Multi-objective combined heat and power with wind–solar–EV of optimal power flow using hybrid evolutionary approach

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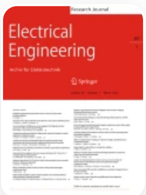

Electrical Engineering

Aims and scope

Submit manuscript

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Abstract

The proposed effort aims to investigate efficient power generation while minimizing emissions, voltage deviations, and maintaining transmission line voltage stability. The combined heat and power of economic dispatch (CHPED) system is incorporated in the IEEE-57 bus in this presentation to ensure the best possible power flow in the transmission line while meeting the load demand. It is crucial to incorporate renewable energy sources for efficient power generation because fossil fuel sources are evolving daily. The main contribution of the proposed work is firstly, to find optimal solution for optimal power flow (OPF)-based combined heat and power economic dispatch (CHPED) problem with wind, solar and electric vehicles (EVs). The target is to find out maximum utilization of renewable energy sources for economic power generation, less emission and reduced transmission losses with maintaining the permissible voltage deviation at load buses. Thus, a new approach of electric vehicle to grid has been adopted with wind–solar-CHPED-based OPF system for improving grid reliability and resilience. Secondly, there is a requirement to overcome the local optima problems having low convergence speed. This is obtained by employing a relatively new methodology, known as chaotic-opposition-based driving training-based optimization (DTBO) (CODTBO). Due to the presence of wind, solar, EVs uncertainties, valve point effect, and transmission losses, the system grew more complex. For three different test systems for CHPED-based OPF with and without RESs, the proposed CODTBO algorithm has been put to the test. Results from the tested DTBO, ODTBO approach and the proposed CODTBO have been compared. After integrating wind–solar–EVs with CHPED–OPF, the total fuel cost and emission are reduced by 3.48% and 5.1%, respectively, as well as L-index is improved by 21.6%. Hence, it has been proved that proposed CODTBO has the capability to easily cope up with nonlinear functions. After adding chaotic-oppositional-based learning (CO) with DTBO (CODTBO), the fuel cost is further reduced by 1.65% and computational time is improved by 45% as compared to DTBO. Henceforth, CODTBO has the better exploration capability and better searching ability as compared to DTBO. The above numerical analysis demonstrated the superiority of the suggested CODTBO technique over DTBO, ODTBO in terms of convergence rate and best-possible solution. Moreover, by doing statistical analysis on IEEE CEC 2017 benchmark functions, the robustness of the suggested CODTBO optimization technique has been assessed.

Data Availability Statement

The data that support the findings of this study are available on request from the corresponding author.

Abbreviations

V_{wind}: Wind initial velocity

$k > 0$: Shape factor

CDF: Cumulative density function

P_{wrated}: Rated wind power

V_{in} : Cut-in wind velocity

$\text{TotalCost}_{\text{wind}}$: Total wind cost

$\text{Cost}^{\text{O}}_{\text{windm}}$: Overestimation wind cost

$\text{Pf}^{\text{U}}_{\text{windm}}$: Underestimation wind cost coefficient

i_{rd} : Solar irradiance

S : Output solar power

R_{C} : Specific irradiance point

P_{solaravl} : Average power

P_{srl} : Rated solar power

N_{l} : Number of vehicles

$E_{\text{EV},t}$: Power to charge

$\text{soc}_{\text{initial}}$: Initial value of state of charging

η_{charging} : Charging efficiency

$E^{\text{driving}}_{\text{EV},q}$: Driving power of vehicle

m : Mean

d^{EV}_{l} : Direct cost coefficients

$Gf\,(*)$: Function of Gauss error

$\mathrm{PF}_{\mathrm{EVl}}^{\mathrm{U}}:$ Underestimated penalty factor of EV

$\mathrm{Cost}_{\mathrm{poui}}\left(P_{\mathrm{poui}}\right):$ Fuel cost of the power generator

$\mathrm{Cost}_{\mathrm{houi}}\left(H_{\mathrm{houi}}\right):$ Generation cost of heat

$N_{\mathrm{pou}}:$ Number of power units

$N_{\mathrm{hou}}:$ Number of heat units

δ_{poui} ***and*** $\varepsilon_{\mathrm{poui}}:$ Valve point coefficients

$\mathrm{Cost}_{\mathrm{windi}}\left(P_{\mathrm{windi}}\right):$ Wind generation cost

$P_{\mathrm{poui}}^{\mathrm{t}}:$ Thermal power output

$N_{\mathrm{L}}:$ Total number of transmission line

$\epsilon_1, \epsilon_2:$ Penalty factor

$P_{Lc}:$ Active power demand of *c*th bus

$Y_{\mathrm{cd}}:$ Admittance of transmission line

$P_{\mathrm{poui}}^{\min}, P_{\mathrm{poui}}^{\max}:$ Minimum and maximum power limits

$P_{\mathrm{windi}}^{\min}, P_{\mathrm{windi}}^{\max}:$ Wind minimum and maximum power

$V_{\mathrm{Gb}}^{\min}, V_{\mathrm{Gb}}^{\max}:$ Lower and upper voltage limits

$Q_{\mathrm{Gb}}^{\min}, Q_{\mathrm{Gb}}^{\max}:$ Minimum and maximum reactive power

${S_{\mathrm{Lb}}}^{\min},\ S_{\mathrm{Lb}}^{\max}:$ Minimum and maximum apparent power

Z_p *pth:* Member of the population

Z_p^{st2} *:* Modified *p*th candidate solution

a and b *:* Minimum and maximum limits of search space's

$j_{\mathrm{R,Min}}, j_{\mathrm{R,Max}}$ *:* Minimum and maximum jumping rate

f_{Max} *:* Maximum iteration

$\mathbf{ran}$ *:* Random value

$d > 0$*:* Scale factor

P_{wind} *:* wind output power

V_{rated} *:* Rated wind velocity

V_{out} *:* Cut-out wind velocity

N_{wind} *:* Total number of wind units

$\mathrm{Cost}_{\mathrm{windm}}^{\mathrm{U}}$ *:* Underestimation wind cost

$\mathrm{Pf}_{\mathrm{windm}}^{\mathrm{O}}$ *:* Overestimation wind cost co-efficient

S_{R} *:* Rated solar power

$i_{\mathrm{rd,sd}}$ *:* Solar standard irradiance

P_{solarshl} *:* Scheduled solar power

$\mathrm{PF}_{\mathrm{solarl}}^{\mathrm{O}}$ *:* Penalty cost coefficient

$\mathrm{PF}_{\mathrm{sl}}^{\mathrm{U}}$ *:* Penalty cost coefficient

I *:* Fleet index

SOC: State of charging

C_{EV} *:* Capacity of EV battery

$\eta_{\mathrm{discharging}}$ *:* discharging efficiency

$f_{P_{\mathrm{EV}}}\left(P_{\mathrm{EV}}\right)$ *:* PDF power output of EV

σ *:* standard deviation

P_{EVshl} *:* scheduled power of EV

P_{EVl} *:* output power

$\mathrm{PF}_{\mathrm{EVl}}^{\mathrm{O}}$ *:* Overestimated panalty factor

$\mathrm{Cost}_{\mathrm{ci}}\left(P_{\mathrm{chpi}},\ H_{\mathrm{chpi}}\right)$ *:* Generation cost of co-generation

P_{poui} *:* Power of *i*th unit

N_{chp} *:* Number of CHP units

$\alpha_{\mathrm{poui}}, \beta_{\mathrm{poui}}$ ***and*** γ_{poui} *:* Coefficients of thermal units

$\mathrm{Cost}_{\mathrm{windi}}\left(P_{\mathrm{windi}}\right)$ *:* Wind generation cost

$b_{i0}, b_{i1}, b_{i2}, b_{i3}$ ***and*** b_{i4} *:* Emission coefficients

$G_{n(pq)}$ *:* Transfer conductance of *n*th line

ϕ_{pq} : voltage angle between buses p and q

H_D **and** B_{im}, B_{ij}, B_{jr} : Power loss coefficients

Q_{Lc} : Reactive power demand of cth bus

φ_{cd} : Admittance angle of transmission line

$P_{\text{chpi}}^{\min}(H_{\text{chpi}}), P_{\text{chpi}}^{\max}(H_{\text{chpi}})$: Minimum and maximum power

$H_{\text{chpi}}^{\min}, H_{\text{chpi}}^{\max}$: Minimum and maximum heat

$P_{\text{Gb}}^{\min}, P_{\text{Gb}}^{\max}$: Lower and upper bounds

$V_{\text{Lb}}^{\min}, V_{\text{Lb}}^{\max}$: Smallest and highest voltage edges

bth: Transformer

N : Population size

ξ : Patterning index

j_{R} : Jumping rate

f : Function for current iteration

t : Time index

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Contributions

"Literature review is done by Chandan Paul and Tushnik sarkar; Algorithm is performed by Provas Kumar Roy and Susanta Dutta; Data collection is done by Chandan Paul; Simulation results with analysis are executed by Chandan Paul; Editing of the manuscript is done by Provas Kumar Roy and finally, all authors read and approved the final manuscript."

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Ethics declarations

Conflict of interest

The authors confirm that they have no noted competing economic concerns or particular communications which can be presented to determine the achievement recorded in the research paper.

Ethical approval

The research paper does not incorporate several works with mortal fields or animals realized through either of the authors.

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