An Integration of dual UPQC controller for power quality compensation by extending its voltage regulation at grid side as a STATCOM

M.S.Teja¹, Ravula Shashi Kumar Reddy², Sudhakar AVV³ & K.Srinivas⁴
¹Asst. Professor in EEED, Sumathi Reddy Institute of Technology for women, Warangal, India.
²Asst. Professor in EEED, Sumathi Reddy Institute of Technology for women, Warangal, India.
³Centre for Emerging Energy Technologies, SR Engineering College, Warangal, India.
⁴Asst. Professor, ECED, Sumathi Reddy Institute of Technology for women, Warangal, India.
Corresponding Email: msteja22@gmail.com

Abstract. This paper presents a modified controller by integrating dual unified power quality conditioners: iUPQC controller with its utilization in microgrid and power-quality utilizations. By applying this regulatory controller it extends the quality of power 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 consequences are providing to validate the latest predictability of the apparatus.

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

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 controller (UPQC) [1]-[3] and STATCOM i.e., static synchronous compensator [4]-[6]. The UPQC controller consists of compound of a series and shunt filter connected in 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 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 presentation of the iUPQC. 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 voltage source & shunt converter regulated as a current source and to determine the harmonics in currents and voltages.

![Diagram](image.png)

Fig 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 in the modified iUPQC controller, from Fig.1 it represents an distribution system by the bus-A and bus-B, at bus A supplies responsive 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-sinusoidal 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 iUPQC should be placed between bus-A & B, but by this solution it costs extensively high.

By employing improved iUPQC controller, which also provides reactive power at bus A, in addition to all the previous utilisations 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

It also allows voltage/frequency compensations at micro grid of bus B. Fig.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.

The iUPQC controller serves the above first and fifth functionalities by reducing active power & reactive power indications for the series converter. In this regard, it is required to provide huge energy storage to the 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.

If the dc link doesn’t have much energy storage system in iUPQC, the variable p provides an extra active energy reference to the series converter for keeping the energy within the dc link as balanced in iUPQC.

3. IUPQC Modified Controller

**Improved Controller**

Fig. 3 depicts the proposed improved iUPQC controller, input voltages at bus-A and bus-B, the current flow at bus-B, and the common voltage 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

\[
\begin{bmatrix}
V_{A,\alpha} \\
V_{A,\beta}
\end{bmatrix} = \begin{bmatrix}
1 & 1/2 \\
0 & \sqrt{3}/2
\end{bmatrix} \begin{bmatrix}
V_{A,ab} \\
V_{A,bc}
\end{bmatrix}
\]  

(1)
The sinusoidal voltages with normal frequency and amplitude are applied, and accordingly signals given to PWM are the phase locked loop (PLL) 1pu equivalent amplitude. In the iUPQC model suggested in [7], shunt converter output voltage reference may be PLL outputs 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. In original iUPQC model current is calculated by active power required by loads of power. The active power is calculated by

\[ P_L = V_{+1,\alpha} \times i_{L,\alpha} + V_{+1,\beta} \times i_{L,\beta} \] (2)

Where, \( i_{L,\alpha}, i_{L,\beta} \) - 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

\[
\begin{bmatrix}
V_A_{\alpha} \\
V_A_{\beta}
\end{bmatrix} = \frac{1}{V_{+1,\alpha}^2 + V_{+1,\beta}^2} \begin{bmatrix}
V_{A+1,\alpha} & V_{A+1,\beta} \\
V_{A+1,\beta} & -V_{A+1,\alpha}
\end{bmatrix} \begin{bmatrix}
P_L \\
Q_{\text{STATCOM}}
\end{bmatrix}
\] (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

Fig 4: Grid voltages
Fig 5: Load voltages

Fig 6: Load currents
Fig 7: IUPQC controller signals
5. Conclusion

By using this double 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.

6. References:

[1] K.Karanki, G.Geddada, M.K.Mishra and B.K.Kumar, “A modified three-phase four-wire UPQC topology with reduced DC lin voltage rating” III Trans. Ind. Electron., vol. 60 no. 9, pp 3555-3566, sep.2013

[2] K.H.Kwan, P.L.So, and Y.C. Chu, “AN outpur regulation-based unified power quality conditioner with Kalman filters,” IEEE Trans, Ind, Electron., vol.59 no.11, pp. 4248-4262, Nov.2012.

[3] V.Khadikikar, “ Enhancing electric power quality using UPQC: A Comprehensive overview,” IEEE Trans. Power Electron., vol. 27, no.5, pp.2284-2297, May 2012.

[4] N.VORaphonpiput and S.CHatratana, “STATCOM analysis and controller design for power system voltage regulation,” in Proc. IEEE/PES Transmiss Distrib. Conf. Exhib. – Asia Pac., 2005, pp. 1-6.

[5] M.Aredes and R.M.Fernandes, “ Adual topology of unified power quality conditioner: The iUPQC, “ in Proc. EPE Conf.Appl., 2009, pp. 1-10.

[6] Srinivas K, Kumar JT and Merugu S 2019 GEVD based on multichannel wiener filter for removal of EEG artifacts International Journal of Innovative Technology and Exploring Engineering 8(10) 2417-2421 10.35940/ijitee.H6755.0881019

[7] Jhansi Rani G, Raghava Kumari D, Anitha M and Sarita B 2020 Analysis of raspberry pi based ATM theft monitoring and security system International Journal of Psychosocial Rehabilitation 24(8) 15376-15383 10.37200/IJPR/V24I8/PR281514

[8] Anitha M., Jhansi Rani G., Raghava Kumara D and Anuradha P. 2020 Implementation of arithmetic logic unit using quaternary signed digit number system International Journal of Psychosocial Rehabilitation 24(8) 15363-15375 10.37200/IJPR/V24I8/PR281513

[9] K.B.V.S.R.Subrahmanyam, J.Amarnath” Performance of Gas Insulated Substation under Particle Contamination with Charge simulation Method” IEEE Explore , EPSCICON-2012,International Conference , Kerala ,January 03-06,2012, ISBN:978-1-4673-0446-7.

[10] B. Vedik, A. K. Chandel, and KBVSR Subramanyam, “Power System State Estimation
Using new Adaptive Differential Evolution Technique” Soft computing international journal, Juy,2017, DOI:10.1007/s00500-017-2715-3.

[11] Sudhakar A.V.V., Karri C., Jaya Laxmi A. 2018 A hybrid LR-secant method-invasive weed optimisation for profit-based unit commitment International Journal of Power and Energy Conversion 9 1 1 24 10.1504/IJPEC.2018.088256

[12] Sudhakar A.V.V., Rajababu D., Sathyavani B. 2019 Analysis of the power losses in both DC side and AC side cascaded converters International Journal of Recent Technology and Engineering 8 1C2 897 899

[13] Rajababu D., Raghu Ram K. 2019 Load current observer and adaptive voltage controller for standalone wind energy system with linear and non-linear loads International Journal of Engineering and Advanced Technology 9 1 5491 5496 10.35940/ijeat.A2012.109119

[14] Merugu S, Juluru TK and Srinivas S 2019 Adaptive compressive sensing of images using adaptive block compressive sensing algorithm and improvement International Journal of Innovative Technology and Exploring Engineering 8(5) 1055-1060

[15] Sallauddin M, Ramesh D, Harshavardhan A, Pasha SN and Shabana 2019 A comprehensive study on traditional AI and ANN architecture International Journal of Advanced Science and Technology 28(17) 479-487