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Unified power flow controller based reactive power dispatch using oppositional krill herd algorithm

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ABSTRACT

In power system, minimizing the power loss in the transmission lines and/or minimizing the voltage deviation at the load buses by controlling the reactive power is referred as optimal reactive power dispatch (ORPD). This paper presents an improved evolutionary algorithm based on oppositional krill herd algorithm (OKHA) for obtaining optimal steady-state performance of power systems. This article also proposes the effect of UPFC location in steady-state analysis and to demonstrate the capabilities of UPFC in controlling active and reactive power flow within any electrical network. To verify the effectiveness of KHA and OKHA, two different single objective functions such as minimization of real power losses and improvement of voltage profile and a multi-objective function that simultaneously minimizes transmission loss and voltage deviation have been studied through standard IEEE 57-bus and 118-bus test systems and their results have been reported. The study results show that the proposed KHA and OKHA approaches are feasible and efficient.

Introduction

Transmission network is the most important component in competitive electricity markets and serves as the key mechanism for generators to compete in the supply to reach large users and distribution companies. In competitive electricity markets [1], energy prices and transmission pricing are highly affected by transmission congestion and other system constraints, where a congested transmission is accompanied by higher costs due to resorting to out-of-merit order as expensive generating units are dispatched to alleviate congestion [2]. Therefore, an increased attention has been paid to new devices that provide more flexibility to operate the transmission system and guarantee lower-cost mechanisms by which transmission constraints can be mitigated.

Available transfer capability (ATC) is the measure of the ability of interconnected electric power systems to reliably move or transfer power from one area to another over all the transmission lines between those areas under specified system conditions [3]. To operate the power system safely and to gain benefits of the bulk power transfer, the transfer capabilities must be calculated and the power system operated so that the power transfers do not exceed the transfer capability. ATC is significantly limited by heavily loaded circuits or buses with relatively low voltages. Flexible AC transmission system (FACTS) technology makes it possible to redistribute line flow and regulate bus voltages. It can be used effectively for the enhancement of ATC.

Continuous and fast improvement of power electronics technology has made FACTS as a promising concept for power system applications during the last decade [4,5]. The use of FACTS controllers provides a flexible controlling of power flow along the transmission lines. It can reduce the flows of heavily loaded lines, maintain the bus voltages at desired levels, and improve the stability of the power network. The UPFC [6,7] is the most versatile FACTS controller envisaged so far. It can not only perform the functions of the STATCOM, TCSC and the phase angle regulator but also provides additional flexibility by combining some of the functions of the above controllers. The UPFC can provide simultaneous control of all basic power system parameters. It can fulfill functions of reactive shunt compensation, series compensation and phase shifting meeting multiple control objectives. From a functional perspective, the objectives are met by applying a boosting transformer injected voltage and an exciting transformer reactive current. The injected voltage is inserted by a series transformer.

In the last decade, various algorithms have been developed for the optimal power flow (OPF) incorporating with UPFC device as well as for the optimal placement of UPFC. Some of them are: a sensitivity based approach which has been developed for finding

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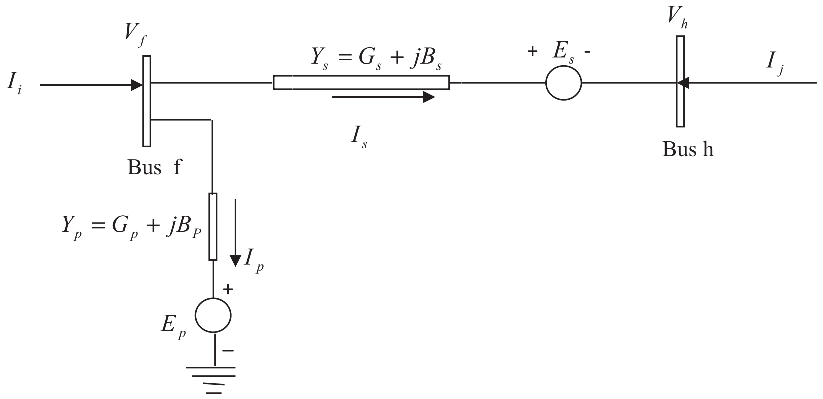

Fig. 1. Circuit model for UPFC.

Table 1
Input parameters setting of different algorithms.

BBO	DE	KHA and OKHA

Mutation probability = 0.005;
maximum immigration rate = 1;
maximum emigration rate = 1;
elitism parameter = 4;
	Scaling factor = 0.7
	crossover probability = 0.2
		Maximum induced speed = 0.01; maximum diffusion speed = 0.05;
		position factor = 0.2; inertia weight = 0.9; jumping probability = 0.3

suitable placement of UPFC [8], an evolutionary-programming-based load flow algorithm for systems containing UPFC [9], a genetic algorithm (GA) which proposed for solving the optimal location problem of UPFC [10], particle swarm optimization (PSO) for optimal location of FACTS devices [11], etc.

Ara et al. [12] proposed a solution procedure using nonlinear programming (NLP) and mixed-integer nonlinear programming (MINLP) for solving the optimal location and setting of FACTS incorporated in the optimal power-flow problem with the objective functions being considered are the total fuel cost, power losses, and system loadability with and without FACTS installation and improving the power system operation. Sawhney and Jeyasurya [13] presented the application of UPFC to improve the transfer capability of a power system to meet some of the challenges of power system operation caused by deregulation in the electric power industry and opening of the market for delivery of cheaper energy to the customers. Alomoush [14] developed a mathematical approach allocating the contributions of UPFCs to transmission system usage by making use of a dc-based load flow model of UPFC-inserted transmission lines based on a previously derived dc-based injection model of UPFC-embedded lines. Relationships were derived to model the impact of UPFC on line flows and transmission usage by using modified admittances and distribution factors that model impact of utilizing UPFC on line flows and system usage. Taher and Amooshahi [15] presented the application of hybrid immune algorithm (HIA) such as immune GA (IGA) and immune PSO (IPSO) to find optimal location of UPFC to achieve optimal performance of power system. Simulations were performed on IEEE 14-bus and IEEE 30-bus test systems considering the overall cost function as the objective function, including the total active and reactive production cost function of the generators and installation cost of UPFCs. Shaheen et al. [16] presented a new

Table 2
Simulation result of different algorithms for loss minimization (IEEE 57-bus system without UPFC).

Control variables	BBO	DE	KHA	OKHA	Control variables	BBO	DE	KHA	OKHA
V_{g1} (p.u.)	1.0599	1.0598	1.0597	1.0600	T_{24-26}	1.0322	1.0285	1.0328	1.0272
V_{g2} (p.u.)	1.0514	1.0483	1.0526	1.0581	T_{7-29}	0.9233	0.9141	0.9285	0.9497
V_{g3} (p.u.)	1.0186	1.0103	1.0241	1.0415	T_{34-32}	0.9203	0.9177	0.9351	0.9303
V_{g6} (p.u.)	0.9964	0.9861	1.0020	1.0249	T_{11-41}	0.9004	0.9107	0.9041	0.9033
V_{g8} (p.u.)	1.0175	1.0083	1.0230	1.0442	T_{15-45}	0.9359	0.9292	0.9440	0.9580
V_{g9} (p.u.)	0.9944	0.9785	1.0013	1.0223	T_{14-46}	0.9203	0.9040	0.9159	0.9349
V_{g12} (p.u.)	1.0061	1.0000	1.0129	1.0386	T_{10-51}	0.9295	0.9164	0.9297	0.9526
Q_{C18} (p.u.)	0.0875	0.0139	0.0972	0.0710	T_{13-49}	0.9010	0.9017	0.9001	0.9209
Q_{C25} (p.u.)	0.0589	0.0589	0.0590	0.0589	T_{11-43}	0.9159	0.9112	0.9157	0.9405
Q_{C53} (p.u.)	0.0629	0.0617	0.0627	0.0630	T_{40-56}	1.0220	1.0497	1.0314	1.0250
T_{4-18}	0.9604	0.9185	0.9905	1.0157	T_{39-57}	0.9624	0.9879	0.9862	0.9792
T_{4-18}	0.9193	0.9197	0.9102	0.9120	T_{9-55}	0.9282	0.9126	0.9358	0.9540
T_{21-20}	1.0033	1.0102	1.0174	1.0153					

	BBO	DE	KHA	OKHA
Loss (MW)	40.5535	41.3003	40.2431	39.8134
Voltage deviation (p.u.)	1.2973	1.3643	1.3150	1.3736
Computational time (s)	16.6843	13.6934	4.8806	4.5349