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Optimal Decentralized Load Frequency Control in a Parallel AC-DC Interconnected Power System Through HVDC Link Using PSO Algorithm

S.Selvakumaran[a]*, S.Parthasarathy[b], R.Karthigaivel[c], V.Rajasekaran [d]

[a]*EEE Department,PSNA College of Engg.& Tech.,Dindigul-624622,Tamilnadu,India,Email:selvame1_2000@yahoo.com*
[b]*EEE Deparment,KLN College of Engineering,Madurai-630611,Tamilnadu,India,Email:sarathy_sps@yahoo.co.in*
[c]*EEE Department,PSNA College of Engg.& Tech.,Dindigul-624622,Tamilnadu,India,Email:karthi.mtech@gmail.com*
[d]*EEE Deparment, PSNA College of Engg.& Tech.,Dindigul-624622,Tamilnadu,India,Email:rajasekaranvm@gmail.com*

Abstract

A new design of decentralized load-frequency controller for interconnected power systems with ac-dc parallel using Particle Swarm Optimization (PSO) algorithm is proposed in this paper. A HVDC link is connected in parallel with an existing ac tie-line to stabilize the frequency oscillations of the ac system. Any optimum controller selected for load frequency control of interconnected power systems should not only stabilize the power system but also reduce the system frequency and tie line power oscillations and settling time of the output responses. In practice Load Frequency Control (LFC) systems use simple Proportional Integral (PI) or Integral (I) controller parameters are usually tuned based on classical or trial-and-error approaches, they are incapable of obtaining good dynamic performance for various load change scenarios in multi-area power system. For this reason, in this paper the PI and I control parameters are tuned based on PSO algorithm method for the LFC control in the two-area power system. A two area interconnected thermal power system is considered to demonstrate the validity of the proposed controller. The simulation results show that the proposed controller provides better dynamic responses with minimal frequency and tie-line power deviations, quick settling time and guarantees closed-loop stability margin.

Keywords *: Load Frequency Control; PSO; ac-dc tie lines; Interconnected Power systems*

1. Introduction

The interconnected power system presents a great challenge in power system design and operation. The load-frequency control (LFC) problem has gained much importance because of the size and complexity of modern interconnected power systems. The objective of LFC is to regulate the output powers of

* Corresponding author. Tel.: +919442056297
E-mail address: selvame1_2000@yahoo.com

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regulating plants so that the frequency of power system and tie-line powers are kept within prescribed limits. Many control strategies for LFC of power systems have been proposed and investigated by many researchers over the past several years [1-4].

Majority of the works carried out earlier is centered on interconnected power systems considering only the area interconnection with ac tie-lines. However, there has been a tremendous growth of the HVDC transmission system due to economic, environmental and performance advantages over the other alternatives. Hence, it has been applied widely in operating a dc link in parallel with an ac link [5-7] interconnecting control areas to get an improved system dynamic performance with greater stability margins under small disturbances in the system. Therefore, this paper considers LFC of an interconnected power system with a dc tie-line in parallel with an ac tie-line. Incremental dc power flow is considered as an additional state variable in the LFC strategy.

There has been considerable effort devoted to LFC of interconnected power systems in the literature [1-4]. A number of control strategies have been employed in the design of load frequency controllers in order to achieve better dynamic performance.

Hence, a new design of PI controllers using PSO [8] algorithm is proposed in this work, for the decentralized LFC of interconnected power systems with ac-dc parallel tie-lines to achieve a better transient, as well as steady state response and closed loop stability of the system. The proposed controller has been applied to an interconnected two-area thermal power system with ac-dc parallel tie-lines.

2. Statement of the problem

The block diagram representation of a two area interconnected thermal power system with ac-dc parallel tie-lines is shown in Fig.1. Each of the area in the interconnected power system consists of two thermal generating units. The dynamic behavior of the LFC system is described by the state space equation:

$$\dot{X} = AX + BU + \Gamma D \tag{1}$$

$$Y = CX \tag{2}$$

where the system state vector can be written as $X = [X_{1,} \; X_2]^T$ and sub vector X_1 and X_2 are the thermal system state vector of area 1 and area 2 respectively. As the two areas are considered to be identical areas the state sub vectors can be written as,

$X_1 = X_2 = X_i, i = 1,2$; $U = [\Delta P_{c1}, \Delta P_{c2}]^T$ and $D = [\Delta P_{d1}, \Delta P_{d2}]^T$

where A, B, Γ, X, U, D are System matrix, input distribution matrix, disturbance distribution matrix, state vector, control input vector, disturbance vector respectively. The corresponding co-efficient matrices are obtained using the nominal system parameter values given in Appendix. A step load disturbance of 1% in area 1 has been considered as a disturbance in the system. It is known that, by incorporating an integral controller, the steady state requirements can be achieved. In order to introduce integral function in the controller, the system equation (3) is augmented with new state variables defined as the integral of ACE_i ($\int$ vidt), i = 1, 2. The augmented system of the order (2 + n) may be described as

$$\dot{\overline{X}} = \overline{A}\overline{X} + \overline{B}u + \overline{\Gamma}d \tag{3}$$

$$\overline{x} = \begin{bmatrix} \int v dt \\ x \end{bmatrix} \begin{matrix} \}2 \\ \}n \end{matrix} \quad \text{and} \quad \overline{A} = \begin{bmatrix} 0 & C \\ 0 & A \end{bmatrix} \overline{B} = \begin{bmatrix} 0 \\ B \end{bmatrix} \quad \text{and} \quad \overline{\Gamma} = \begin{bmatrix} 0 \\ \Gamma \end{bmatrix}$$

The decentralized feedback control law may be written in terms of *vi* as:

$$u_i = -k_{i1} \int v_i dt - k_{i2} v_i, \quad i = 1,2 \tag{4}$$

where $k_i^{\,T} = [k_{i1} \quad k_{i2}]$ is a two dimensional integral and proportional feedback gain vector.