IEEE PES Working Group on Modern Heuristic Optimization
Intelligent Systems Subcommittee
Analytic Methods in Power Systems (AMPS) Committee

2017 PANEL & COMPETITION

"Evaluating the Performance of Modern Heuristic Optimizers on Smart Grid Operation Problems"

Organizers:

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Test bed 1: Stochastic OPF based active-reactive power dispatch.

Developers:

Sergio Rivera, Universidad Nacional de Colombia, Colombia

Andres Romero, Universidad Nacional de San Juan, Argentina

José Rueda, Delft University of Technology, Netherlands

Kwang Y. Lee, Baylor University, USA

István Erlich, University Duisburg-Essen, Germany

Objective

Minimize the total fuel cost of traditional generators plus the expected cost of the uncertainty cost function for renewable generators.

s.t.

Technical constraints (e.g. voltage limits, thermal limits) for N-0 and N-1 conditions

6 cases defined to consider different combinations of RES (wind, solar, hydro)

Test bed 2: Optimal scheduling of distributed energy resources.

Developers:

João Soares, Institute of Engineering – Polytechnic of Porto, Portugal

Zita Vale, Institute of Engineering – Polytechnic of Porto, Portugal

Fernando Lezama, Institute of Engineering – Polytechnic of Porto, Portugal

Objective

Maximize the profit of an energy aggregator under centralized day-ahead energy resource scenarios.

s.t.

- Dispatchable generation limits
- Electric vehicles trips requirements, charge and V2G limits
- Stationary battery charge and discharge rates and capacity limits
- Demand response (direct load control)
- Market transactions (bids)

2 scenarios (cases) defined to consider 33-bus and 180-bus systems

Test bed 1: Stochastic OPF based active-reactive power dispatch

Presenter:

Sergio Rivera, Universidad Nacional de Colombia (Colombia)

Abstract

Normally, the target in the ORAPD (Optimal Reactive-Active Power Dispatch) is to minimize the total fuel cost while fulfilling constraints (associated to nodal balance of power, nodal voltages, allowable branch power flows, generator reactive power capability, and maximum active power output of slack generator) for normal (non-contingency) and selected N-1 conditions. In the Test bed 1: Stochastic OPF based active-reactive power dispatch competition the target is to minimize the total fuel cost of the traditional generators plus the expected cost of an uncertainty cost function for renewable generators. In this way, each renewable generator is considered to be a dispatchable generator; and depending of the available real power, it is considered an underestimated or overestimated condition.

The available real power of a renewable generator is not known with certainty. Nevertheless, in some cases, it is possible to know the probability distribution of the primary energy source like the wind speed, solar irradiance or the river flow. In this way, considering the relation between the primary energy source and the available real power, it is possible to get the probability distribution of available real power. Thus, using the Understimated and Overestimated condition, it is proposed in this competition to calculate through Monte Carlo simulations an uncertainty cost function given by the different costs for the different available real power scenarios.

Test bed 2: Optimal scheduling of distributed energy resources.

Presenter:

João Soares, Institute of Engineering – Polytechnic of Porto, Portugal

Zita Vale, Institute of Engineering – Polytechnic of Porto, Portugal

Fernando Lezama, Institute of Engineering – Polytechnic of Porto, Portugal

Abstract

Test bed 2 presents two large-scale energy resources optimization case studies with a large number of distributed generators, energy storage systems, electric vehicles, and demand response. Classical optimization methods are not able to deal with the proposed optimization problems within reasonable time, often requiring more than one day to provide the optimal solution. The proposed problems can be addressed using modern heuristic optimization approaches, enabling the achievement of good solutions in much lower execution times, adequate for the envisaged decision making processes.

Solving Smart Grid Operation Problems Through Variable Neighborhood Search

Developers:

Leonardo H. Macedo, São Paulo State University-Ilha Solteira (Brazil)

John F. Franco, São Paulo State University-Ilha Solteira (Brazil)

Rubén Romero, São Paulo State University-Ilha Solteira (Brazil)

Miguel A. Ortega-Vazquez, University of Washington (USA)

Marcos J. Rider, University of Campinas (Brazil).

Abstract

The Variable Neighborhood Search metaheuristic is based on the strategy of performing systematic changes of neighborhoods in the search for the optimal solution of a complex problem. To solve the stochastic optimal power flow based active-reactive power dispatch and the optimal scheduling of distributed energy resources problems, a basic form of this algorithm, based on the Variable Neighborhood Descent (VND) version was developed. The main feature of the VND algorithm is that it does not allow any degradation of the current (incumbent) solution, i.e., the search is performed in a sequence of neighborhoods, always with the current best solution as a starting point. In the VND algorithm, a Nelder-Mead's Simplex method and a Cyclic Coordinated Method using Fibonacci line search algorithm were included as local search strategies. The proposed algorithm was able to minimize the cost of generation in the first problem and maximize the profit in the second problem.

Levy Differential Evolutionary Particle Swarm Optimization (LEVY DEEPSO)

Developers:

Kartik S. Pandya, CSPIT CHARUSAT-Gujarat (India)

S.K. Joshi, The M.S. University of Baroda-Gujarat (India)

S.N.Singh, IIT-Kanpur U.P. (India)

Abstract

The increasing use of renewable energy sources and demand side response has created highly non-linear, discontinuous and multi-model optimization problems of electrical power systems. In this context, there is a need to develop the robust optimization algorithm to find near global optimum solutions that guarantee efficient and economical operation. In this competition, a Levy enhanced differential Evolutionary Particle Swarm Optimization (LEVY DEEPSO) has been proposed to solve Test bed: 1 entitled Stochastic OPF based active-reactive power dispatch. In the basic DEEPSO, the velocity of each particle is adjusted using self-adaptive mutated inertia weights, sampling and recombination of current generation and individual past best particle and probabilistically controlled communication between the particles. To further enhance the global search ability of DEEPSO, the velocity of each particle has been also updated using Levy flight, which is a random walk whose step length is drawn from the Levy distribution. So the proposed method is known as LEVY DEEPSO.

Modified Chaotic Biogeography-based Optimisation (CBBO) with Random Sinusoidal Migration

Developers:

Sergio Rivera, Universidad Nacional de Colombia (Colombia)

Camilo Cortes, Universidad Nacional de Colombia (Colombia)

Sergio Contreras, Universidad Nacional de Colombia (Colombia)

María Guzmán, Universidad Nacional de Colombia (Colombia)

Abstract

The algorithm used proposed for the solution of test bed 2 (Optimal scheduling of distributed energy resources) is a modification of the traditional Biogeography-based Optimisation (BBO). It is implemented a combination of two chaotic operators, after test several of these operators in the solution of test bed 2. Additionally, in order to avoid local optimum, the algorithm use random sinusoidal migration.

Cooperative Combination of the Cross-Entropy Method and the Evolutionary Particle Swarm Optimization to Improve Search Domain Exploration and Exploitation

Developers:

Leonel Carvalho, INESC TEC (Portugal)

Vladimiro Miranda, INESC TEC and Faculty of Engineering of the University of Porto - FEUP, (Portugal)

Armando Leite da Silva, Pontifícia Universidade Católica do Rio de Janeiro (Brazil)

Carolina Marcelino, Centro Federal de Educação de Minas Gerais (Brazil)

Elizabeth Wanner, School of Engineering and Applied Sciences (UK) and Centro Federal de Educação de Minas Gerais (Brazil)

Jean Sumaili, INESC TEC (Portugal)

Abstract

Metaheuristics are optimization methods extremely useful to tackle high-dimensional, non-linear, non-differential and combinatorial problems. Amongst the variety of metaheuristics available in the literature, the Evolutionary Particle Swarm Optimization (EPSO) and its variants have repeatedly proven its efficiency and efficacy in solving a wide variety of problems in power systems. Inspired by the PSO's movement equation, EPSO is endowed with a unique evolutionary self-adaptive recombination operator that makes it less sensitive to the shape of the fitness landscape enabling a better exploit of the search domain. Recently, the Cross-Entropy (CE) Method, which can be seen as an adaptive variance minimization algorithm for estimating probabilities of rare events, was successfully applied to power system reliability assessment with remarkable computational gains. Experiments have shown that the CE Method is able to find the region near the optimal solution after a small number of fitness evaluations. This presentation will describe the application of the two aforementioned methods in the IEEE 2017 Smart Grid Operation Problems Competition, namely, by showing that near optimal solutions can repeatedly be achieved through the combination of the remarkable space exploration characteristic of the CE Method with the EPSO's enhanced capability for quick assimilation and exploitation of promising regions of the search domain. Finally, this presentation will describe the Two-way Analysis of Variance (ANOVA)-based iterative algorithm for fine-tuning EPSO's strategic parameters in order to obtain the best performance possible in all optimization problems.

Evaluation criterion

The success for the 31 runs is quantified as:

$$\text{Score} = \frac{1}{31}\sum_{i=1}^{31} f_{best,i}$$

where $f_{\text{best},i}$ represents the final (best) fitness achieved in each run.

For each test bed, the total score is calculated as the sum of the individual scores corresponding to the total number of cases N_{cases} belonging to the corresponding test bed:

Test Bed 1:

$$\text{Total\_score} = \sum_{i=1}^{6} \text{Score}_i$$

Test Bed 2:

$$\text{Total\_score} = \text{Score}_{33} + \text{Score}_{180}$$

The **first three ranked** algorithms are selected for presentation at the panel, for which only PowerPoint presentations are required.

Ranking results – Test bed 1

		Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Total score
Rank	Algorithm	Score	Score	Score	Score	Score	Score	
1	Cross entropy method and evolutionary particle swarm optimization (CEEPSO)	72.686,5316	72.049,5290	60.286,3664	71.396,1385	70.572,4373	60.805,3257	407.796,3285
2	Variable Neighborhood Search algorithm (VNS)	72.683,9737	72.045,8425	60.284,2795	71.943,9128	70.929,2153	60.461,5010	408.348,7249
3	Levy Differential Evolutionary Particle Swarm Optimization (LEVY DEEPSO)	72.704,1895	72.077,5682	60.312,7890	72.922,1708	72.068,9216	60.639,5309	410.725,1701
4	CHAOS Differential Evolutionary Particle Swarm Optimization (CHAOS DEEPSO)	72.693,4419	72.064,9104	60.299,3471	72.910,9008	71.700,9445	61.292,5909	410.962,1357
5	HybridLocal Search based Differential Evolution	75.311,7174	73.020,8555	61.663,6073	73.475,2174	72.300,2068	62.075,0946	417.846,6989

First Place: CEEPSO. Developers: Leonel Carvalho, Vladimiro Miranda, Armando Leite da Silva, Carolina Marcelino, Elizabeth Wanner, Jean Sumaili; INESC TEC, Pontifícia Universidade Católica do Rio de Janeiro, Centro Federal de Educação de Minas Gerais, School of Engineering and Applied Sciences - Birmimgham

Second Place: VNS. Developers: Leonardo Macedo, John Franco, Rubén Romero, Miguel Ortega-Vazquez, Marcos Rider, Sao Paulo State University Ilha Solteira, Brazil, University of Washington, UNICAMP Campinas

Third Place: LEVY DEEPSO. Developers: Kartik Pandya, S. Joshi, S. Singh; Electrical Engg. Dept, CSPIT, CHARUSAT; Electrical Engg. Dept., The M.S. University of Baroda; IIT-Kanpur, U.P.

Ranking results – Test bed 2

		33-bus	180-bus	Total score
Rank	Algorithm	Score	Score	
1	Variable Neighborhood Search algorithm (VNS)	-5595,98303	-3054	-8649,9874
2	Modified Chaotic Biogeography-based Optimisation (CBBO) with Random Sinusoidal Migration	-5387,59706	-2652,86	-8040,4587
3	Cross entropy method and evolutionary particle swarm optimization (CEEPSO)	-5185,25515	-2550,12	-7735,3761
4	CHAOS Differential Evolutionary Particle Swarm Optimization (CHAOS DEEPSO)	-4655,80705	-2500,55	-7156,3617
5	Levy Differential Evolutionary Particle Swarm Optimization (LEVY DEEPSO)	-4538,08215	-2494,26	-7032,3407

First Place: VNS. Developers: Leonardo Macedo, John Franco, Rubén Romero, Miguel Ortega-Vazquez, Marcos Rider, Sao Paulo State University Ilha Solteira, Brazil, University of Washington, UNICAMP Campinas

Second Place: Modified CBBO. Developers: Sergio Rivera, Camilo Cortes, Sergio Contreras, María Guzmán; Universidad Nacional de Colombia

Third Place: CEEPSO. Developers: Leonel Carvalho, Vladimiro Miranda, Armando Leite da Silva, Carolina Marcelino, Elizabeth Wanner, Jean Sumaili; INESC TEC, Pontifícia Universidade Católica do Rio de Janeiro, Centro Federal de Educação de Minas Gerais, School of Engineering and Applied Sciences – Birmimgham.