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A Novel PSO based iUPQC Controller For Improvement Of System Performance By Additional Grid-Voltage Regulation

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ABSTRACT: This paper presents an improved PSO based controller for the dual topology of the unified power quality conditioner (iUPQC) extending its applicability in power-quality compensation, as well as in microgrid applications. By using this controller, beyond the conventional UPQC power quality features, including voltage sag/swell compensation, the iUPQC will also provide reactive power support to regulate not only the load-bus voltage but also the volt- age at the grid-side bus. In other words, the PSO based iUPQC will work as a static synchronous compensator (STATCOM) at the grid side, while providing also the conventional UPQC compensations at the load or microgrid side. Experimental results are provided to verify the new functionality of the equipment.

KEYWORDS*:* Micro Grid; iUPQC; PSO;

I. INTRODUCTION

Power-Electronics devices have brought about great technological improvements. However, the increasing number of power-electronics-driven loads used gen- erally in the industry has brought about uncommon power- quality problems. In contrast, power-electronics-driven loads generally require ideal sinusoidal supply voltage in order to function properly, whereas they are the most responsible ones for abnormal harmonic currents level in the distribution system. In this scenario, devices that can mitigate these drawbacks have been developed over the years. Some of the solutions involve a flexible compensator, known as the unified power quality conditioner (UPQC) [1]–[7] and the static synchronous compensator (STATCOM) [8]–[13].

The power circuit of a UPQC consists of a combination of a shunt active filter and a series active filter connected in a back-to-back configuration. This combination allows the simultaneous compensation of the load current and the supply voltage, so that the compensated current drawn from the grid and the compensated supply voltage delivered to the load are kept balanced and sinusoidal. The dual topology of the UPQC, i.e., the iUPQC, was presented in [14]–[19], where the shunt active filter behaves as an ac-voltage source and the series one as an ac-current source, both at the fundamental frequency. This is a key point to better design the control gains, as well as to optimize the LC L filter of the power converters, which allows improving significantly the overall performance of the compensator [20].

The STATCOM has been used widely in transmission net- works to regulate the voltage by means of dynamic reactive- power compensation. Nowadays, the STATCOM is largely used for voltage regulation [9], whereas the UPQC and the iUPQC have been selected as solution for more specific applications [21]. Moreover, these last ones are used only in particular cases, where their relatively high costs are justified by the power quality improvement it can provide, which would be unfeasible by using conventional solutions. By joining the extra functionality like a STATCOM in the iUPQC device, a wider scenario of applications can be reached, particularly in case of distributed generation in smart grids and as the coupling device in grid-tied microgrids.

In [16], the performance of the iUPQC and the UPQC was compared when working as UPQCs. The main difference be- tween these compensators is the sort of source emulated by the series and shunt power converters. In the UPQC approach, the series converter is controlled as a nonsinusoidal voltage source and the shunt one as a nonsinusoidal current source. Hence, in real time, the UPQC controller has to determine and synthesize accurately the harmonic voltage and current to be compensated. On the other hand, in the iUPQC approach, the series converter behaves as a controlled sinusoidal current source and the shunt converter as a controlled sinusoidal voltage source. This means that it is not

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necessary to determine the harmonic voltage and current to be compensated, since the harmonic voltages appear naturally across the series current source and the harmonic currents flow naturally into the shunt voltage source.

In actual power converters, as the switching frequency in- creases, the power rate capability is reduced. Therefore, the iUPQC offers better solutions if compared with the UPQC in case of high-power applications, since the iUPQC compensat- ing references are pure sinusoidal waveforms at the fundamen- tal frequency. Moreover, the UPQC has higher switching losses due to its higher switching frequency.

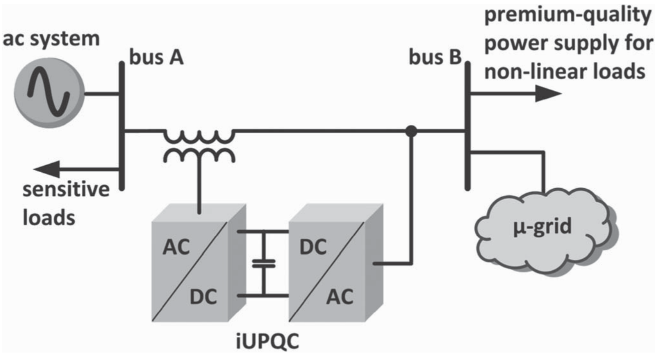

Fig. 1. Example of applicability of iUPQC.

This paper proposes an improved PSO based controller, which expands the iUPQC functionalities. This improved version of iUPQC controller includes all functionalities of those previous ones, including the voltage regulation at the load-side bus, and now providing also voltage regulation at the grid-side bus, like a STATCOM to the grid. Experimental results are provided to validate the new controller design.

II. PSO PROPOSED MODEL

A. *PARTICLE SWARM OPTIMIZATION*

Particle swarm optimization (PSO) is a population based stochastic optimization technique developed by Dr. Eberhart and Dr. Kennedy in 1995, inspired by social behavior of bird flocking or fish schooling. PSO shares many similarities with evolutionary computation techniques such as Genetic Algorithms (GA). The system is initialized with a population of random solutions and searches for optima by updating generations. However, unlike GA, PSO has no evolution operators such as crossover and mutation. In PSO, the potential solutions, called particles, fly through the problem space by following the current optimum particles.

B. PSO OPERATION:

PSO technique lies in accelerating each particle towards its Pbest and Gbest locations, with a random weighted acceleration at each time step.[5]

The main steps in the particle swarm optimization and selection process are described as follows:

a. Initialize a population of particles with random positions and velocities in d dimensions of the problem space and fly them.

b. Evaluate the fitness of each particle in the swarm

c. For every iteration, compare each particle's fitness with its previous best fitness (Pbest) obtained. If the current value is better than Pbest, then set Pbest equal to the current value and the Pbest location equal to the current location in the d-dimensional space.

d. Compare Pbest of particles with each other and update the swarm global best location with the greatest fitness (Gbest).

e. Change the velocity and position of the particle According to equations (1) and (2) respectively.

a. velocity = w *velocity + c1*(R1.*(local_best_position-current_position)) + c2*(R2.*(globl_best_position-current_position))

b. current_position = current_position+velocity

Repeat steps (a) to (e) until convergence is reached based on some desired single or multiple criteria

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III. IMPROVED IUPQC CONFIGARATION

Fig. 2 depicts the iUPQC hardware and the measured units of a three-phase three-wire system that are used in the controller. Fig. 3 shows the proposed controller. The controller inputs are the voltages at buses A and B, the current demanded by bus B (iL), and the voltage vDC of the common dc link. The outputs are the shunt-voltage reference and the series-current reference to the pulsewidth modulation (PWM) controllers. The voltage and current PWM controllers can be as simple as those employed in [18], or be improved further to better deal with voltage and current imbalance and harmonics [23]–[28].

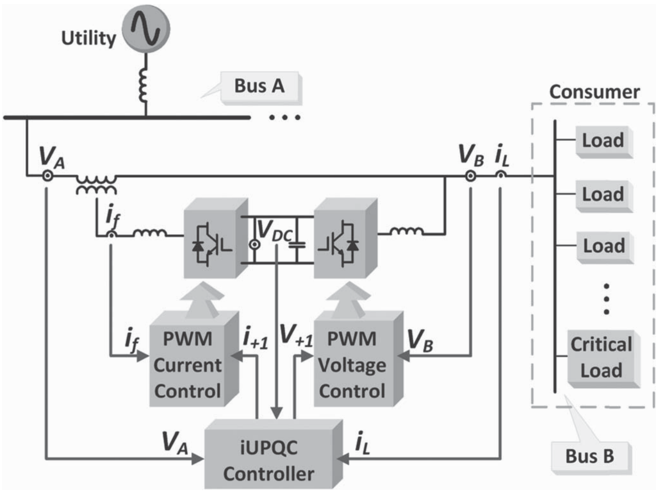

Fig. 2. Modified iUPQC configuration

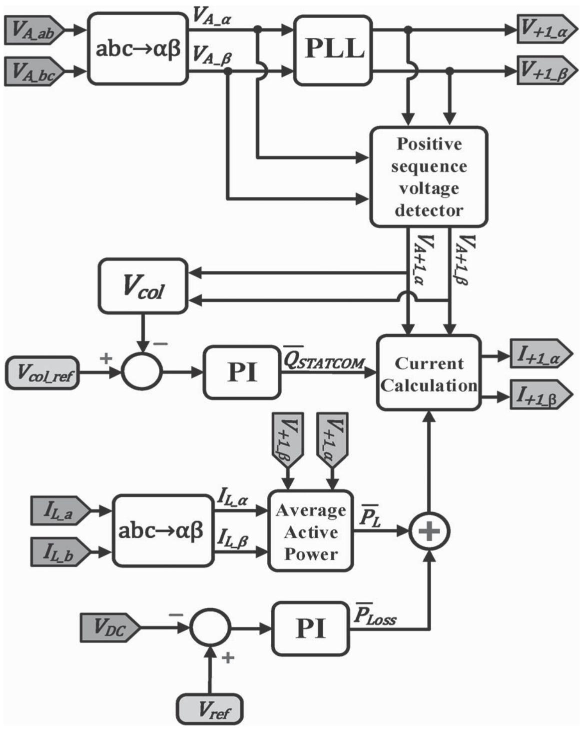

Fig. 3. Novel iUPQC controller.

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IV. SIMULATION RESULTS

Case: 1. Conventional iUPQC

A. *iUPQC with NO-Load:*

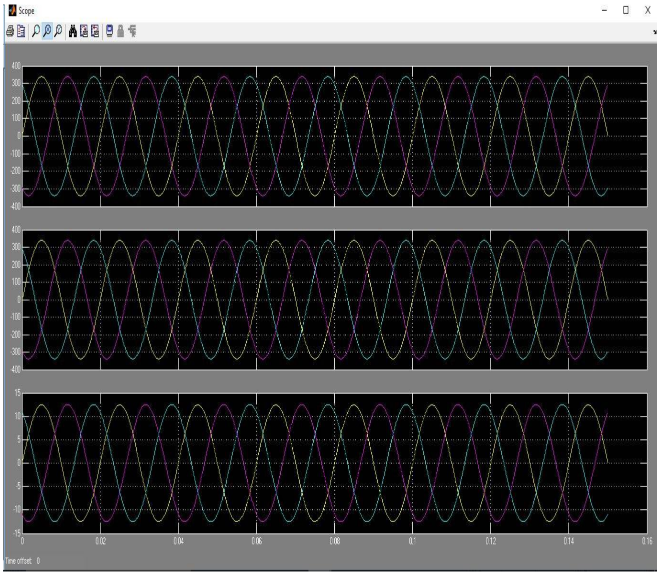

Fig: 4 (a) grid voltages VA, (b) load voltages VB, and (c) grid currents.

B. *iUPQC with 2-Arm Rectifier*

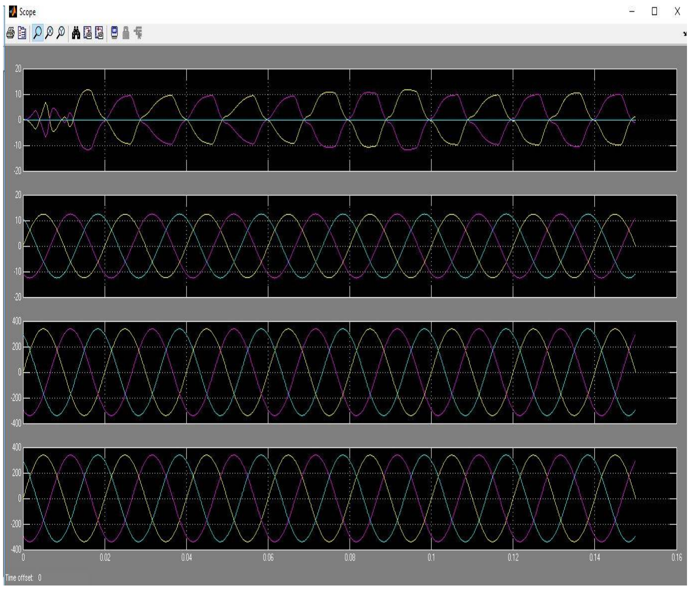

Fig: 5 iUPQC transitory response during the connection of a twophase diode rectifier: (a) load currents, (b) source currents, (c) load voltages, and (c) source voltages.

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C. ***iUPQC with 3-Arm Rectifier:***

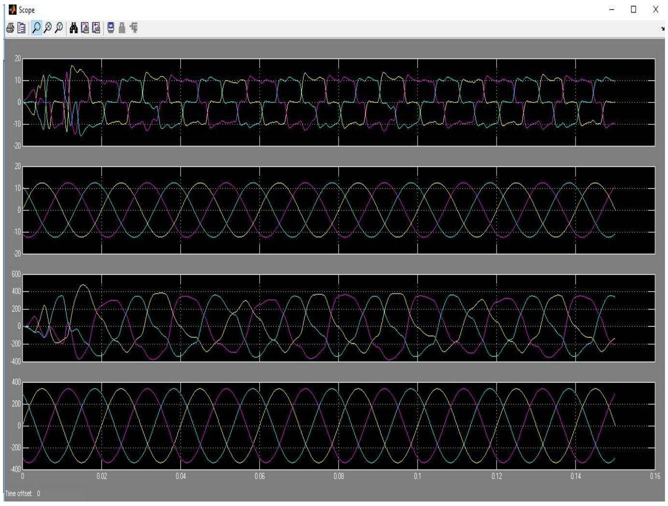

Fig: 6 iUPQC transitory response during the connection of a threephase diode rectifier: (a) load currents, (b) grid currents, (c) load voltages and (d) grid voltages.

Case: 2. PSO Based iUPQC

D. ***iUPQC with NO-Load:***

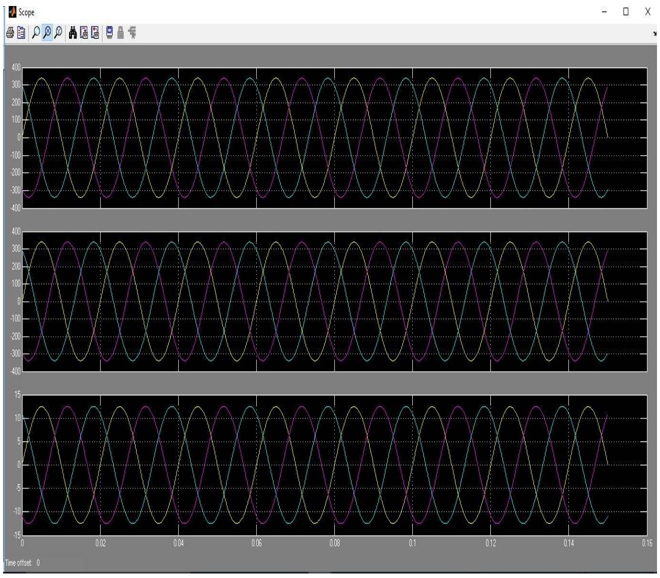

Fig: 7 (a) grid voltages VA, (b) load voltages VB, and (c) grid currents.

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E. *iUPQC with 2-Arm Rectifier*

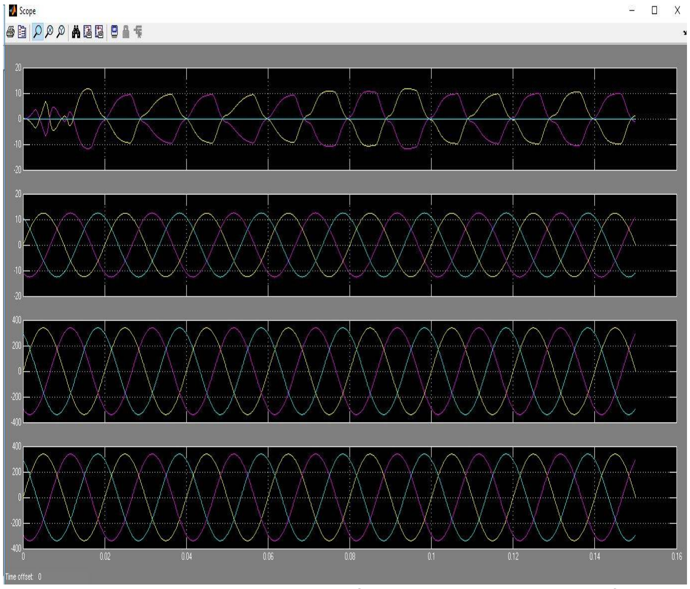

Fig: 8 iUPQC transitory response during the connection of a twophase diode rectifier: (a) load currents, (b) source currents, (c) load voltages, and (c) source voltages.

F. *iUPQC with 3-Arm Rectifier:*

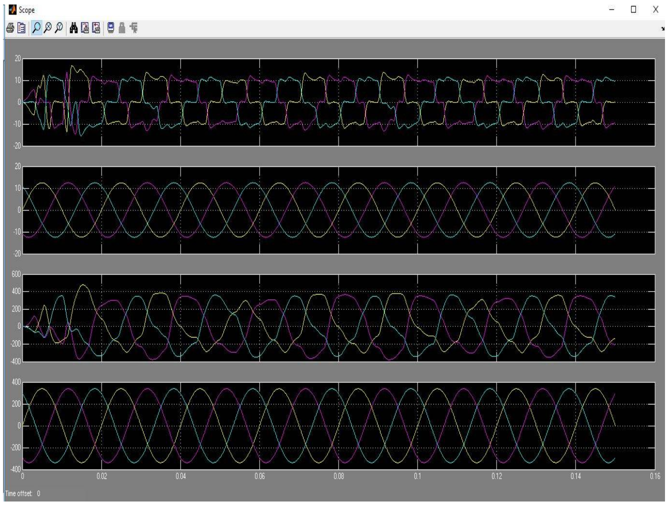

Fig: 9 iUPQC transitory response during the connection of a threephase diode rectifier: (a) load currents, (b) grid currents, (c) load voltages and (d) grid voltages.

V. CONCLUSION

In the improved iUPQC controller, the currents synthesized by the series converter are determined by the average active power of the load and the active power to provide the dc-link voltage regulation, together with an average reactive power to regulate the grid-bus voltage. In this manner, in addition to all the power-quality compensation features of a conventional UPQC or an iUPQC, this improved controller also mimics a STATCOM to the grid bus. This new feature enhances the applicability of the iUPQC and provides new solutions in future scenarios

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involving smart grids and microgrids, including distributed generation and energy storage systems to better deal with the inherent variability of renewable resources such as solar and wind power.

Moreover, the improved PSO based iUPQC controller may justify the costs and promotes the iUPQC applicability in power quality issues of critical systems, where it is necessary not only an iUPQC or a STATCOM, but both, simultaneously. Despite the addition of one more power-quality compensation feature, the grid-voltage regulation reduces the inner-loop circulating power inside the iUPQC, which would allow lower power rating for the series converter.

The experimental results verified the improved PSO based iUPQC goals. The grid-voltage regulation was achieved with no load, as well as when supplying a three-phase nonlinear load. These results have demonstrated a suitable performance of voltage regulation at both sides of the iUPQC, even while compensating harmonic current and voltage imbalances

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