Secondary Frequency Control based on Consensus Algorithm and Fuzzy Gain Scheduling for Islanded Microgrids

S.Gholamalipour, M.B.Menhaj, G.B. Gharehpetian, A.Suratgar

INTRODUCTION

In this paper, a novel secondary frequency controller is proposed to correct the deviation of the reference frequency of islanded microgrid, which is caused by the primary control. In the proposed secondary control, the microgrid is considered as a multi-agent system in which each inverter-based distributed generation is indeed represented as an agent. These agents should cooperate to reach the nominal frequency and share the required power among resources based on their nominal power rating. A consensus algorithm is then used to fulfill all agents. An adaptive proportional controller using fuzzy logic is also designed in the secondary control to optimally tune the proportional gain and perform properly against uncertainties in microgrid parameters, leading to a more smooth transient response while the amount of the overshoot and undershoot is significantly decreased. The proposed controller is totally distributed so that there is no need for an expensive centralized controller and communication infrastructures, and therefore, the reliability of the overall system is increased.

HIGHLIGHTS

- the secondary controller will be adaptive without adding complexity to the control system.
- in the case of any changes in the topology and operating point of MG, the proposed controller optimally tunes the proportional gain and the MG simultaneously will supply loads properly.

PROBLEM FORMULATIO

In this paper, every DG with a connected inverter is considered as an agent which is connected to other DGs through a digraph. The aim of these agents is restoring the frequency (ωi) to the nominal value (ωref) and, meanwhile, guarantee autonomous real power sharing in the MG, which is based on
the equation (3); i.e.,

$\omega 1 = \omega 2 = \cdots = \omega i = \omega ref$

$\{m1P1 = m2P2 = \cdots = miPi$

Differentiating the equation in (3) yields the following control
system:

$$\dot{\omega}_{ni} = \dot{\omega}_i + m_{pi}\dot{P}_i = u_i$$

The input signal ui is chosen such that the frequency control signal (ωi) has some predefined characteristics. Based on multi-agent theory by considering ui as given in equation (6), the frequency of DGi will converge to the reference value and the required active power will properly be shared among DGs.

The final equation will be the following equation

$$u_i = -k_p\Big(\sum_{i\in N_i} a_{ij}\,(\omega_i - \omega_j) + a_{i(n+1)}(\omega_i - \omega_{ref})$$

$$+\sum_{i\in N_i}(m_{pi}P_i - m_{pj}P_j)\Big)$$

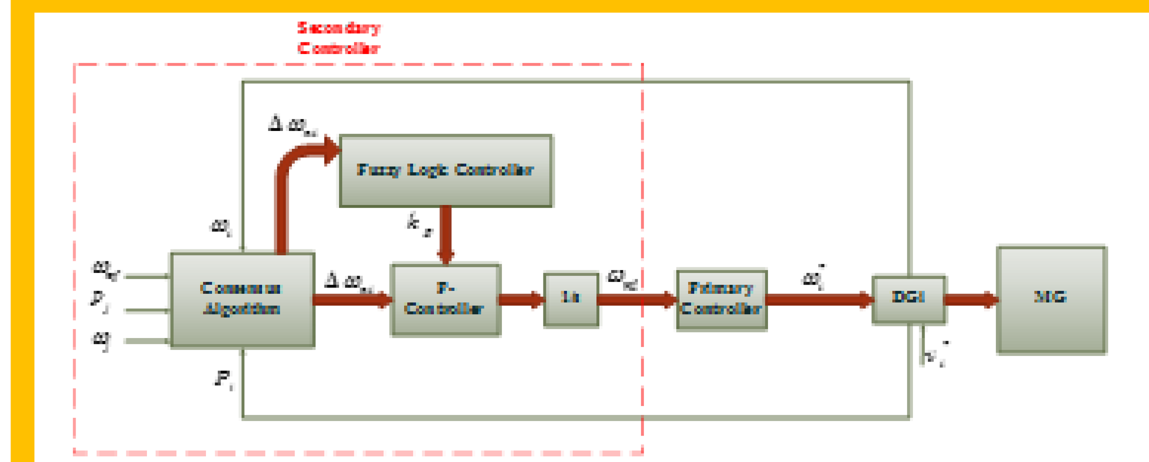
and kp is calculated by following equation:

$IF\ \Delta\omega_n$ is A_i $THEN$ k'_p is C_i

$A_i(x) = -0.25 \times \log(x)$ $for\ small$

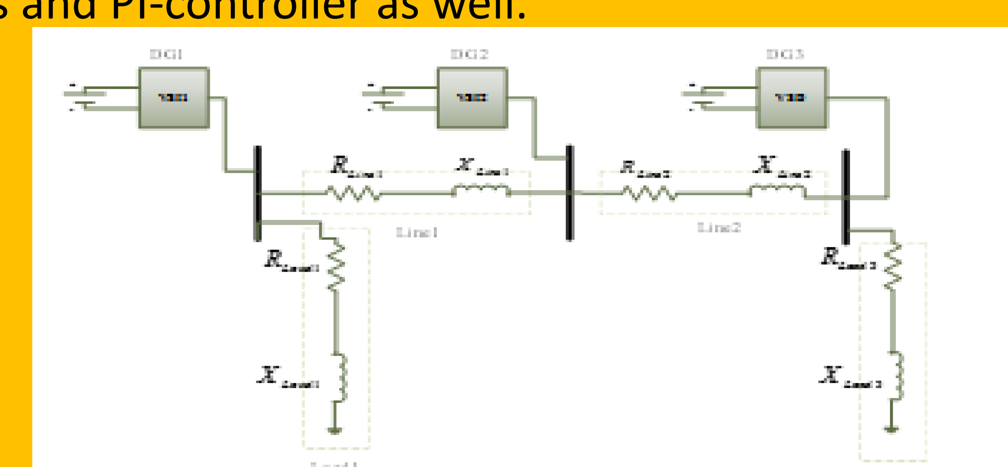
$A_i(x) = -0.25 \times \log(1-x)$ $for\ big$

$$k_p = (k_{p\,max} - k_{p\,min})k'_p + k_{p\,min}$$



RESULTS

A secondary frequency controller based on the MASs theory and fuzzy gain scheduling has been fully developed and then tested on an islanded MG in this paper. The MG has been considered as a MAS in which DGs connect to each other through communication links. These connections are modeled by a directed graph. To overcome the uncertainty of MG's parameters, fuzzy rules have been used to tune the proportional gain in the P- controller. Therefore, in the case of any changes in the topology and operating point of MG, the proposed controller optimally tunes the proportional gain and the MG simultaneously will supply loads properly. Compared with the conventional P-controller and PI-controller, the frequency response becomes smoother and the power sharing is more accurate. Furthermore, the control strategy is totally distributed and an expensive centralized controller is unnecessary, so the reliability is improved appreciably. Moreover, to demonstrate the effectiveness of the proposed secondary controller, some benchmark cases are considered. The results of simulations are compared with those of the secondary controllers based on the consensus algorithm with the constant proportional gains and PI-controller as well.



SIMULATION RESULTS