An LFC Model For Competitive Power System Markets

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1. Abstract

The modeling idea presented in Ref. (1) is generalized to obtain the dynamical model for load-frequency control (LFC) analysis and synthesis in a bilateral-based restructured power system. In each control area, the effect of bilateral contracts is taken into account as a set of new input signals. It is assumed that each distribution company (Disco) is responsible for tracking its own load and honoring tie-line power exchange contracts with its neighbors by securing as much transmission and generation capacity as needed.

2. Introduction

In an open energy market, generation companies (Gencos) may or may not participate in LFC task. On other hand a distribution company (Disco) may contract individually with Gencos or independent power producers (IPPs) for power in its area or other areas. Currently, these transactions are done under the supervision of the independent system operator (ISO), independent contract administrator (ICA) or other responsible organizations.

This paper introduces a modified model to adapt well-tested classical LFC scheme to the changing environment of power system operation under deregulation. The main advantage of this strategy is in using the basic concepts of traditional framework and avoid of using the impractical or untested LFC models. In vertically integrated power system structure, it is assumed that each bulk generator unit is equipped with secondary control and frequency regulation requirements, but in an open energy market, Gencos may or may not participate in LFC problem. Therefore, in a control area including numerous distributed generators with an open access policy and a few LFC participators, comes the need for novel modeling strategies for control synthesis and LFC analysis. Here, a modified dynamical model is performed for traditional LFC model by taken into account the effect of bilateral contracts on the dynamics, following the ideas presented in Ref. (1). In Ref. (1), a traditional-based dynamical model is proposed for two-control area in deregulated environment. This idea is generalised for a multi-area power system. The new LFC model includes all the information required in a vertically operated utility industry plus the contract data information..

3. Proposed LFC model

In a deregulated environment, vertically integrated utilities (VIU) no longer exist, however the common objectives, i.e. restoring the frequency and the net interchanges to their desired values for each control area are remained. Technically, the basic concepts of conventional LFC structure are not changed, and therefore it is possible to adapt well tested conventional LFC scheme to the changing environment of power system operation under deregulation as shown in Ref. (1) and (2). Here, the traditional-based dynamical LFC model is generalized for a given control area in deregulated environment under bilateral LFC scheme.

Based on mentioned model, overall power system structure can be considered as a collection of distribution areas or Discos as separate control areas interconnected through high voltage transmission lines or tie-lines. Each control area has its own LFC and is responsible for tracking its own load and honoring tie-line power exchange contracts with its neighbors. There can be various combinations of contracts between each Disco and available Gencos. On the other hand each Genco can contract with various Discos. The "generation participation matrix (GPM)" concept is defined to express these bilateral contracts in the generalized model. GPM shows the participation factor of each Genco in the considered control areas and each control area is determined by a Disco. The rows of a GPM correspond to Gencos and columns to control areas which contract power. For example, for a large scale power system with m control area (Discos) and n Gencos, the GPM will have the following structure. Where gpf_{ij} refers to "generation participation factor" and shows the participation factor of Genco i in the load following of area j (based on a specified bilateral contract).

$$GPM = \begin{bmatrix} gpf_{11} & gpf_{12} & \cdots & gpf_{1(m-1)} & gpf_{1m} \\ gpf_{21} & gpf_{22} & \cdots & gpf_{2(m-1)} & gpf_{2m} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ gpf_{(n-1)1} & gpf_{(n-1)2} & \cdots & gpf_{(n-1)(m-1)} & gpf_{(n-1)m} \\ gpf_{n1} & gpf_{n2} & \cdots & gpf_{n(m-1)} & gpf_{nm} \end{bmatrix} \quad (1)$$

The generalized LFC block diagram for control area i can be obtained in a deregulated environment as shown in Fig. 1. New information signals due to possible various contracts between Disco i and other Discos and Gencos are shown as dashed-line inputs, and, we can write [2]:

$$v_{1i} = \Delta P_{Loc\text{-}i} + \Delta P_{di} \quad (2)$$

$$v_{2i} = \sum_{\substack{j=1 \\ j\neq i}}^{N} T_{ij}\Delta f_j \quad (3)$$

$$\begin{aligned} v_{3i} &= \sum (Total\ export\ power - Total\ import\ power) \\ &= \sum_{\substack{j=1 \\ j\neq i}}^{N} \Big(\sum_{k=1}^{n} gpf_{kj}\Big)\Delta P_{Lj} - \sum_{k=1}^{n}\Big(\sum_{\substack{j=1 \\ j\neq i}}^{N} gpf_{jk}\Big)\Delta P_{Li} \end{aligned} \quad (4)$$

$$v_{4i} = \begin{bmatrix} v_{4i\text{-}1} & v_{4i\text{-}2} & \cdots & v_{4i\text{-}n} \end{bmatrix} \quad (5)$$

$$v_{4i\text{-}1} = \sum_{j=1}^{N} gpf_{1j} \Delta P_{Lj}$$
$$\vdots \qquad (6)$$
$$v_{4i\text{-}n} = \sum_{j=1}^{N} gpf_{nj} \Delta P_{Lj}$$

$$\Delta P_{tie\text{-}i,error} = \Delta P_{tie\text{-}i,actual} - v_{3i} \qquad (7)$$

$$\sum_{i=1}^{n} gpf_{ij} = 1 \qquad (8)$$

$$\sum_{k=1}^{n} \alpha_{ki} = 1 \quad ; \quad 0 \le \alpha_{ki} \le 1 \qquad (9)$$

$$\Delta P_{mi} = \sum_{j=1}^{N} gpf_{ij} \Delta P_{Lj} \qquad (10)$$

where,

Δf_i : frequency deviation, ΔP_{gi} : governor valve position, ΔP_{ci} : governor load setpoint, ΔP_{ti} : turbine power, ΔP_{tie-i} : net tie-line power flow, ΔP_{di} :area load disturbance, M_i : equivalent inertia constant, D_i : equivalent damping coefficient, T_{gi} : governor time constant, T_{ti} : turbine time constant, T_{ij} : tie-line synchronizing coefficient between area i & j, B_i : frequency bias, R_i : drooping characteristic, α : ACE participation factor, N: number of control areas, ΔP_{Li} : contracted demand of area i, ΔP_{mi} :power generation of a Genco i, ΔP_{Loc-i} : total local demand (contracted and uncontracted) in area i, v_{3i} : scheduled ΔP_{tie-i} ($\Delta P_{tie\text{-}i,scheduled}$) and $\Delta P_{tie\text{-}i,actual}$: actual ΔP_{tie-i} .

v_{1i} (includes the local load variation) and v_{2i} (includes the interface effects between each control area and others) are exist in both traditional and modified LFC models and they and their place are defined already. But the new input signals v_{3i} (includes the scheduled tie-line power flow) and v_{4i} (includes contracted demands of various Discos from Gencos of area i) are performed based on bilateral contract information as expressed in (4) and (6). These expressions and the place of signals in the dynamical model were such selected that:

i) The new model covers all of possible contract combinations given by *GPM*.

ii) The calculation results from equations (4), (6) and (10) are completely matched to the corresponded simulation results for a given set of bilateral contracts.

In summary, the difference between proposed LFC structures and conventional one is in the existence of contract data information. This introduces new information signals which were absent in the conventional structure. These signals identify which Genco has to follow a load demanded by a specified Disco. The validity of this modeling is shown for a given multi-area power system in our work. Interested readers can find more details on above LFC modeling and several simulation scenarios for a given restructured power system in Ref. (2).

4. Conclusion

The conventional LFC model is generalized for a restructured power system under bilateral contracts, by adding the new input channels due to possible various contracts between Gencos and Discos. The simulation results for various cases demonstrate the effectiveness of the proposed model as a suitable dynamical model for LFC analysis and synthesis in a bilateral-based large scale power system.

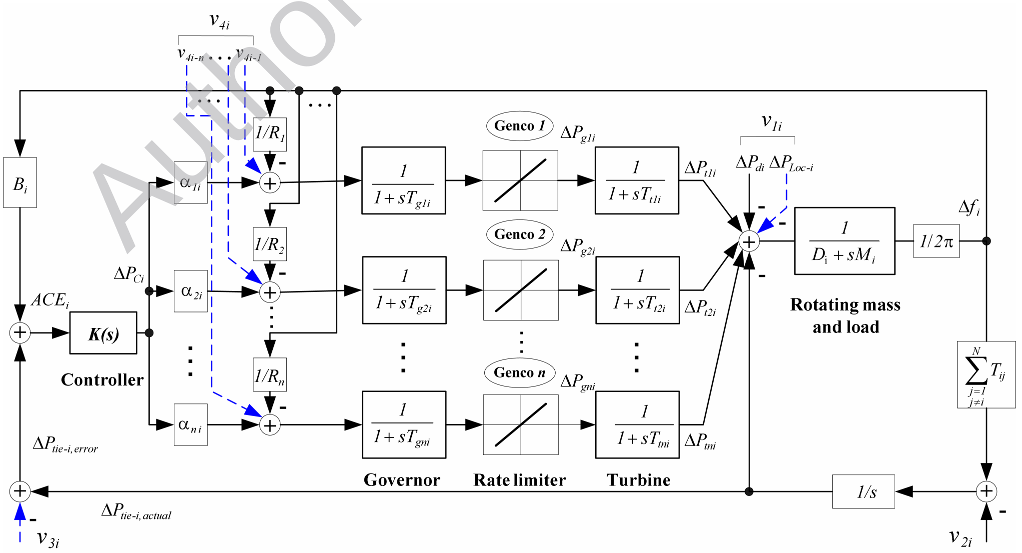

Fig. 1. Generalized LFC model in a deregulated environment

5. Reference

(1) V. Donde, M. A. Pai and I. A. Hiskens : "Simulation and optimization in a AGC system after deregulation", IEEE Trans. On Power Systems, Vol. 16, No. 3, pp. 481-489 (2001)

(2) H. Bevrani, Y. Mitani and K. Tsuji : "A generalized dynamical model for analysis and synthesis of bilateral-based LFC scheme", Submitted to 2nd Int. Conf. on Electric Utility Dereg., Restruct. and Power Tech. (DRPT), Hong Kong (2004)