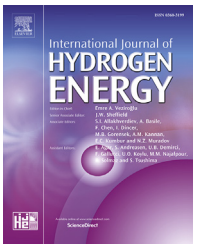
INTERNATIONAL JOURNAL OF HYDROGEN ENERGY XXX (2018) 1–19

Available online at www.sciencedirect.com

ScienceDirect

journal homepage: www.elsevier.com/locate/he



Fuzzy multi-objective technique combined with VCS algorithm for unified power quality conditioner based on hybrid power source PEMFC/SC

Brahim Berbaoui

Unité de Recherche en Energie Renouvelables en Milieu Saharien, URERMS, Centre de Développement des Energies Renouvelables, CDER, 01000, Adrar, Algeria

ARTICLE INFO

Article history:
Received 28 November 2017
Received in revised form
21 January 2018
Accepted 23 January 2018
Available online xxx

Keywords:
Power quality
UPQC
PEMFC-SC power source
Optimization
VCS algorithm

ABSTRACT

This paper is proposed to establish an optimal control method for UPQC (Unified Power Quality Conditioner) to improve power quality and manage effectively equal power sharing between shunt and series inverter of UPQC under electrical faults condition. The UPQC is modeled to protect sensitive load from source side voltage disturbances under nonlinear load conditions. A hybrid power generator that integrates a proton exchange membrane fuel cell (PEMFC) as the main energy source and a super capacitor (SC) as secondary source is proposed to feed the FACT device. In this work, a new control strategy is presented for considering the voltage sag, power factor and total harmonic distortion (THD) as multi-objective of UPQC controller. For this purpose, a new powerful algorithm named virus colony search (VCS) is used for determining the coefficients of the PI controller of UPQC. By using the fuzzification process for the objectives function, a suitable fitness function is established for the optimization method. From the simulations, it can be seen that the results obtained by the proposed algorithm are best and attractive compared to other method. Consequently, the proposed strategy is effective and outstrips other strategies.

Introduction

Currently the demand for stable and high quality electrical power has been increased considerably regarding to the progressive uses of semiconductor devices for different applications, such as uninterruptible power supply systems, computer processors, lighting and adjustable speed drivers. These nonlinear loads can draw non-sinusoidal current and voltage and result harmonic distortion in power systems. Consequently, all electrical and electronic equipment irrespective of its sensitivity might suffer due to degrading power quality. Moreover, due to sudden load activation and load shedding, voltage unbalancing among the three phases occurs at the common coupling point. Maintaining a steady state voltage is a major factor that can affect the consumer loads [1–2]. Power quality has become an important issue in differentiating between successful utilities in the power system specially deregulated environment. Relevant researches demonstrate that the Unified Power Quality Conditioner (UPQC) is an affordable custom power device employed at the point of common coupling (PCC) to protect the load from the

E-mail addresses: b.berbaoui@urerms.dz, berbaoui.brahim@gmail.com.
https://doi.org/10.1016/j.ijhydene.2018.01.149
0360-3199/

Nomenclature

UPQC	Unified power quality controller
PEMFC	proton electrolyte membrane fuel cell
SC	super capacitor
FACT	Flexible alternative current transmission
SAPF	Series active power filter
DVR	Dynamic voltage restorer
PCC	point of common coupling
VCS	virus colony search
DE	Differential evolution
PSO	Particle swarm optimization
APF	Active power filter
THD	Total harmonic distortion
PQ	Power quality
$E_{reversible}$	Reversible voltage
$V_{ohmloss}$	Ohmic voltage loss
$V_{actloss}$	Activation voltage loss
$V_{concloss}$	Concentration voltage loss
R_{act}	Activation resistance
R_{conc}	Concentration resistance
T	Temperature
T_{cell}	Cell temperature
P_{H2}	Hydrogen partial pressures
P_{O2}	Oxygen partial pressures
ESR	Equivalent series resistance
$V_{st}(t)$	Supply voltage
R_{fs}	Series filter resistance
L_{fs}	Series filter inductance
C_{fs}	Series filter capacitance
R_{fp}	Shunt filter resistance
L_{fp}	Shunt filter inductance
C_{fp}	Shunt filter capacitance
PWM	Pulse wave modulation
DC	Direct current
LPF	Low pass filter
V_b	Bus voltage

PQ distortions [3]. The structure of UPQC in simple terms has a single topology that combines shunt and series active filter with a common DC capacitor.

The UPQC is used to act for voltage harmonics, voltage sag or swells on the series side and reactive power compensation, current harmonic compensation, load unbalance compensation and power factor improvement on the parallel side. The Super capacitor Energy is used as a battery storage device across the DC link for short time duration. On the other hand, the power quality problems through electrical networks have attracted the intention of many researchers; ArindamGhosh [4] has presented the topology and the control of a unified power quality conditioner (UPQC) that can be used for power quality enhancement. Also, RudrarajuTejasvi [5]studied an improved fuel cell based controller for dual topology of the UPQC extending its capability in power quality. Ch.sumathianjana rani [6]has explained a three -phase UPQC based integration of proton exchange membrane fuel cell (PEMFC) to mitigate current harmonic and voltage sag. The classical PI method has poor performance, since it cannot obtain zero steady-state error, when the reference is a sinusoidal signal superposed of different frequencies, because of its bandwidth limitation [7]. There are many researchers who have operated to intelligent techniques to control these FACTS such as Performance of fuzzy logic controller for controlling Shunt active power filter (SAPF) is investigated [8] which is well recognized for improvements of both transient and steady-state performances. Emotional controller is implemented as an adaptive controller which reveals to have high capability control DVR with simple structure [9–10].

Optimization is the process of searching for the global optima of a problem under a given circumstance. The Virus colony search (VCS) has been recognized as a powerful and efficacious technique to solve complex problems. In addition, the VCS offers competitive solutions compared with other metaheuristic optimizers based on the reported results of series of classic benchmark functions [11]. Improving voltage THD and power factor indexes have been reflected as an objective function. Though, algorithms with high level of complexity have been used which may have problems in real-time implementation. In order to use stable controllers in the system, it should react in instantaneous to different faults conditions in the best way. In this paper, a multi-objective control structure is proposed to obtain an appropriate performance in term of sensitive load harmonic current, voltage sag and THD [36]. During this work, a new nature-inspired algorithm for optimization (VCS) is introduced and discussed. It will be shown that proposed approach can be effective for controlling UPQC based hybrid PEMFC/SC. To evaluate the performance of the proposed optimal controllers, the results are compared with those obtained by regulating PI's coefficients with multi-objective DE and PSO algorithm.

Renewable energy policy has become an essential ingredient of social and economic development plans in the world due to the deficiency of fossil fuel and CO_2 emission reducing [12,13]. The electrochemical energy is an alternative power source, more environmentally friendly. Systems for electrochemical energy storage and conversion include fuel cells, super capacitors and batteries. High power and high energy can be well achieved when two or more electrochemical systems are combined. In such hybrid electrochemical schemes, super capacitors provide high power while the fuel cells provide high energy [14]. The PEMFC/SC hybrid power source is emerging as an economically viable option for providing UPQC systems, which play a very important role as the backup and emergency power supply for important applications.

The recap of this paper is organized as follows:

Section Introduction reviews the introduction to hybrid energy source PEMFC/SC for UPQC system.

Section UPQC structure description configuration shows the UPQC structure description.

Section Modeling of hybrid power source shows hybrid power source modeling.

Section Basic concepts and structure approach of UPQC Basic concepts and the structure approach of UPQC.

Section Objective functions shows objective functions.

Section VCS algorithm for optimization problem describes VSC algorithm working.

Section Proposed approach show proposed method.

Please cite this article in press as: Berbaoui B, Fuzzy multi-objective technique combined with VCS algorithm for unified power quality conditioner based on hybrid power source PEMFC/SC, International Journal of Hydrogen Energy (2018), https://doi.org/10.1016/j.ijhydene.2018.01.149