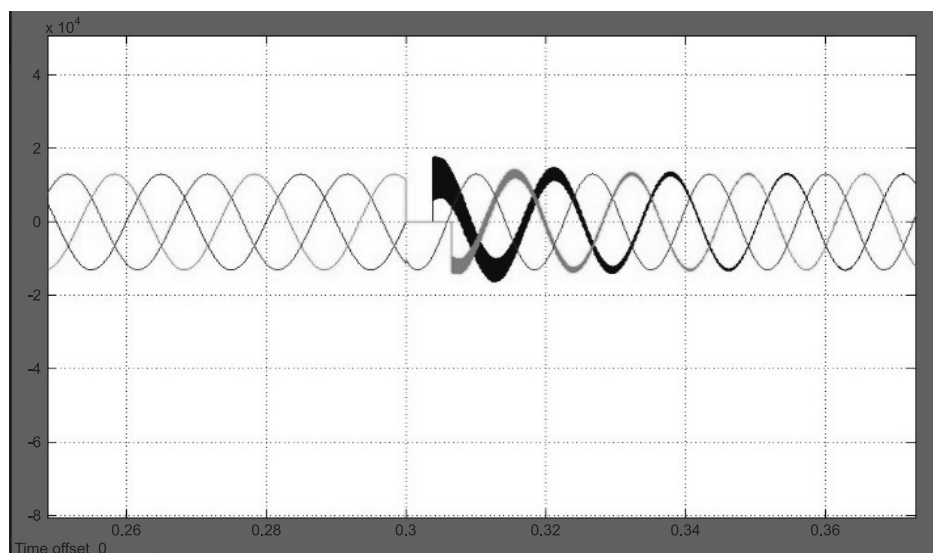

Figure 5: Load voltages
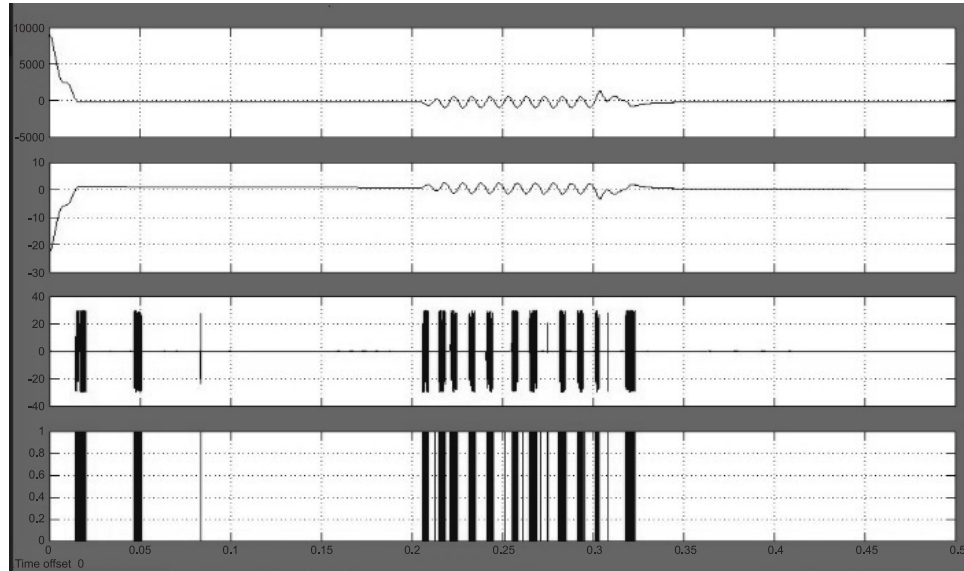

Figure 6: Load currents

Figure 7: IUPQC controller signals

5. CONCLUSION

By using this dual topology of UPQC i.e., iUPQC allows all the features of conventional UPQC controller and extending its utilization power quality and microgrid applications, which also includes voltage swell/ sag and also provide reactive power compensation to control load bus voltage as well as voltage at grid side, this works as STATCOM on the grid side. The simulink results validate the modified iUPQC controller at grid side load and nonlinear loads.

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