Economic Power Dispatch of Power System with Pollution Control using Multiobjective Artificial Bee Colony Optimization with FACTS devices

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Abstract: This paper presents solution of optimal power flow (OPF) problem of medium-sized power systems via an Artificial Bee Colony (ABC) algorithm. The objective is to minimise the total fuel cost of generation and environmental pollution caused by fossil based thermal generating units and also maintain an acceptable system performance in terms of limits on generator real and reactive power outputs, bus voltages, shunt capacitors/reactors and power flow of transmission lines. In order to maximise the relief of congestion in power system and to reduce the total system real power loss we propose also the placement of FACTS devices in the power system. In this work the standard IEEE 30-bus test system with six generating units has been used to test the effectiveness of the proposed method. The results of the proposed technique are compared with that of the Particle Swarm Optimization (PSO) technique. The simulation results show that by the ABC method with FACTS devices is superior in convergence compared to PSO. The ABC is used to obtain Economic dispatch of generators such that these generations give minimum cost as well as does not result in line flow violation. It reveals also that incorporation of FACTS devices with optimal location significantly enhance load margin as well as system stability.

***Keywords*:** Optimal Power Flow, Power Systems, Pollution Control, NOx emission, Artificial Bee Colony, FACTS Device.

Introduction:

The optimal power flow (OPF) calculation optimises the static operating condition of a power generation-transmission system. The main benefits of optimal power flow are (i) to ensure static security of quality of service by imposing limits on generation-transmission system's operation, (ii) to optimise reactive-power/voltage scheduling and (iii) to improve economy of operation through the full utilisation of the system's feasible operating range and by the accurate coordination of transmission losses in the scheduling process. The OPF has been usually considered as the minimisation of an objective function representing the generation cost and/or the transmission loss. The constraints involved are the physical laws governing the power generation-transmission systems and the operating limitations of the equipment.

The optimal power flow has been frequently solved using classical optimisation methods. Effective optimal power flow is limited by (i) the high dimensionality of power systems and (ii) the incomplete domain dependent knowledge of power system engineers [1][2].

The first limitation is addressed by numerical optimisation procedures based on successive linearization using the first and the second derivatives of objective functions and their constraints as the search directions or by linear programming solutions to imprecise models [3]. The advantages of such methods are in their mathematical underpinnings, but disadvantages exist also in the sensitivity to problem formulation, algorithm selection and usually converge to local minima [4].

The second limitation, incomplete domain knowledge, precludes also the reliable use of expert systems where rule completeness is not possible.

As modern electrical power systems become more complex, planning, operation and control of such systems using conventional methods face increasing difficulties. Intelligent systems have been developed and applied for solving problems in such complex power systems.

Several major blackouts throughout the world have been directly associated to the voltage collapse, the application of Flexible Alternative Current Transmission Systems (FACTS) in electric power system is intended for the control of power flow, improvement of stability, voltage profile management, power factor correction, and loss minimization.

Swarm intelligence is an innovative computational way to solving hard problems. This discipline is inspired by the behavior of social insects such as fish schools and bird flocks and colonies of ants, termites, bees and wasps. In general, this is done by mimicking the behavior of the biological creatures within their swarms and colonies.

In a previous paper [5], the authors have proposed the use of the Particle Swarm Optimization (PSO) on the optimal power flow problem using as objective function the minimisation of the fuel cost and NOx emission control. More than 6 small-sized test cases were used to demonstrate the performance of the proposed algorithm. Consistently acceptable results were observed.

In this paper, ABC algorithm inspired by the foraging behavior of honeybees is proposed to solve the optimal power flow problem using as objective function the minimisation of the fuel cost and NOx emission control. CPU times can be reduced by decomposing the optimisation constraints of the power system to active constraints manipulated directly by ABC, and passive constraints maintained in their soft limits using a conventional constraint load flow.

This paper investigates also the use of the parallel FACTS device, the Static VAR Compensator (SVC) from the point of load margin and reactive power loss sensitivity index to increase voltage stability. We demonstrate also that the optimal location of FACTS device increase as much as possible capacity of the network. i.e loadability.

Application Study

To verify the proposed approach and for comparison purposes, we perform simulations on an IEEE 30-bus power systems. The obtained results indicate that ABC is an easy to use, fast, robust and powerful optimization technique compared with Particle Swarm Optimization (PSO) (table 1 & 2). Installing FACTS device such SVC in optimal location can significantly enhance the security of power system by minimizing the overloaded lines and the bus voltage limit violations and also improves the loadability of the system. The FACTS improves the stability, reduces the losses and reduces the cost of generation (table 3).

Table 1. Results of minimum total cost for IEEE 30-bus system in three cases (α=1, α=0.5 and α=0) by ABC

Variable	**Generation cost minimum**	**Generation cost + Emission minimum**	**Emission minimum**
Pg_{01}(MW)	180.5218	130.3310	68.3474
Pg_{02}(MW)	48.7845	58.2344	71.0885
Pg_{05}(MW)	21.2598	26.2496	50.0000
Pg_{08}(MW)	18.6469	35.0000	35.0000
Pg_{11}(MW)	11.8145	21.3800	30.0000
Pg_{13}(MW)	12.1011	18.9294	32.8553
Generation cost ($/hr)	802.1649	820.1666	935.275
Emission (ton/h)	0.3781	0.2712	0.2176
Total cost ($/h)	1010,4	969.511	1055.10
Power Loss (MW)	9.7286	6.7256	3.8912
∑|Vi-Vref|	0.4403	0.3596	0.3773

Table 2: Comparison between ABC and PSO in IEEE 30 bus system

	Generation cost minimum		**Generation cost + Emission minimum**		**Emission minimum**	
	ABC	**PSO**	**ABC**	**PSO**	**ABC**	**PSO**
Generation cost ($/h	802.1649	802,377	820.1666	822,092	935.275	948,399
Emission (ton/h)	0.3781	0,372	0.2712	0,268	0.2176	0,218
Total cost ($/h)	1010,4	1007,577	969.511	969,845	1055.10	1068,854

Table 3: Main results of IEEE 30-bus system with one SVC installation.

	Load increase	**SVC in 30**	**SVC in 26**	**SVC in 10**	**SVC in 14**	**SVC in 28**
B(pu)	5%	0.072881	0.062236	-0.014568	-0.04585	-0.2118
	10%	0.080124	0.068999	0.011481	-0.033004	-0.190713
Vmin	5%	0.9725	0.9654	0.9499	0.9491	0.9412
	10%	0.9694	0.9621	0.9459	0.9444	0.9370
Cost PLoss	5%	856.4659 11.466	856.3666 11.4374	856.6351 11.5147	856.7453 11.5465	857.0381 11.6307
	10%	912.2490 13.0877	912.1405 13.0575	912.3627 13.1194	912.4996 13.1575	912.8329 13.2502

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