

Grid-Voltage Regulation Controller: IUPQC



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ABSTRACT:

This paper presents an improved controller for the dual topology of the unified power quality conditioner (iUPQC) extending its applicability in power-quality compensation, as well as in micro grid 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 voltage at the grid-side bus. In other words, the iUPQC will work as a static synchronous compensator (STATCOM) at the grid side, while providing also the conventional UPQC compensations at the load or micro grid side. Experimental results are provided to verify the new functionality of the equipment. The same calculations is going to use for fuzzy controller.

I. INTRODUCTION:

VOLTAGE control in medium voltage (MV) or low voltage(LV) distribution networks is typically exercised through transformer tap-changers and/or switched capacitors/reactors. Sometimes a STATic Compensator (STATCOM) is used for fast and precise voltage regulation, especially for the sensitive/critical loads [1] The novel concept of electric spring (ES) has been proposed as an effective means of distributed voltage control [2]. The idea is to regulate the voltage across the critical loads while allowing the noncritical (NC) impedance-type loads (e.g., water heaters) to vary their power consumption and thus contribute to demand-side response [3], [4] as well.

This would allow and facilitate large penetration of intermittent renewable energy sources without requiring huge amounts of energy storage to act as a buffer between supply and demand [5]. The basic proof of concept of ES has already been demonstrated through hardware experimentation with the developed prototypes [2], [6]. Distributed voltage regulation through collective action of a cluster of ESs, each employing droop control has also been illustrated [7]. In this paper, the focus is to compare the effectiveness of single point voltage control using STATCOM against distributed voltage control using a group of ESs. The basis for comparison is total voltage regulation [root mean square of the deviation of the actual voltages from the rated (1.0 p.u) values] achieved and the overall reactive capability required for each option in order to achieve that [8], [9].

A number of papers [2], [5]–[7] have been published recently on the ES concept and its control. However, none of those papers have focused on the collective performance of multiple of ESs considering realistic distribution networks. This paper demonstrates the effectiveness of multiple ESs working in unison through case studies on an IEEE test feeder network and also a part of a real distribution system in Hong Kong. The voltage regulation performance and total reactive power requirement of a group of ESs in case of distributed voltage control is compared against the single-point control using a STATCOM. In both cases, it turns out that a group of ESs achieves better total voltage regulation than STATCOM with less overall reactive power capacity.

To validate the performance of the proposed Unified power quality conditioner (UPQC) an investigation is carried out for changes in input and output conditions. From the investigations the variations of voltage control, voltage gain, voltage regulation. ES has to compare to UPQC. a group of ESs achieves better voltage regulation than UPQC with less overall reactive capability. Finally the simulation results and theoretical concept of the proposed Unified power quality conditioner (UPQC) have been verified with experimental set up.

II UNIFIED POWER QUALITY CONDITIONER (UPQC):

Unified power quality conditioner (UPQC), which aims at the integration of series active and shunt-active power filters. The main purpose of a UPQC is to compensate for voltage imbalance, reactive power, negative-sequence current and harmonics. The UPQC is a combination of series and shunt active filters connected in cascade via a common DC link capacitor. The main purpose of a UPQC is to compensate for supply voltage power quality issues such as, sags, swells, unbalance, flicker, harmonics, and for load current power quality problems such as, harmonics, unbalance, reactive current and neutral current.

BASIC CONFIGURATION OF UPQC:

- UPQC is the integration of series and shunt active power filters connected back to back on the dc side sharing on common DC capacitor.
- The series component of the UPQC is responsible for mitigation of the supply side disturbances.
- The shunt component is responsible for mitigating the current quality problems caused by the consumer.

The series APF inserts a voltage, which is added at the point of common coupling (PCC) such that the load end voltage remains unaffected by any voltage disturbance, whereas, the shunt APF is most suitable to

compensate for load reactive power demand and unbalance, to eliminate the harmonics from supply current, and to regulate the common DC link voltage[2].

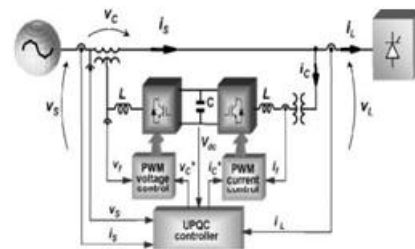


Fig 1: Basic configuration of the UPQC

SIMULATION RESULTS:

III. FUZZY LOGIC CONTROLLER

In FLC, basic control action is determined by a set of linguistic rules. These rules are determined by the system. Since the numerical variables are converted into linguistic variables, mathematical modeling of the system is not required in FC.

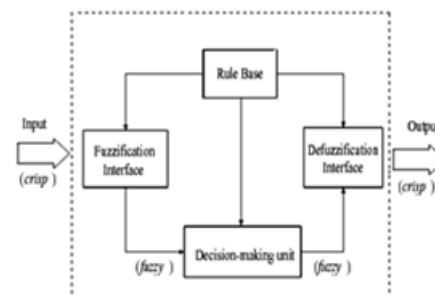


Fig.2. Fuzzy logic controller

The FLC comprises of three parts: fuzzification, interference engine and defuzzification. The FC is characterized as i. seven fuzzy sets for each input and output. ii. Triangular membership functions for simplicity. iii. Fuzzification using continuous universe of discourse. iv. Implication using Mamdani's, 'min' operator. v. Defuzzification using the height method.

Fuzzification: Membership function values are assigned to the linguistic variables, using seven fuzzy subsets: NB (Negative Big), NM (Negative Medium), NS (Negative Small), ZE (Zero), PS (Positive Small), PM (Positive Medium), and PB (Positive Big). The partition of fuzzy subsets and the shape of membership

CE(k) E(k) function adapt the shape up to appropriate system. The value of input error and change in error are normalized by an input scaling factor.

TABLE III:FUZZY RULES

Change in error	Error						
	NB	NM	NS	Z	PS	PM	PB
NB	PB	PB	PB	PM	PM	PS	Z
NM	PB	PB	PM	PM	PS	Z	Z
NS	PB	PM	PS	PS	Z	NM	NB
Z	PB	PM	PS	Z	NS	NM	NB
PS	PM	PS	Z	NS	NM	NB	NB
PM	PS	Z	NS	NM	NM	NB	NB
PB	Z	NS	NM	NM	NB	NB	NB

In this system the input scaling factor has been designed such that input values are between -1 and +1. The triangular shape of the membership function of this arrangement presumes that for any particular E(k) input there is only one dominant fuzzy subset. The input error for the FLC is given as

$$E(k) = \frac{P_{ph}(k) - P_{ph}(k-1)}{V_{ph}(k) - V_{ph}(k-1)} \quad (9)$$

$$CE(k) = E(k) - E(k-1) \quad (10)$$

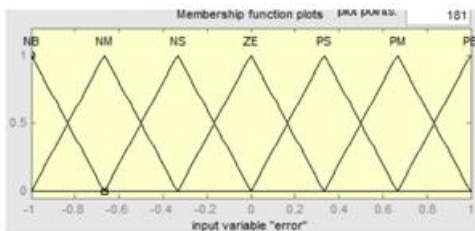


Fig.3. Membership functions

Inference Method: Several composition methods such as Max-Min and Max-Dot have been proposed in the literature. In this paper Min method is used. The output membership function of each rule is given by the minimum operator and maximum operator. Table 1 shows rule base of the FLC.

Defuzzification: As a plant usually requires a non-fuzzy value of control, a defuzzification stage is needed.

To compute the output of the FLC, „height“ method is used and the FLC output modifies the control output. Further, the output of FLC controls the switch in the inverter. In UPQC, the active power, reactive power, terminal voltage of the line and capacitor voltage are required to be maintained. In order to control these parameters, they are sensed and compared with the reference values. To achieve this, the membership functions of FC are: error, change in error and output. The set of FC rules are derived from

$$u = -[\alpha E + (1-\alpha) * C] \quad (5)$$

Where α is self-adjustable factor which can regulate the whole operation. E is the error of the system, C is the change in error and u is the control variable. A large value of error E indicates that given system is not in the balanced state. If the system is unbalanced, the controller should enlarge its control variables to balance the system as early as possible. Set of FC rules is made using Fig.(9) is given in Table 3.

RESULTS:

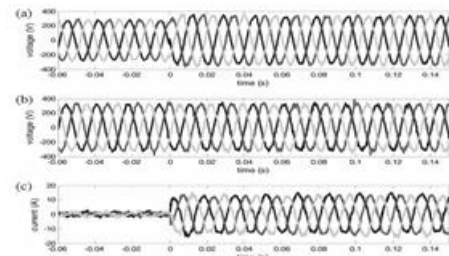


Fig 4: iUPQC response at no load conditions : a) Grid voltages V_A b)load voltages V_Band c)grid currents

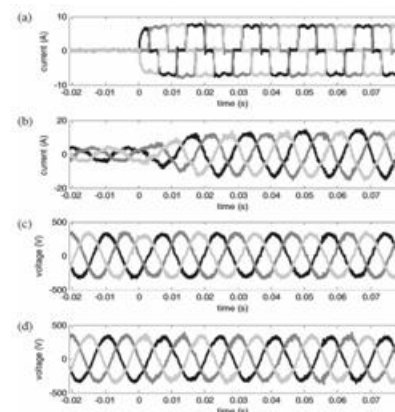


Fig 5 : iUPQC transitory response during the connection of a three phase diode rectifier: (a) load currents, (b) grid currents, (c) load voltages and (d) grid voltages

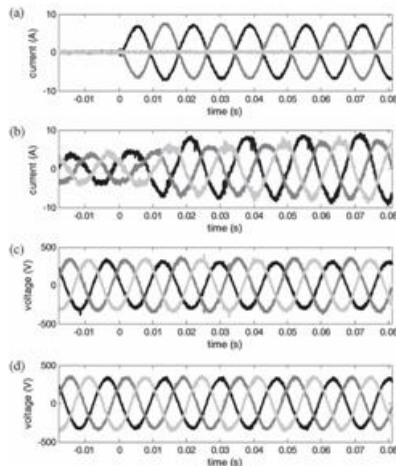


Fig 6: iUPQC transitory response during the connection of a two phase diode rectifier: (a) load currents, (b) source currents, (c) load voltages, and (c) source voltages.

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 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 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 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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