## LIST OF SYMBOLS

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>$a_i$</td>
<td>Cost coefficient of generator ($$/MWh^2$)</td>
</tr>
<tr>
<td>$b_i$</td>
<td>Cost coefficient of generator ($$/MWh$)</td>
</tr>
<tr>
<td>$c_i$</td>
<td>Cost coefficient of generator</td>
</tr>
<tr>
<td>$\alpha_i$</td>
<td>Emission coefficient of generator (kg/MWh$^2$)</td>
</tr>
<tr>
<td>$\beta_i$</td>
<td>Emission coefficient of generator (kg/MWh)</td>
</tr>
<tr>
<td>$\gamma_i$</td>
<td>Emission coefficient of generator</td>
</tr>
<tr>
<td>$\Phi_t$</td>
<td>Total operating cost ($$/h or Rs/h$)</td>
</tr>
<tr>
<td>$h_i$</td>
<td>Price penalty factor ($$/kg$)</td>
</tr>
<tr>
<td>$h_m$</td>
<td>Modified price penalty factor ($$/kg$)</td>
</tr>
<tr>
<td>$F_i$</td>
<td>Total fuel cost of generation ($$/h or Rs/h$)</td>
</tr>
<tr>
<td>$F_i(P_i)$</td>
<td>Fuel cost function of $i^{th}$ generator ($$/h or Rs/h$)</td>
</tr>
<tr>
<td>$P_i$</td>
<td>Real power generation of $i^{th}$ generator (MW)</td>
</tr>
<tr>
<td>$d$</td>
<td>Number of generators connected in the network</td>
</tr>
<tr>
<td>$P_{du}$</td>
<td>Dependent unit power output (MW)</td>
</tr>
<tr>
<td>$P_D$</td>
<td>Total load of the system (MW)</td>
</tr>
<tr>
<td>$P_L$</td>
<td>Transmission loss of the system (MW)</td>
</tr>
<tr>
<td>$P_{m}, P_m$</td>
<td>Real power injections at $m^{th}$ and $n^{th}$ buses (MW)</td>
</tr>
<tr>
<td>$B_{mn}$</td>
<td>Generalized loss coefficients (MW$^{-1}$)</td>
</tr>
<tr>
<td>$P_{min}$</td>
<td>Minimum value of real power allowed at generator $i$ (MW)</td>
</tr>
<tr>
<td>$P_{max}$</td>
<td>Maximum value of real power allowed at generator $i$ (MW)</td>
</tr>
<tr>
<td>$n$</td>
<td>Population size</td>
</tr>
<tr>
<td>$m$</td>
<td>Number of members in a particle</td>
</tr>
<tr>
<td>$V_i^k$</td>
<td>Velocity of individual $i$ at iteration $k$</td>
</tr>
<tr>
<td>$k$</td>
<td>Pointer of iterations</td>
</tr>
<tr>
<td>$W$</td>
<td>Weighing factor</td>
</tr>
<tr>
<td>$c_1, c_2$</td>
<td>Acceleration coefficients</td>
</tr>
<tr>
<td>$\text{Rand}_1(\cdot)$</td>
<td>Random numbers between 0 and 1</td>
</tr>
<tr>
<td>$\text{Rand}_2(\cdot)$</td>
<td>Random numbers between 0 and 1</td>
</tr>
<tr>
<td>$S_i^k$</td>
<td>Current position of individual $i$ at iteration $k$</td>
</tr>
<tr>
<td>$p_{best_i}$</td>
<td>Best position of individual $i$</td>
</tr>
<tr>
<td>$g_{best}$</td>
<td>Best position of the group</td>
</tr>
</tbody>
</table>
\(W_{\text{max}}\)  
Initial weight

\(W_{\text{min}}\)  
Final weight

\(\text{iter}_{\text{max}}\)  
Maximum iteration number

\(V_{\text{max}}\)  
Maximum velocity limit

\(V_{\text{min}}\)  
Minimum velocity limit

\(\text{iter}\)  
Current iteration number

\(F\)  
Optimal cost of generation ($$/h or Rs/h)

\(FC\)  
Fuel cost ($$/h)

\(EC\)  
Emission cost (kg/h)

\(P_i\)  
Calculated real power for PQ bus i (MW)

\(Q_i\)  
Calculated reactive power for PQ bus i (MW)

\(P_{i,\text{net}}\)  
Specified real power for PQ bus i (MW)

\(Q_{i,\text{net}}\)  
Specified reactive power for PQ bus i (MW)

\(P_{\text{Cal},m}\)  
Calculated real power of PV bus m (MW)

\(P_{\text{net},\text{Spec},m}\)  
Specified real power of PV bus m (MW)

\(|V|\)  
Voltage magnitude of buses (per unit)

\(\delta\)  
Phase angle of buses (degrees)

\(V_{\text{min}}(i)\)  
Minimum value of voltage at bus i (per unit)

\(V_{\text{max}}(i)\)  
Maximum value of voltage at bus i (per unit)

\(nl\)  
Number of branches or transmission lines

\(L_{\text{calMVA}}\)  
Calculated line flow of each transmission line (MVA)

\(L_{\text{ratedMVA}}\)  
Rated line flow of each transmission line (MVA)

\(P_i^0\)  
Power generation of unit i at previous hour (MW)

\(UR_i\)  
Ramp rate limit of unit i as power generation increases (MW/h)

\(DR_i\)  
Ramp rate limit of unit i as power generation decreases (MW/h)

\(\overline{P}_{i,\text{min}}\)  
Effective lower limit of \(i^{th}\) unit with ramp rate constraint (MW)

\(\overline{P}_{i,\text{max}}\)  
Effective upper limit of \(i^{th}\) unit with ramp rate constraint (MW)

\(z\)  
Number of prohibited zones of a unit

\(P_{l,z}, P_{u,z}\)  
Lower and upper limits of \(z\) prohibited zones of unit i (MW)

\(F_{\text{cost}}\)  
Generation cost function ($$/h)

\(P_{\text{pbc}}\)  
Power balance constraint
$F_{\text{max}}$  
Maximum generation cost among the individuals in the initial population ($$/h$)

$F_{\text{min}}$  
Minimum generation cost among the individuals in the initial population ($$/h$)

$I_i(t)$  
Commitment status of $i^{\text{th}}$ generator at hour $t$

$F_i(P_i(t))$  
Fuel cost of $i^{\text{th}}$ generator at hour $t$ ($$/h$)

$S_i(t)$  
Start-up cost of $i^{\text{th}}$ unit at hour $t$ ($$/h$)

$T_{\text{up},i}$  
Minimum uptime of $i^{\text{th}}$ generator ($h$)

$T_{\text{on},i}$  
Time duration for which $i^{\text{th}}$ generator is continuously ON ($h$)

$T_{\text{down},i}$  
Minimum down time of generator $i$ ($h$)

$T_{\text{off},i}$  
Time duration for which $i^{\text{th}}$ generator is continuously OFF ($h$)

$x$  
Continuous variables (AVR values)

$y$  
Discrete variables (OLTC and SC values)

$\text{LOSS}_i$  
Power loss ($P_i$) at branch $i$ (MW)

$Q_{\text{min}}$  
Minimum limit of reactive power at a node (MVAr)

$Q_{\text{max}}$  
Maximum limit of reactive power at a node (MVAr)

$L_{\text{S},i}$  
Line stability index at $i^{\text{th}}$ line or branch

$P_m$  
Real power at the receiving end (per unit)

$Q_m$  
Reactive power at the receiving end (per unit)

$V_K$  
Voltage magnitude at the sending end (per unit)

$V_m$  
Voltage magnitude at the receiving end (per unit)

$V_1$  
Voltage magnitude at bus $i$ (per unit)

$V_{P/W/DG}$  
Voltage profile of the system with DG (per unit)

$V_{P/Wo/DG}$  
Voltage profile of the system without DG (per unit)

$L_i$  
Load at bus $i$ (per unit)

$K_i$  
Weighing factor for load at bus $i$ (per unit)

$N$  
Total number of load buses

$\text{LL}_{W/DG}$  
Total line losses in the system with DG (per unit)

$\text{LL}_{Wo/DG}$  
Total line losses in the system without DG (per unit)

$\lambda_p$  
Penalty factor of bus voltages

$V_2$  
Balanced output voltage (per unit)
\( I \quad \text{Balanced load current (per unit)} \)

\( \Phi \quad \text{Load power factor angle} \)

\( V_1 \quad \text{Source side voltage (per unit)} \)

\( \text{Subscript } j \quad j^{th} \text{ phase ( } j = 1, 2, 3 ) \)

\( P_{dvr}^{\text{in-phase}} \quad \text{Real power supplied by DVR using in-phase voltage injection technique (KW)} \)

\( Q_{dvr}^{\text{in-phase}} \quad \text{Reactive power supplied by DVR using in-phase voltage injection technique (KVAR)} \)

\( \alpha \quad \text{Load voltage phase advancement angle (degrees)} \)

\( P_{in} \quad \text{Input power from the source (KW)} \)

\( P_{out} \quad \text{Load power (KW)} \)

\( P_{dvr} \quad \text{Real power supplied by DVR (KW)} \)

\( Q_{in} \quad \text{Input reactive power from the source (KVAR)} \)

\( Q_{out} \quad \text{Load reactive power (KVAR)} \)

\( Q_{dvr} \quad \text{Reactive power supplied by DVR (KVAR)} \)

\( \alpha_{\text{opt}} \quad \text{Optimum value of load voltage phase advancement angle for minimum power operation (degrees)} \)

\( S_S \quad \text{Complex bus power at the sending end (per unit)} \)

\( P_S \quad \text{Total real power at the sending end bus (per unit)} \)

\( Q_S \quad \text{Total reactive power at sending end bus (per unit)} \)

\( P_R \quad \text{Total reactive power at receiving end bus (per unit)} \)

\( Q_R \quad \text{Total reactive power at receiving end bus (per unit)} \)

\( V_S \quad \text{Voltage at the sending end (per unit)} \)

\( V_R \quad \text{Voltage at the receiving end (per unit)} \)

\( \delta_1, \delta_2 \quad \text{Voltage angle (degree)} \)

\( I_R \quad \text{Current at the receiving end (per unit)} \)

\( A,B,C,D \quad \text{Transmission line constants} \)

\( \alpha_1, \beta_1 \quad \text{Constant angles of transmission lines} \)

\( Z \quad \text{Series line impedance magnitude of transmission lines (ohms)} \)

\( Y \quad \text{Total line charging susceptance (mho)} \)

\( \gamma \quad \text{Propagation constant} \)

\( l \quad \text{Length of a transmission line (km)} \)

\( h_{i1} \quad \text{Price penalty factor associated with the last unit ($/kg)} \)

\( h_{i2} \quad \text{Price penalty factor associated with the current unit ($/kg)} \)
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<tr>
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<tbody>
<tr>
<td>$P_{max1}$</td>
<td>Maximum power associated with the last unit (MW)</td>
</tr>
<tr>
<td>$P_{max2}$</td>
<td>Maximum power associated with the current unit (MW)</td>
</tr>
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