IET Generation, Transmission & Distribution

Research Article

Cascaded controller for a standalone microgrid-connected inverter based on triple-action controller and particle swarm optimisation

ISSN 1751-8687
Received on 13th November 2019
Revised 14th May 2020
Accepted on 21st May 2020
doi: 10.1049/iet-gtd.2019.1641
www.ietdl.org

Omar M. Salim[1] ✉, *Amgad Aboraya*[1], *Shawky I. Arafa*[1]
[1]*Department of Electrical Engineering, Benha University, Benha, Egypt*
✉ *E-mail: omar.salim@bhit.bu.edu.eg*

Abstract: In this study, power quality (PQ) improvement has been addressed, in the form of total harmonic distortion (THD) minimisation, as well as, voltage regulation using two cascaded schemes. The first scheme is the optimised triple action controller (TAC)-based pulse width modulated voltage source inverter. TAC consists of a proportional resonant controller, selective harmonic compensator, and a new added current-assisted feed forward controller. The second scheme is the optimised cascaded dual-level control of a standalone microgrid. Cascaded level control consists of droop, secondary, and synchronisation control loops. The two approaches have been optimised for best parameter selection out of the possible solution space using a particle swarm optimisation algorithm to satisfy the study objectives. The optimisation objectives/ constraints were to minimise THD and minimise overshoot/undershoot, rise time, and steady-state error for voltage compensation under two disturbance scenarios, sudden load change, and voltage flicker injection as a power frequency disturbance. These research results have been compared to other existing simulation and experimental work. The results proved to be better in output voltage, frequency, response time, and THD. Furthermore, the proposed schemes ensure power factor improvement, high efficiency, overall system PQ, and reliability at various load conditions.

Nomenclature

α	individual harmonic component on the signal
ω_{ref}, ω_{drp}	reference and droop angular frequency
E_{ref}, E_{drp}	reference and droop voltage amplitude
P^*, Q^*	reference active and reactive power
P_{dem}, Q_{dem}	active and reactive power demand
K_{ip}, K_{PQ}	droop coefficients
K_{PP}	system virtual inertia
P_{inst}, Q_{inst}	instantaneous active and reactive power
$v_{\text{c}\alpha\beta}$	capacitor voltage in $\alpha\beta$-frame
$i_{\text{o}\alpha\beta}$	output current in $\alpha\beta$-frame
$v_{\text{virt}\alpha}$, $v_{\text{virt}\beta}$	virtual voltage in $\alpha\beta$-frame
R_{virt}, L_{virt}	virtual resistance and inductance
ω_{sec}, E_{sec}	frequency and voltage of secondary control
K_{pF}, K_{iF}	parameters of frequency restoration
K_{pE}, K_{iE}	parameters of voltage restoration
ω_{sync}	output signal of phase-locked loop

1 Introduction

1.1 Motivation and incitement

Microgrid (MG) should be able to operate either in 'islanded mode' or 'grid-connected mode'. In grid-connected mode, the active and reactive power can be either imported or exported between both grids according to the strategy of system management [1]. The MG feeds the critical loads with power during stand-alone mode [2, 3]. The infrastructure of MG adopted distributed generation (DG). DG offers many advantages such as efficiency improvement, power losses reduction in the distribution system by integrating DG micro-sources adjacent load centre, carbon emission reduction etc. However, DG produces many technical challenges as well, some of these challenges are the voltage regulation, increased fault level, and bi-directional power flow between MG and utility grid. On the other hand, some power quality (PQ) issues appear in MGs such as power variation, voltage and frequency deviation, voltage sag/swell, flickers due to fast voltage variation, poor power factor, total harmonic distortion (THD) due to the natural loads and unbalanced voltage due to load unbalance [4, 5]. It is known that the term PQ generally refers to sustain sinusoidal voltage at rated magnitude and frequency.

Harmonics represents a major PQ issue in power systems especially MG. Harmonics have significant negative impacts on the electrical power system. The negative impacts are the increased transformer losses (copper, iron, and stray losses), heating of neutral lines, circuit breakers and panels heating, effect on electromagnetic equipment, problems concerning capacitors used for power factor correction and lifetime reduction for all equipment under harmonics effect [2, 6–8]. In MG, due to the extensive use of power; the electronic interface between highly dynamic large loads (such as pulsating or propulsion loads) and sources leads to severe PQ issues in MGs [9].

Furthermore, one of the issues related to the quality of energy in electrical systems is the voltage flicker. It has a negative impact on maintaining the nominal values of supply voltage and frequency. It also contributes to the creation of undesirable harmonics in electrical systems. Voltage flicker or light flicker is the response of the lighting system to such load variations as observed by the human eye. The main reason for the voltage flicker is the rapid load current variations [10].

1.2 Literature review

The main source of harmonics is normally produced by non-linear loads such as arc furnace, arc-discharge devices, magnetic cores, variable speed drives, solid-state switches, and switched-mode power supplies. These loads introduce a non-sinusoidal wave and as a result, they produce harmonics. To quantify the harmonics of electrical variables, including voltages and currents, THD of voltage source inverter (VSI) output defined as

$$\text{THD} = \frac{\sqrt{\sum_{h=2}^{\infty} \alpha_h^2}}{\alpha_1} \tag{1}$$