Economic load sharing in a D-STATCOM Integrated Islanded Microgrid based on Fuzzy Logic and Seeker Optimization Approach

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**ABSTRACT**

In this manuscript, an optimized Dynamic PI-Controller based on Fuzzy logic and Seeker Optimization Approach (SOA) are proposed for a Microgrid comprised with hybrid micro-sources to ensure the highest end-user energy cost efficiency and energy supply reliability. The two micro-sources Photovoltaic and Fuel Cell are considered taking the first one with an objective to act as a primary source and later is integrated to enhance the economic load sharing and power quality of the overall system. Furthermore, the effect of D-STATCOM as a reactive power compensator is investigated not only for the above factors but also for the load balancing enhancement. With the addition to the above, a communication less modified Virtual Impedance Drooping power sharing scheme is proposed to ensure the improvement in stability related issues like transient and sub-transient disturbances by optimal power sharing. To ensure the proposed approach for its practical implementation harmonic analysis has been carried out by computing Total Harmonic Distortion (THD) through Fast Fourier Transform (FFT) and to make sure its value well within the prescribed limit IEEE-519 standard. The comparative simulated results are demonstrated under various abnormal operating conditions to justify the enhanced performance of the proposed control approach.

1. Introduction

Gradually the conventional power grid networks are becoming incompatible with the modern society mainly due to the issues related to the environmental pollution, sky-scraping fuel cost and high transmission loss. At the same time, potential renewable energy sources offer clean energy along with the low operational cost. However, integrating renewable sources is extremely difficult due to its small scalability and highly nonlinear operational characteristics (Moslehi & Kumar, 2010). The issues related to unpredictability in terms of source input and instability due to nonlinear dynamics are keeping the renewable sources away from the real-time implementation (Kovendan & Sridharan, 2017). Hence the concept of Microgrid is developed to incorporate renewable micro-sources without significantly affecting the system stability (Lasseter, 2002). However, in a Microgrid there are many crucial issues which have to be considered for the stable operation such as (1) Proper selection of micro-sources and their control strategy to ensure high energy supply reliability; (2) Optimal power sharing among the DGs to ensure high energy cost efficiency; (3) Active Demand Management (ADM); (4) Dynamic stability during fault condition (Lasseter & Paigi, 2004; Rocabet, Luna, Blaabjerg, & Rodriguez, 2012).

Generally, as the renewable micro-sources are climate depended, the incorporation of different micro-sources to form a hybrid source of electrical energy as a solution to the stated issue ensures less dependency on the ambient scenario. This in turn significantly improves the associated problems such as reliability, stability, power quality and load demand balance irrespective of different ambient and system fault conditions (Majumder, Dewadasa, Ghosh, Ledwich, & Zare, 2011; Zhang, Gari, & Hmurcik, 2014). For the enrichment of the energy supply potentiality under a hybrid structure, micro-sources can be hybridized in many ways such as (1) DC side coupling; (2) AC side coupling Agbossou, Kolhe, Hamelin, & Bose, 2004; Agbossou et al., 2001); (3) crossbreed coupling (Farret & Simões, 2006; Ko, Lee, Dehbonei, & Nayar, 2006). Looking to the extensive use of Photovoltaic (PV) array in recent past due to its abundant energy source availability and low operating cost, it has been considered as a primary source to meet the load demand. Along with that, Solid Oxide Fuel Cell (SOFC) is considered as a secondary generating micro-source not only to support PV micro-source but also to enhance system stability and power quality problems under transient conditions. Power sharing and related power quality problems in Microgrid comprised with hybrid micro-sources are focused with an objective to design an optimal controller.

Drooping based power sharing schemes are preferred over communication-based schemes because the later having major limitations.
like high installation cost for communication lines, communication gap, signal transportation delay, phase angle disparity and multifaceted operation (Pogaku, Prodanovic, & Green, 2007). Even if several methods have been suggested in the recent past related to power sharing problem in microgrid several drawbacks are observed such as: load dependency of frequency and voltage deviations, not taking into account the harmonic sharing of non-linear loads, adverse effect of different and unknown line impedances on power sharing performance, fluctuant and changeable output power of DG’s itself. In the recent past, numerous attempts have been made to overcome these drawbacks and minimize the circulating current under all situations by several proposed methods.

However, the conventional Droop control techniques fail to operate optimally to account harmonic current and regulating feeder active and reactive power sharing in case of hybrid micro-source operation under nonlinear or unsymmetrical load (He et al., 2017). Conventional Drooping schemes are challenged in principle by the unknown line impedances (Yu, Khambadkone, & Wang, 2010). Comparatively, the conventional Virtual Impedance Drooping (VID) scheme is capable of withstanding against the effects of unknown line impedances (Guerrero, Garcia-de Vicuna, & Matas, 2005; Yao, Chen, & Matas, 2011). Still, it lacks to deliver precise power sharing when subjected to non-linear load conditions (Wu, Chen, & Reza, 2017). In this study, an attempt has been made in the direction to further enhance the dynamic performance of the optimal power sharing and active demand management.

During any fault condition in case of the grid-connected mode of operation, large inertia supply high fault current to trigger fault protection devices like Inverse Definite Minimum Time relay (IDMT-relay). However, in the case of islanded microgrid system, it has very low inertia (Lasseter, 2001). Consequently, during any fault condition to stabilize the grid voltage rapidly during the sub-transient period, FACTS
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