To the almighty.

KASHI VISWANATH

CERTIFICATE

It is certified that the work contained in the thesis titled **"Voltage Stability Enhancement and Loss Reduction in Distribution Networks through DG Placement and Reconfiguration"** by **Akhilesh Kumar Barnwal** has been carried out under my supervision and that this work has not been submitted elsewhere for a degree.

It is further certified that the student has fulfilled all the requirements of Comprehensive Examination, Candidacy and SOTA for the award of Ph.D. Degree.

Signature of Supervisor

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DECLARATION BY THE CANDIDATE

I, **Akhilesh Kumar Barnwal**, certify that the work embodied in this thesis is my own bona-fide work and carried out by me under the supervision of **Prof. M. K. Verma** from July-2016 to September-2022, at the Department of Electrical Engineering, Indian Institute of Technology (BHU), Varanasi. The matter embodied in this thesis has not been submitted for the award of any other degree/diploma. I declare that I have faithfully acknowledged and given credits to the research workers wherever their works have been cited in my work in this thesis. I further declare that I have not wilfully copied any other's work, paragraphs, text, data, results, etc., reported in journals, books, magazines, reports dissertations, theses, etc., or available at websites and have not included them in this thesis and have not cited as my own work.

Date: 10/08/2023

Place: Varanasi

Signature of the Student

(Akhilesh Kumar Barnwal)

CERTIFICATE BY THE SUPERVISOR

It is certified that the above statement made by the student is correct to the best of my/our knowledge.

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Signature of Head of Department

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Date: 10/08/2023

Place: Varanasi

(Akhilesh Kumar Barnwal)

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LIST OF ABBREVIATIONS AND SYMBOLS

DG	Distributed Generation
DER	Distributed Energy Resources
VSM	Voltage stability margin
GWO	Grey wolf optimization
RDS	Radial distribution system
$\vec{D}$	Distance between grey wolf and prey
$\vec{A}, \vec{C}$	Coefficient vectors
$\vec{P}_{prey}, \vec{P}_{wolf}$	Position vector of the prey and grey wolf
$\vec{a}$	Coefficient of acceleration
$\vec{r}_1, \vec{r}_2$	Random vectors in [0 1]
$\vec{P}_\alpha, \vec{P}_\beta, \vec{P}_\delta$	Position of alpha, beta and delta wolf, respectively
$\vec{D}_\alpha, \vec{D}_\beta, \vec{D}_\delta$	Distance between the prey and alpha wolf, beta wolf, and delta wolf, respectively
t, T	Current and maximum iterations count, respectively
$P_{load,i}, Q_{load,i}$	Voltage dependent real and reactive power load at bus-i, respectively
$P^0_{load,i}, Q^0_{load,i}$	Values of real and reactive power load at bus i at nominal voltage, respectively
V_i	Voltage magnitude at bus-i
pr, qr	Exponent coefficients for voltage dependent real and reactive power load, respectively
P_L, Q_L	Real and reactive power loss of the network
nb, b	Total number of buses and branches in the network

R_i, X_i	Resistance and the reactance, respectively, of branch-i
$\bar{I}_i$	Complex current flowing through branch-i
$\bar{I}_{load,n}$	Load current at bus-n
V_n^*	Conjugate of complex voltage $\bar{V}$ at bus-n
I_{ri}, I_{qi}	Real and reactive component of branch current $\bar{I}_i$
I_{rk}, I_{qk}	Active and reactive currents of a DG unit injected at bus-k
P_{LDG}, Q_{LDG}	Real and reactive power loss, respectively after DG placement
P_{grid}^S, Q_{grid}^S	Real and reactive power supplied by the grid, respectively
$P_{DG,i}$, $Q_{DG,i}$	Real and reactive power, respectively, supplied by DG connected at bus-*i*
ndg	Set of DG connected buses
$V_{L,min}$, $V_{L,max}$	Minimum and maximum limit of bus voltage magnitude
$I_{k,max}$	Maximum limit of current magnitude in branch-*k*
DG_{size}^i	Size of DG to be placed at bus-*i*
DG_{size}^{max}	Maximum limit of DG size to be placed at bus-*i*
DG_{loc}^n	Location of nth DG to be placed in the system
DG_{pf}^k	Power factor of k^{th} Type-3 DG
NTie	Number of tie-lines
nFL	Number of fundamental loops
FL	Fundamental loop
DV_R	Decision variables for reconfiguration
TS_i	Tie-switch to be opened in the ith fundamental loop
B_{jk}	Vectors of common branches having the set of switches common

	between two fundamental loops FL_j and FL_k
RG_i	Vectors of restricted group having cluster of common branch vectors incident at the i^{th} common bus(es)
G	Adjacency matrix of the network
sw_i	Status of ith branch
P_L	Total network real power loss
$DVSI_{system}$	Voltage stability index of whole distribution system
VSI_i	Voltage stability index at bus-i
P_{ei}, Q_{ei}	Effective real and reactive power load at ith bus
W_i	Weightage assigned to f_i
DV_{RDG}	Decision vector for reconfiguration and DG placement
DG_l	DG location
DG_s	DG size
DVPM	Decision vector population matrix
U_x^k	x^{th} decision variable of k^{th} population
λ	Loading factor
λ_{max}	Maximum loadability
P_0, Q_0	Active and reactive power loads at initial operating point
P_{new}, Q_{new}	New active and reactive power demand at loading factor λ
NVVB	Number of buses violating the permissible voltage limits
VDI	Voltage deviation index
VPI	Voltage profile improvement index
V_i^{base}	Voltage magnitude at bus-i at the base case operating point

$V_i^{RDG/DG}$	Voltage magnitude at bus-i after reconfiguration and /or DG placement
QLI	Qualified load index
$P_{L,i}^{base}$	Real power drawn by load at bus-i at the base case operating point
QLI^m	Modified value of QLI after network reconfiguration/DG placement
APLR	Percent reduction in active power loss
APL_{old}	Active power loss in the radial distribution system without DG and/ or reconfiguration
APL_{new}	Active power loss in the radial distribution system with DG and/ or reconfiguration
QPLR	Percent reduction in reactive power loss
QPL_{old}	Reactive power loss in the radial distribution system without DG and/ or reconfiguration
QPL_{new}	Reactive power loss in the radial distribution system with DG and/ or reconfiguration
$\Delta P_i, \Delta Q_i$	Change in real and reactive power at bus-i
$\Delta\delta_i, \Delta V_i$	Change in voltage angle and magnitude at bus-i
$\frac{\partial P_i}{\partial \delta_j}$	Sensitivity of real power injection at bus-i w.r.t. voltage angle at bus-j
$\frac{\partial P_i}{\partial V_j}$	Sensitivity of real power injection at bus-i w.r.t. voltage magnitude at bus-j
$\frac{\partial Q_i}{\partial \delta_j}$	Sensitivity of reactive power injection at bus-i w.r.t. voltage angle at bus-j
$\frac{\partial Q_i}{\partial V_j}$	Sensitivity of reactive power injection at bus-i w.r.t. voltage magnitude at bus-*j*
$\bar{y}_{3j}$	Corresponds to elements of bus admittance matrix
Q_3	Net reactive power injection at bus 3

P_3	Net real power injection at bus-3
P_{DG3}	Real power injection by DG at bus-3
APL	Active power loss
pf	power factor
RL	Residential summer night loads
EV	Electric vehicle
$\frac{\partial P_L}{\partial P_j}$	Sensitivity of real power loss w.r.t. real power injection at bus-*j*
$\frac{\partial Q_L}{\partial P_j}$	Sensitivity of reactive power loss w.r.t. real power injection at bus-*j*
$\frac{\partial P_L}{\partial Q_j}$	Sensitivity of real power loss w.r.t. reactive power injection at bus-*j*
$\frac{\partial Q_L}{\partial Q_j}$	Sensitivity of reactive power loss w.r.t. reactive power injection at bus-j
CS_j	Collective power loss sensitivity at bus-j