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 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,

I. 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 aims 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.

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.

II. IUPQC APPLICABILITY

Fig 1 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.

Fig 2: Improved iUPQC arrangement

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 utilities 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:

- It Regulates the power flow and energy between microgrid and grid
- It supports to provide reactive power at bus A.
- It allows current isolation and harmonic voltage between buses A and B
- It compensates current and voltage imbalances
- 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.

III. 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 $\alpha\beta$-reference by using clark transformation

$$VA_\alpha, VA_\beta = \frac{11/203}{2VA_{ab}VA_{bc}}$$

(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 iUQPC model current is calculated by active power required by loads of power. The active power is calculated by

$$P_L = V_{+1_\alpha}iL_{+1_\alpha} + V_{+1_\beta}iL_{+1_\beta}$$

(2)

Where, $iL_{+1_\alpha}$, $iL_{+1_\beta}$ -> 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, \( P_{\text{loss}} \) is calculated by PI controller by comparing calculated \( V_{\text{DC}} \) with its references, an extended control loop is used to supply voltage regulation just like STATCOM to the grid bus, is denoted with \( Q_{\text{STATCOM}} \), this will be attained by a PI controller. The current references of series converter are given by

\[
V_{\alpha} V_{\beta} = V_{\alpha} + 1 \text{ } \bar{V}_{\alpha} + V_{\beta} + 1 \text{ } \bar{V}_{\beta} + P_{\text{loss}} Q_{\text{STATCOM}}(3)
\]

IV. 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

V. 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.

REFERENCES