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Puma Optimization-Based Frequency Regulation in Deregulated Hybrid Power Systems

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Abstract: ***The present work emphasizes on the Load Frequency Control (LFC) of a hybrid power system under deregulated scenarios. To optimize the parameters of the controller, a puma optimization technique is used for the FOPID-FI controller. Puma optimized FOPID-FI controller is designed for the hybrid power system under deregulated scheme. The proposed technique is utilized with the combination of FACTS controllers like RFB and UPFC. The performance has been compared with the hybrid system without RFB and UPFC. The efficacy of the proposed controller is analyzed using MATLAB/SIMULINK in deregulated scenarios like Poolco and bilateral transactions. Further the hybrid power system is also examined using random step load changes and parametric variation.***

Keywords: Load Frequency Control (LFC), Puma Optimization, FACTs Technology

1. Introduction

Electric power systems rely heavily on automatic generation control (AGC) for operation and control. Frequency, generation, and tie-line power all deviate from their assigned line power levels due to the ongoing disparity between total generation and reported power consumption. As a result, real-time maintenance of system integrity requires matching generation, load requirements, and related losses. Frequency deviation from its nominal range has a direct impact on network operation reliability. Thus, the primary function of AGC is to maintain the operating frequency and tie-line power within permissible limits. [1] [2] [3] [4]. In conevetional power system, vertically integrated utility (VIU), a single company manages all the process of distribution, transmission and generation. Utilizing their monopoly, this VIU sold power at regulated rates that left consumers with no other option and resulted in a price gap. Numerous research of conventional power systems, including thermal, gas, and hydro, have been conducted over the years. The authors of these research did not discuss deregulated power systems, but they did apply load frequency control (LFC) in traditional systems [5] [6] [7] [8]. A transparent system that benefits energy customers is created by competitiveness among all market participants in the energy sector. Deregulation aims to help consumers by giving them more options, better services, and less expensive electricity. In a deregulated system, the industry is driven more effectively and the cost of electricity is decreased. Customers profited from a drop in electricity costs with the implementation of the deregulated system [9] [10] [11] [12] [13]. Further deregulation has expanded customer choice, encouraged innovation, and compelled companies to adopt more customer-centric services. Due to this, the power industry decided to deregulate the electrical power sector. By intensifying the competition new entities like TRANSCOs, DISCOs, GENCOs and ISOs entered into the market. In a deregulated power system, GENCOs supply electricity to multiple DISCOs at competitive prices, while DISCOs are not limited to purchasing power from specific GENCOs. Since the power network consists of several GENCOs and DISCOs, each entity has the freedom to establish power transaction contracts independently. The ISO is in charge of offering several auxiliary services for reliable and secure power system operations [14] [15] [16] [17] [18]. Maintaining LFC in deregulated power systems is crucial. LFC problems in deregulated power systems have been the subject of some recent research [15–20]. Deregulation allows for three distinct types of transactions: contract violation-based transactions (CVT), bilateral-based transactions (BBT), and poolco-based transactions (PBT). In the case of bilateral bilateral transaction (BBT) demand, DISCOs may obtain power from GENCOs within their own area as well as from GENCOs located in other areas, resulting in a non-zero tie-line power exchange. In contrast, under the poolco transaction model, DISCOs are supplied only by GENCOs within their respective areas, leading to no tie-line power exchange. As the term implies, there is a breach of the previously signed contract. In this instance, the GENCOs are required to supply the extra power that DISCOs want; this is referred to as un-contracted load requests from their areas [19] [20] [21].

2. Proposed System

Area-1is consisting of a thermal, hydro, wind, and three DISCOs namely $DISCO_1$, $DISCO_2$, and $DISCO_3$. Area-2 have thermal, hydro, and gas power plants and three DISCOs namely $DISCO_4$, $DISCO_5$, and $DISCO_{6.}$ DISCOs can demand power from DISCOs of other areas in restructured power system.

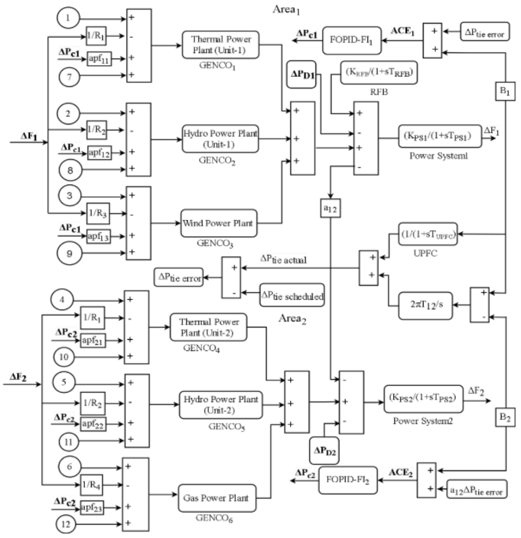


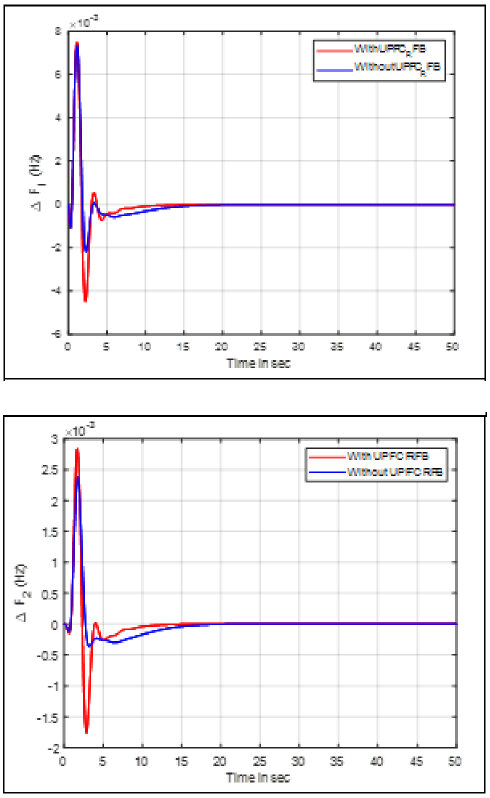
Figure 2: Block diagram of the hybrid power system under the restructured scenario

Every component in the DPM matrix represents a percentage of the overall load that is moved from a jth- DISCO (column) to an ith-GENCO (row).

$$\sum_{i=1}^{6} cpf_{ij} = 1 \tag{3}$$

3. Result & Discussion

Case 1 (PBT):



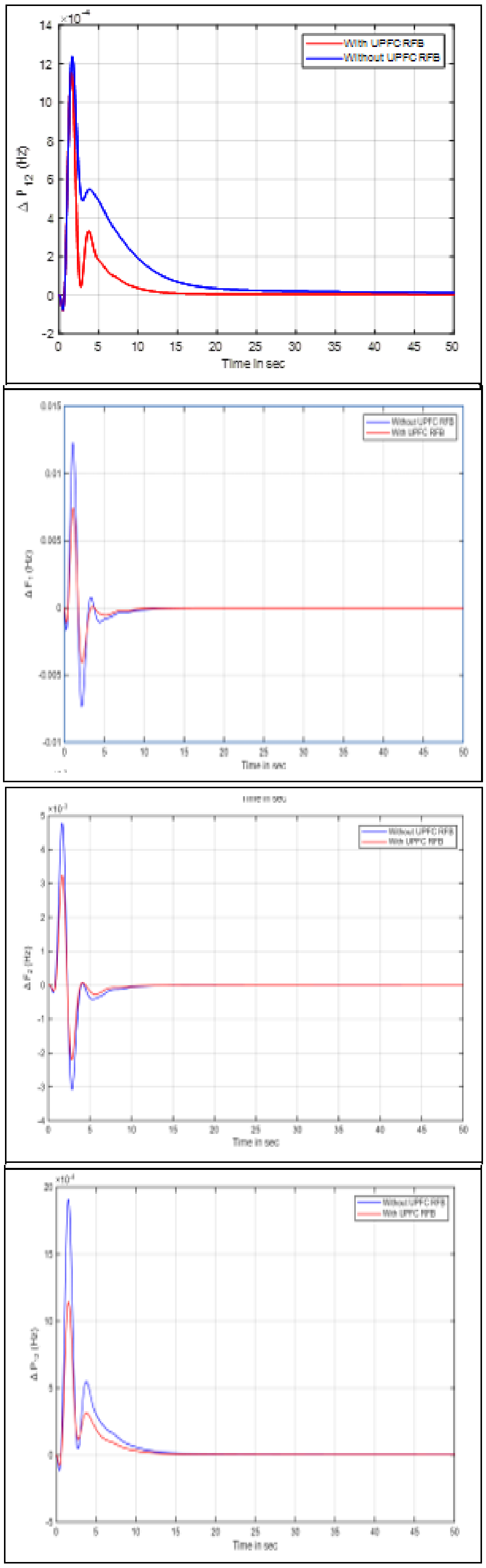


Figure 3: Dynamic response of frequencies, tie-line power and power for generator for PBT

Table I: Controller's Parameters Tuned with Different Optimization Techniques

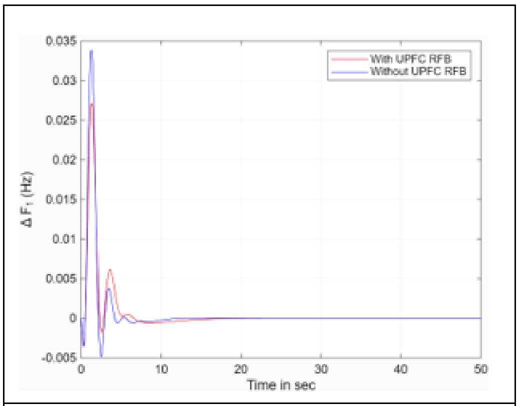
PO –FOPID-FI.	Without UPFC & RFB	Both UPFC & RFB
K_{P1}	0.1	0.5
K_{I1}	12.62	12.32
K_{D1}	6.57	6.18
λ_1	0.49	0.5
μ_1	0.5	0.5
I1	0.82	0.76
K_{P2}	0.88	0.1

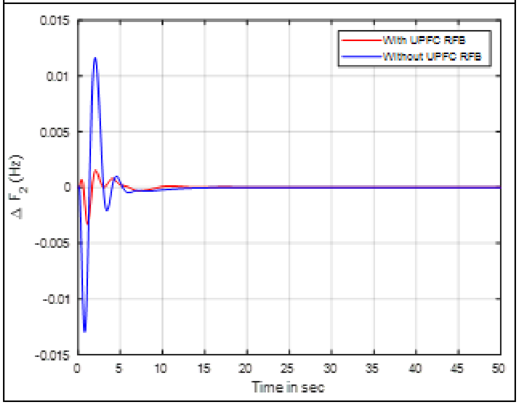
K_{I2}	0.1	0.1
K_{D2}	8.39	10.6
λ2	0.5	0.33
μ2	0.5	0.5
I2	0.93	1
ITAE	0.055	0.043

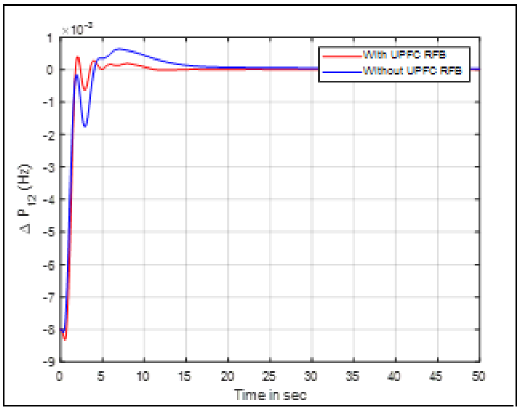
Table II: Settling Time and Overshoot

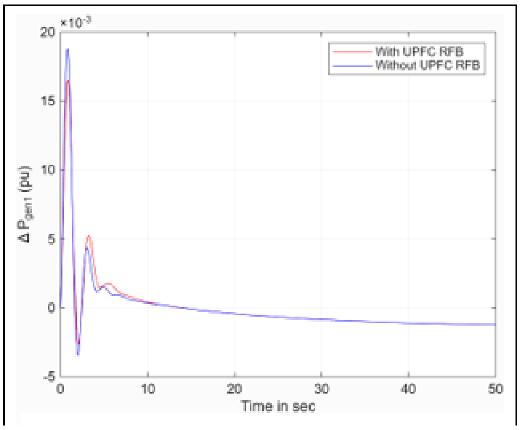
System Configuration	States	Overshoot (p.u.)	Settling time(sec)
Without UPFC & RFB	ΔF1	0.0072	9.58
	ΔF2	0.0047	10.7
	ΔP12	0.0018	12.2
	Pgen1	0.0068	9.09
	Pgen2	0.0068	8.4
	Pgen3	0.0068	10.01
Both UPFC & RFB	ΔF1	0.0119	6.86
	ΔF2	0.0031	9.12
	ΔP12	0.0011	9.11
	Pgen1	0.004	6.2
	Pgen2	0.0028	7.67
	Pgen3	0.0034	7.66

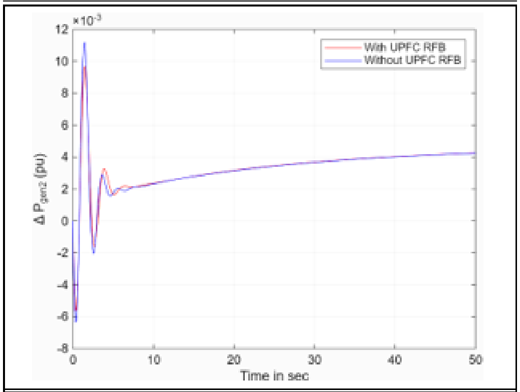
Case II (BBT):

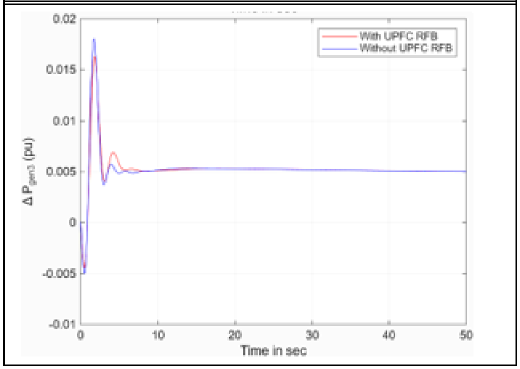


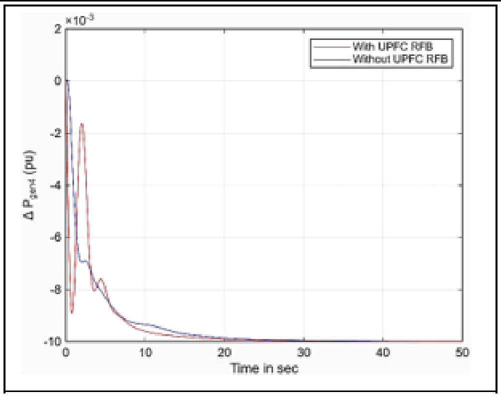












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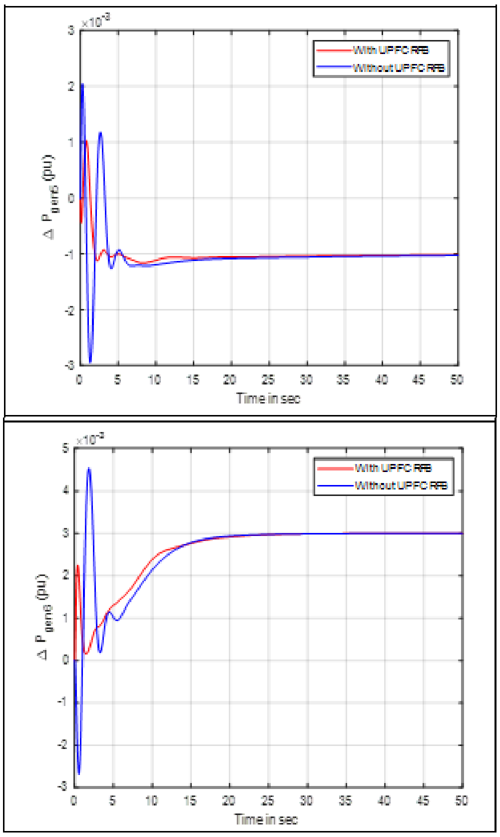

Figure 4: Dynamic response of frequencies, tie-line power and generator power for BBT

Table I: Controller's Parameters Tuned with Different Optimization Techniques

PO –FOPID-FI.	Without UPFC & RFB	Both UPFC & RFB
K_{P1}	1.0391	3.5929
K_{I1}	10.301	9.075
K_{D1}	5.0674	5.6033
λ_1	0.4935	0.4910
μ_1	0.4980	0.4988
I1	0.9202	0.9713
K_{P2}	0.1988	0.1861
K_{I2}	1.3464	7.9459
K_{D2}	3.2435	7.7377
λ2	0.4871	0.4992
μ2	0.5	0.48278
I2	0.9033	1
ITAE	2.3599	0.9130

Table II: Settling Time and Overshoot

System Configuration	States	Overshoot (p.u.)	Settling time (sec)
Without UPFC & RFB	ΔF1	0.026	9.64
	ΔF2	0.013	5.83
	ΔP12	0.6	9.9
	Pgen1	0.018	11.39
	Pgen2	0.01	8.12
	Pgen3	0.19	9.18
	Pgen4	-6.012	19.05
	Pgen5	2.12	15.04
	Pgen6	4.72	15.83
Both UPFC & RFB	ΔF1	0.033	14.98
	ΔF2	0.002	5.62
	ΔP12	0.4	9.8
	Pgen1	0.016	9.18
	Pgen2	0.009	7.23
	Pgen3	0.016	7.52
	Pgen4	-0.0002	18.65
	Pgen5	1.03	15.01
	Pgen6	2.23	10.62

From the above analysis, the results show that the performance of controller is more stable and robust with RFB and UPFC. Frequencies and tie-line power settles faster with FACTS controller devices. The proposed model with FACTS controller showing more convenient result without FACTS controller.

4. Conclusion

The FACTS controller for frequency regulation in a deregulated, RES-integrated electrical power system is covered in this chapter. Redox Flow Batteries (RFBs) are taken into consideration for control area-1 and area-2, and the Unified Power Flow Controller (UPFC) is installed in the tie-line to improve system performance. Additionally, the dynamics of ISO test systems, Poolco, and bilateral agreements between GENCOs and DISCOs have been examined. The suggested method is validated by dynamic reactions such as overshoot, settling time, and tie-line power variations. The settling times for Δf1, Δf2, and ΔP12 with both UPFC and RFB are 6.86s, 9.12s, and 9.11s in Case Study I, PoolCo-based transaction (PBT) and 9.58s, 10.7s, and 12.20s without UPFC and RFB. Similar to this, the settling times for Δf1, Δf2, and ΔP12 in Case Study II, Bilateral Based Transaction (BBT) are 9.64s, 5.62s, and 9.8s when both UPFC and RFB are used and 14.98s, 5.83s, and 9.9s when UPFC and RFB are not. Both UPFC and RFB minimize peak overshoot and settling time while controlling load frequency. Random step load disturbances are utilized to confirm the robustness of the proposed system, and sensitivity analysis is performed by changing the system parameters.

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