An adaptive strategy based on Radial Basis Function for distribution network loss minimization

Dissertation

submitted

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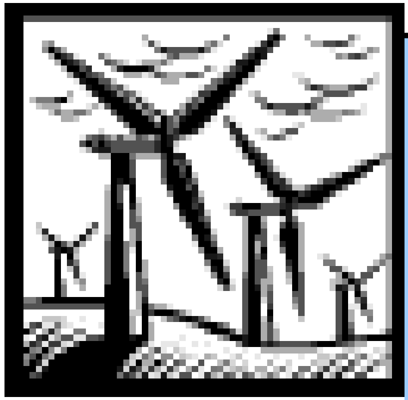
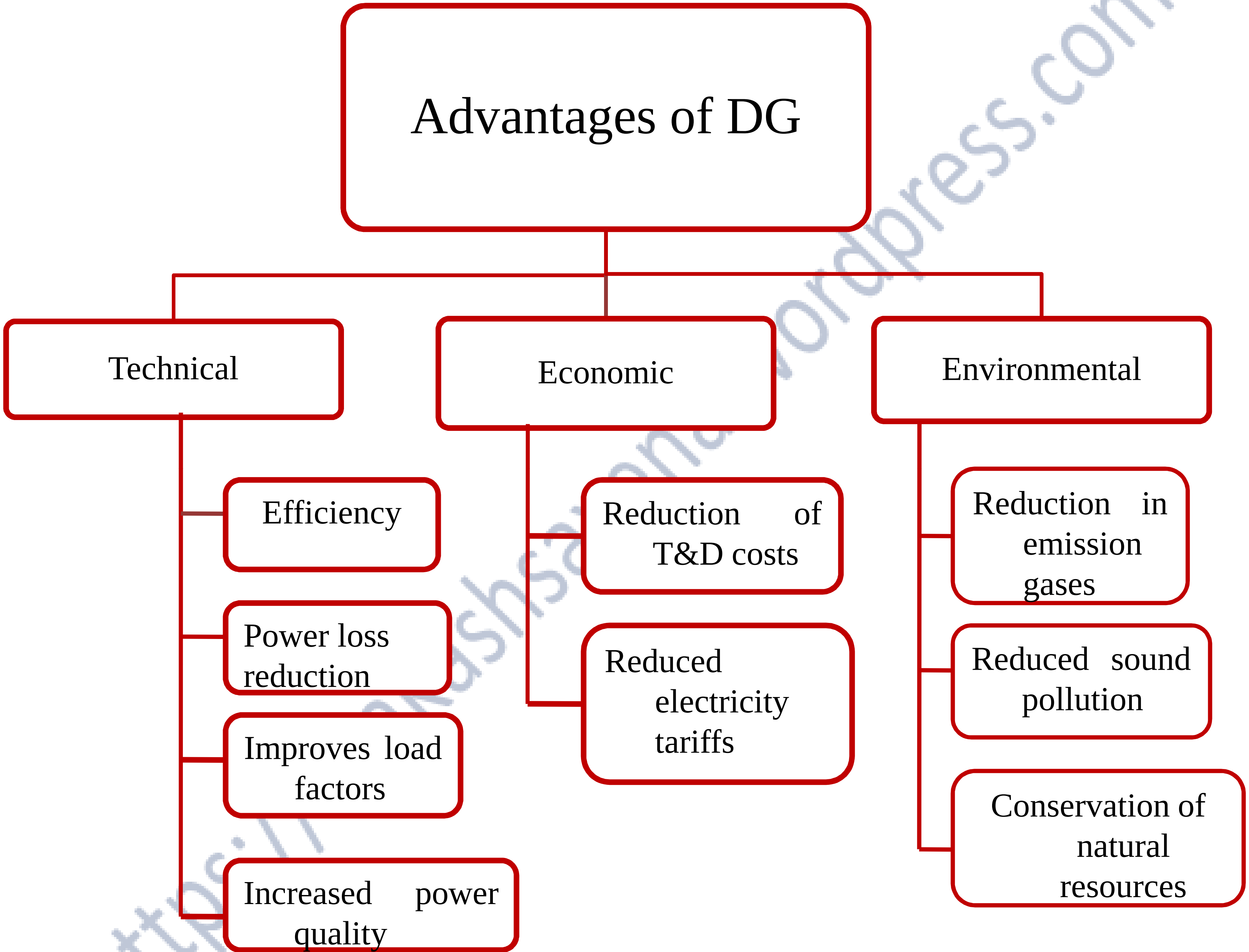
Distributed generators (DG)



Also known as
"Distributed Resources"
"Decentralized Generations"
"Production Decentralized"

Distributed generation can be defined as "the generation having a capacity of about 50 MW to 100 MW and placed at distribution side and that are neither centrally planned nor dispatched".


Advantages of DG
Technical
Economic
Environmental
Efficiency
Power loss reduction
Improves load factors
Increased power quality
Reduction of T&D costs
Reduced electricity tariffs
Reduction in emission gases
Reduced sound pollution
Conservation of natural resources

Optimization of DG using PSO

- The benefits of DG are site specific.
- Various optimization techniques are implemented to optimize site and size of DG for enhanced benefits.
- Particle Swarm Optimization technique is applied in this work for optimal placement of DG for power loss mitigation.

Particle Swarm Optimization

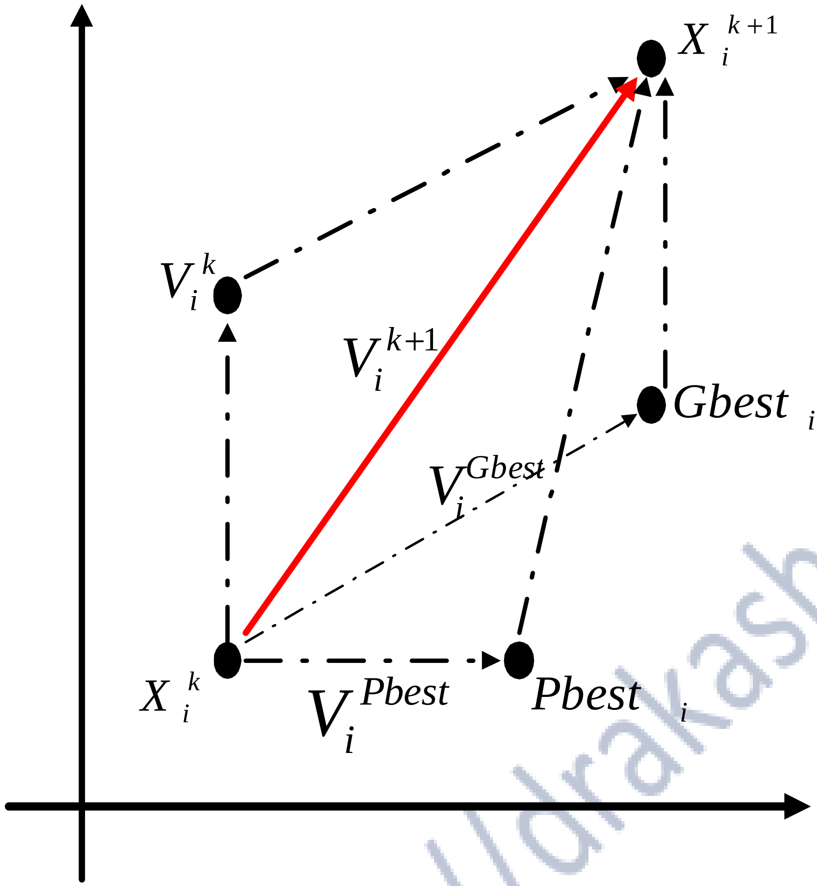
The basic idea:

- Each particle is searching for the optima.
- Each particle is *moving* and hence has a *velocity*.
- Each particle remembers the position it was in where it had its best result so far (its *personal best Pbest*)
- *But this would not be much good on its own; particles need help in figuring out where to search.*

The basic idea II:

- The particles in the swarm *co-operate*. They exchange information about what they've discovered in the places they have visited
- The co-operation is very simple. In basic PSO it is like this:
  - A particle has a *neighborhood* associated with it.
  - A particle knows the fitness of those in its neighborhood, and uses the *position* of the one with best fitness *(Gbest).*
  - This position is simply used to adjust the particle's velocity

Concept of PSO



V_i^k Is the current velocity of particle i at k iteration

V_i^{k+1} Is the modified velocity

X_i^k Is the current position of particle i

X_i^{k+1} Is the modified position of particle i

V_i^{Pbest} Is the velocity at Pbest

V_i^{Gbest} Is the velocity at Gbest

Velocity of each agent can be modified by following equation:

$$V_i^{k+1} = wV_i^k + c_1 rand * (pbest_i - X_i^k) + c_2 rand * (gbest_i - X_i^k)$$

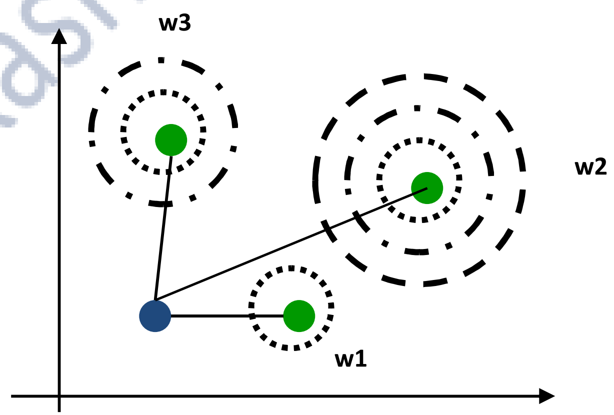
And hence the position of the particle can be modified by

$$X_i^{k+1} = X_i^k + V_i^{k+1}$$

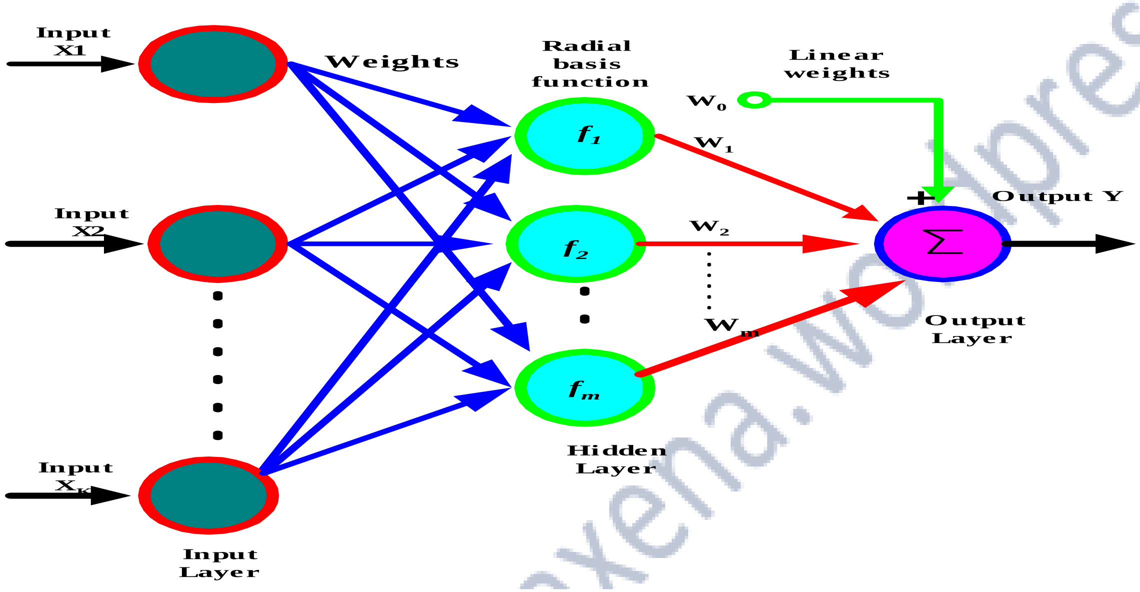
In this work PSO serves two purposes at first PSO calculates the size and optimal location of DG and at second the tuning of RBFNN is carried out by the PSO.

Radial-Basis Function Networks

- A function is radial basis (RBF) if its output depends on (is a non-increasing function of) the distance of the input from a given stored vector.
- RBFs represent local receptors, as illustrated below, where each green point is a stored vector used in one RBF.
- In a RBF network one hidden layer uses neurons with RBF activation functions describing local receptors. Then one output node is used to combine linearly the outputs of the hidden neurons.



RBF ARCHITECTURE



- **One hidden layer with RBF activation functions**

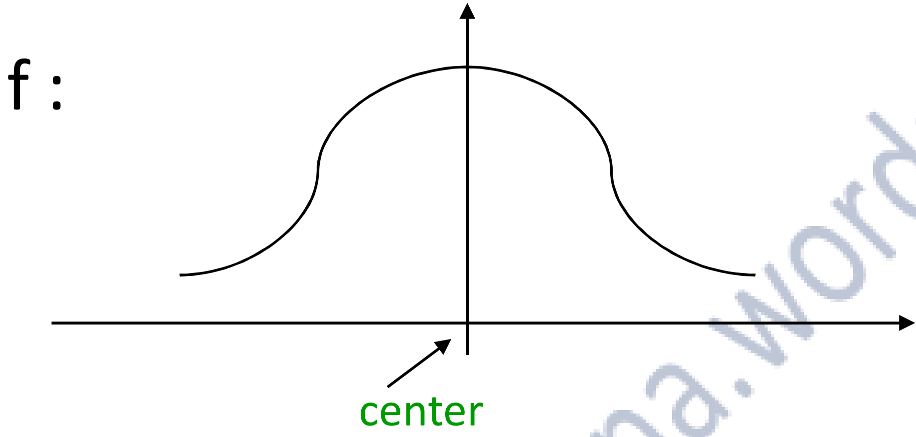
$$f_1 \cdots f_{m1}$$

- **Output layer with linear activation function.**

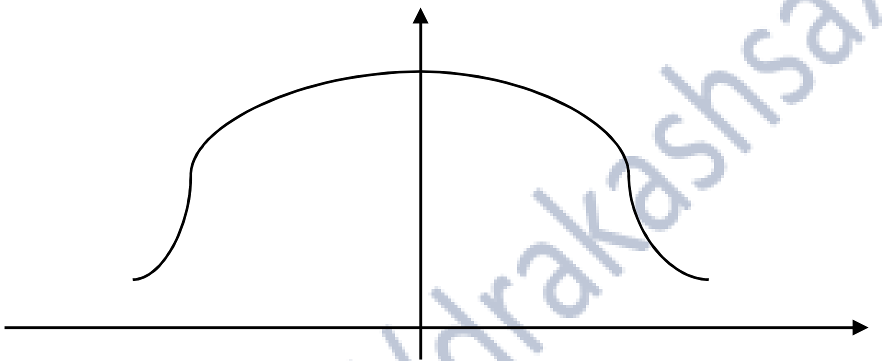
$$y = w_1 f_1(\| x - t_1 \|) + \ldots + w_{m1} f_{m1}(\| x - t_{m1} \|)$$

$$\| x - t \| \text{distance of } x = (x_1, \ldots, x_m) \text{ from vector } t$$

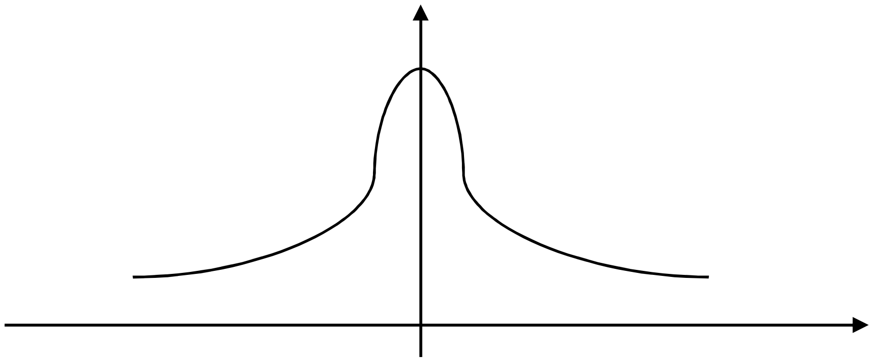
Gaussian RBF f



σ is a measure of how much spread of the curve is:



Large σ



Small σ

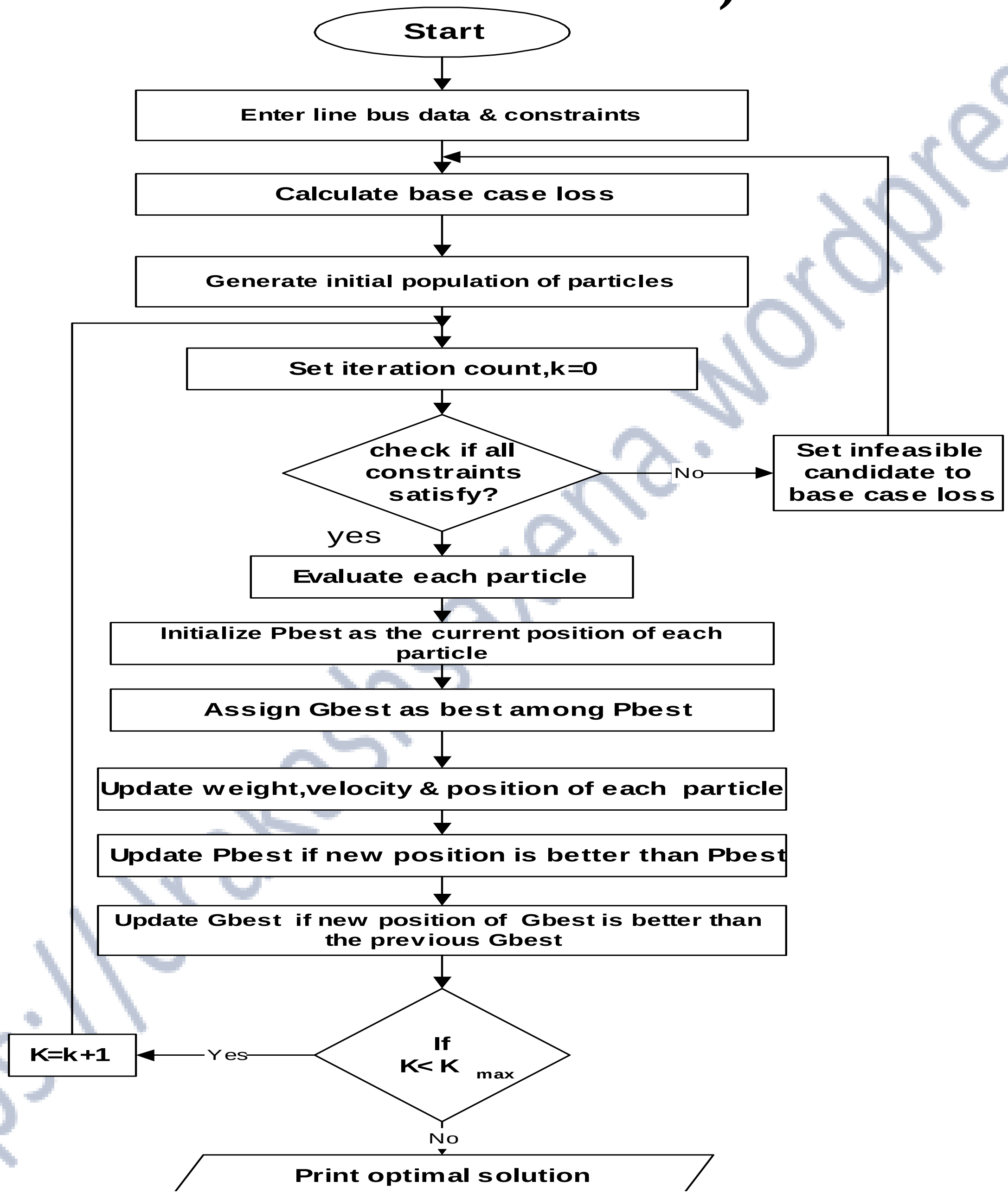
RBF network parameters

- **What do we have to learn for a RBF NN with a given architecture?**
  - The centers of the RBF activation functions
  - the spreads of the Gaussian RBF activation functions
  - the weights from the hidden to the output layer
- Different learning algorithms may be used for learning the RBF network parameters.
- In this work Particle Swarm Optimization is used to train RBFN network.

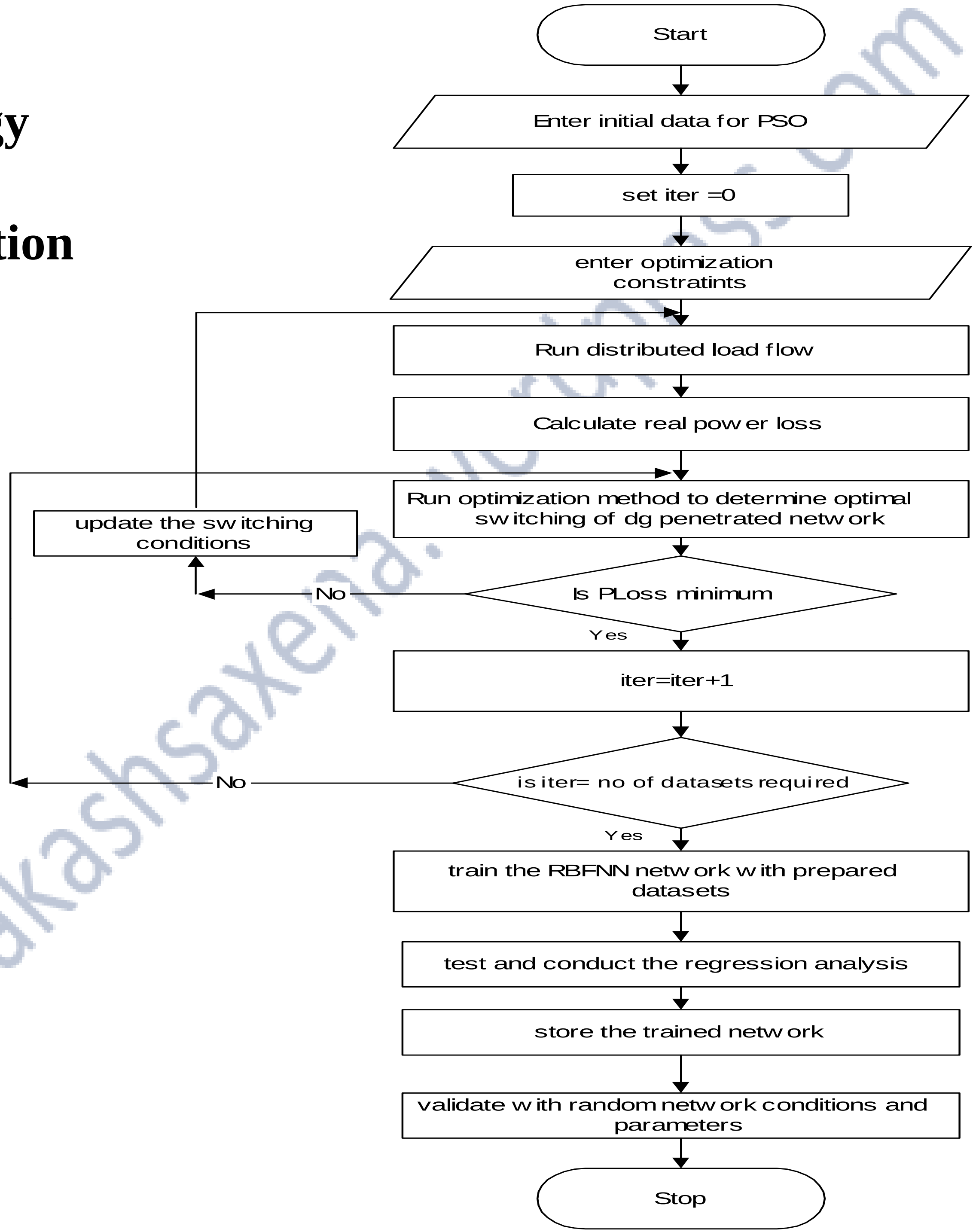
Network Reconfiguration

- Electrical power distribution system consists of groups of interconnected radial circuits. They have switches to configure the network's topology via switching operations to transfer loads among the feeders.
- The state of the switches determines the configuration of network. The configuration of the distribution system is changed by opening sectionalizing switches and closing tie switches such that the radial structure of the network is maintained and power losses are reduced, voltage profile is improved, power quality is improved.
- Since network reconfiguration is a complex combinatorial, constrained optimization problem, many algorithms have been proposed to optimize the system configuration.
- It is very surprising to find all these approaches are addressed with particular loading conditions, however in real time application these load levels are dynamic and it is probable that the approach presents erroneous results when subjected to a particular operating condition.

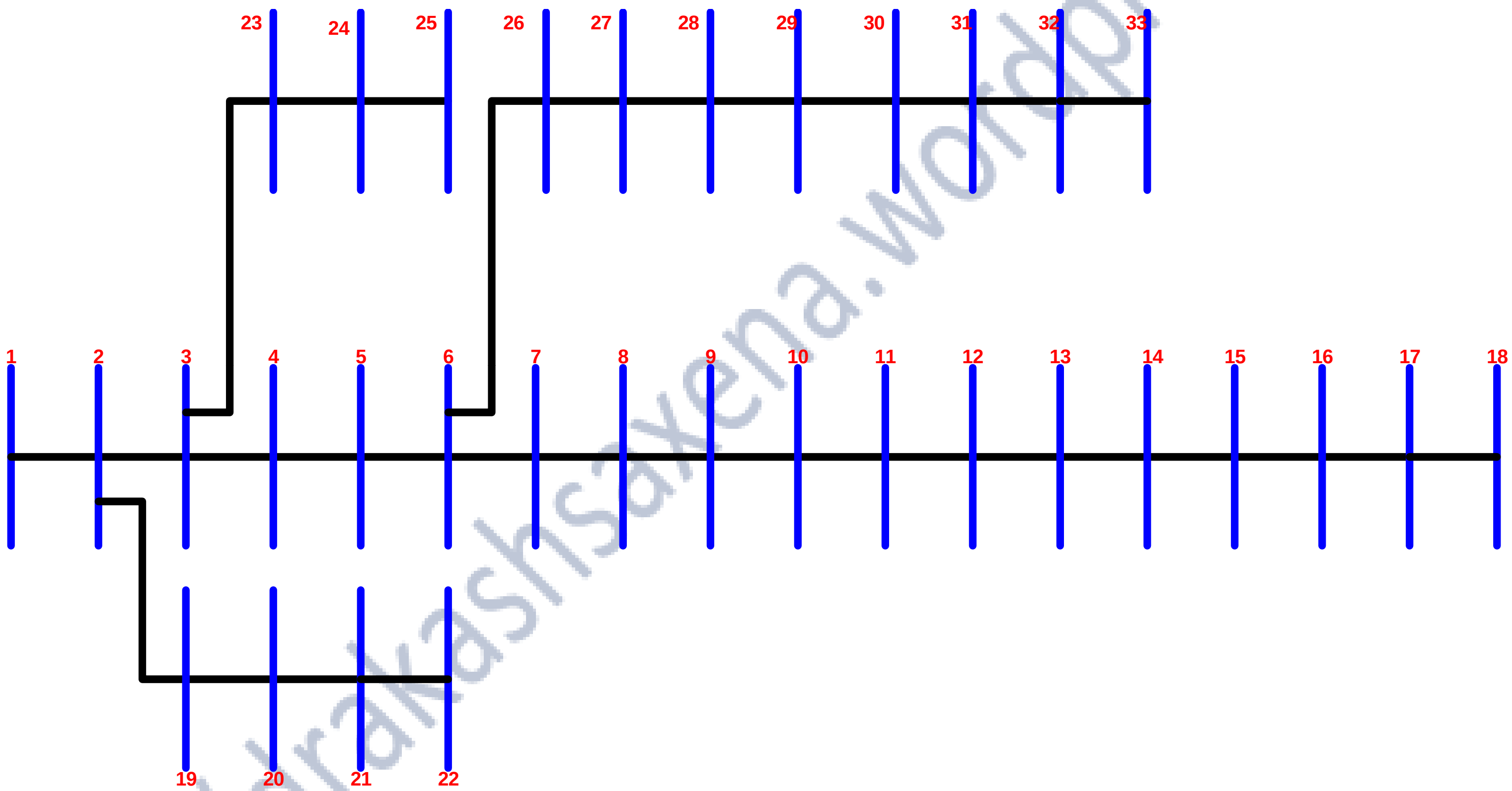
Proposed methodology
(Optimization of DG size and Location)



Proposed methodology contd..
Network reconfiguration using RBFNN-PSO

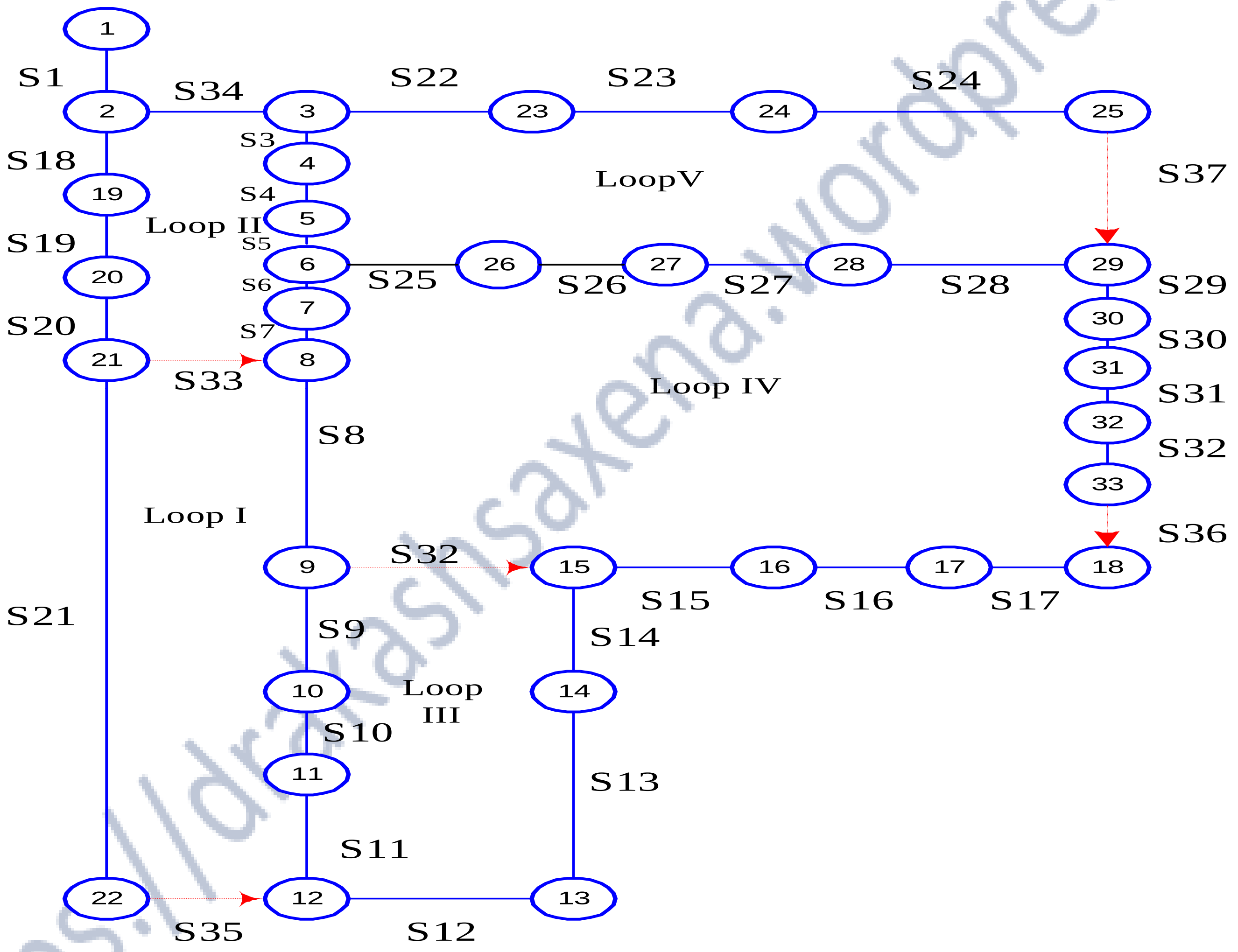


Test system-I

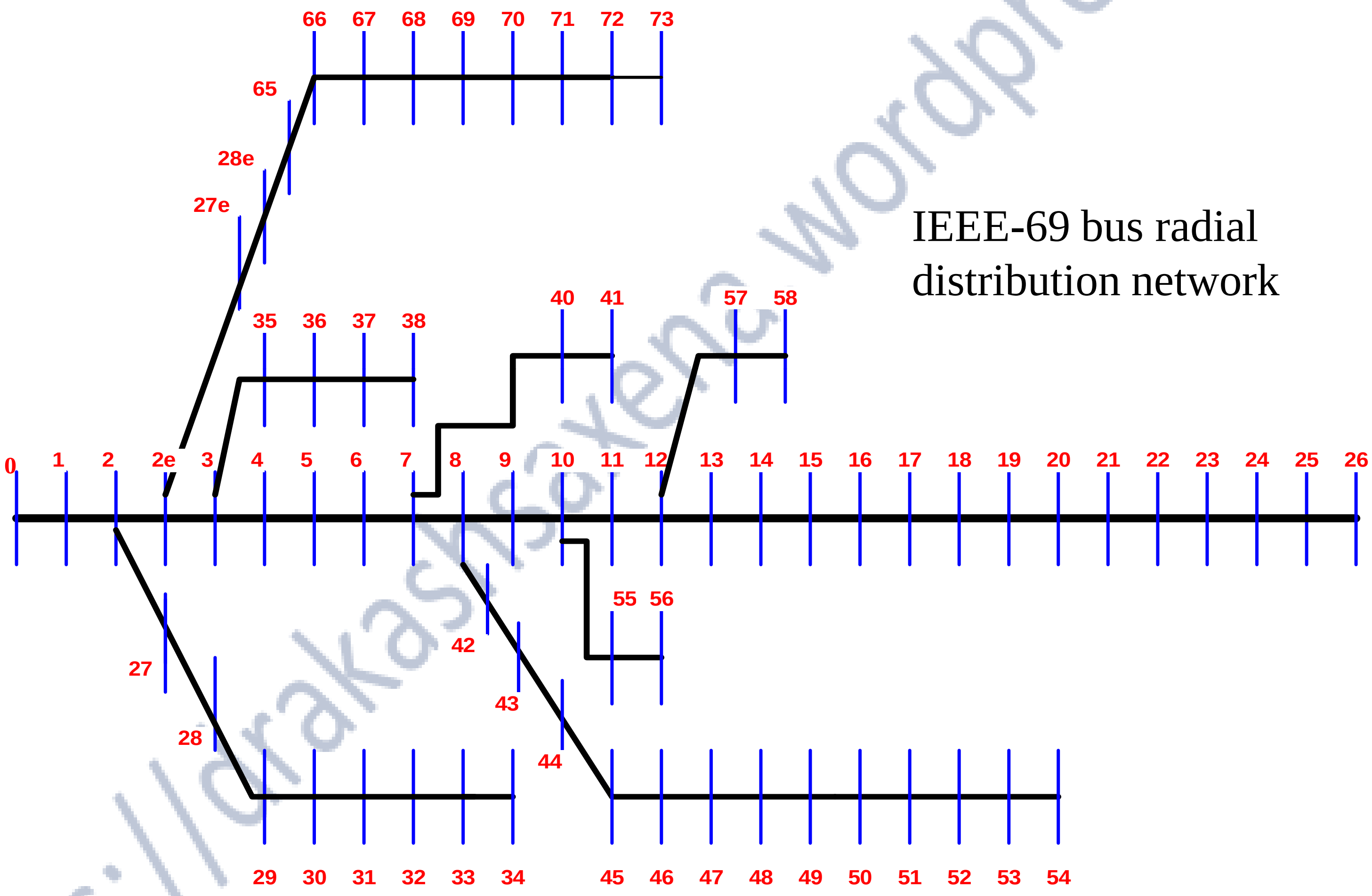


Single line diagram of IEEE -33 bus radial distribution system

Initial switching configuration of IEEE-33 bus system

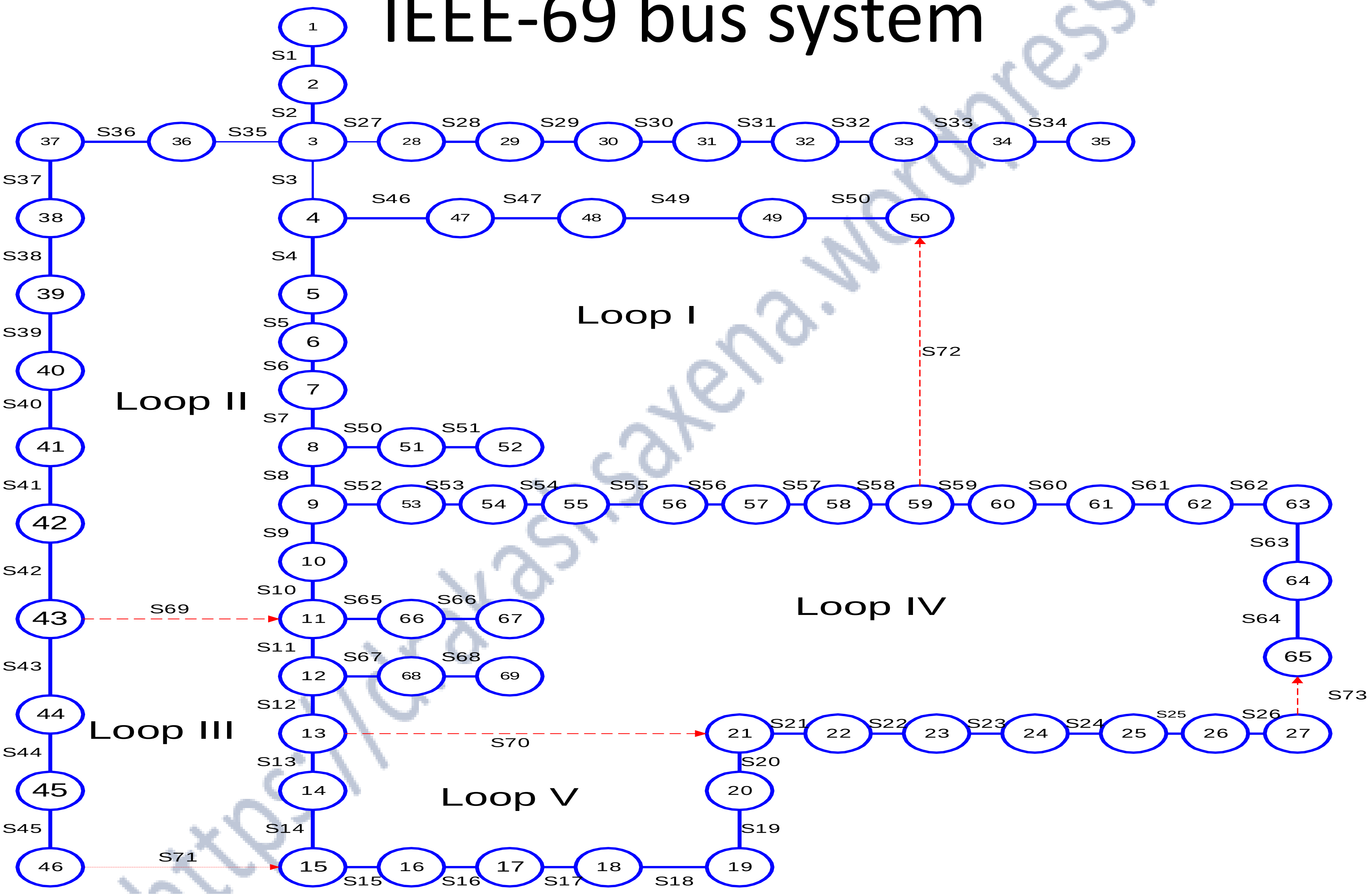


Test system-II



IEEE-69 bus radial distribution network

Initial switching configuration of IEEE-69 bus system



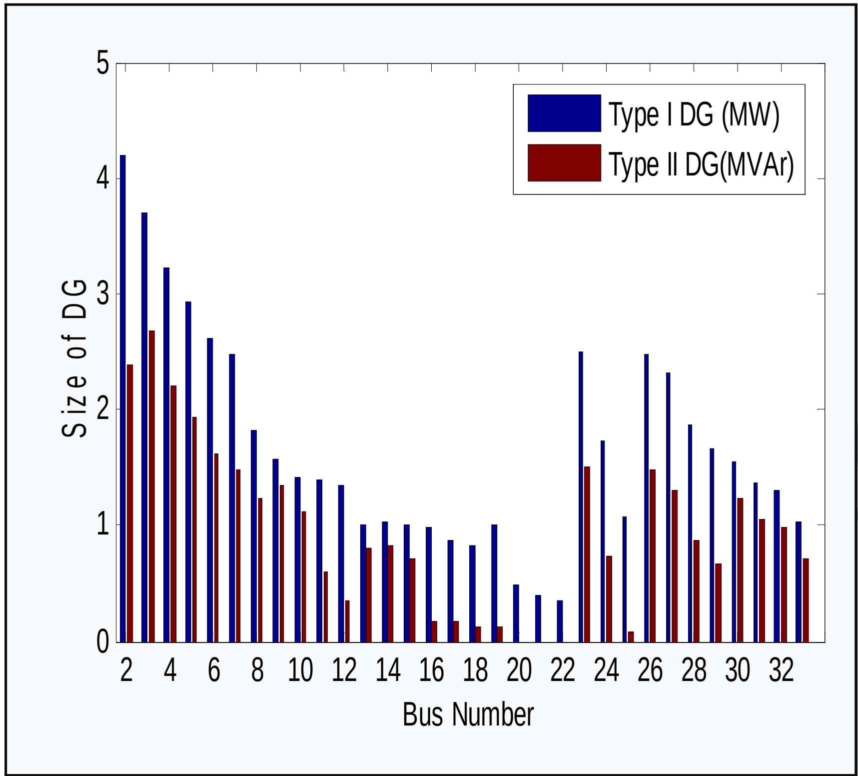
Results
IEEE-33 Bus radial distribution system

Optimal placement, sizing of DG and system reconfiguration for IEEE 33 bus distribution system

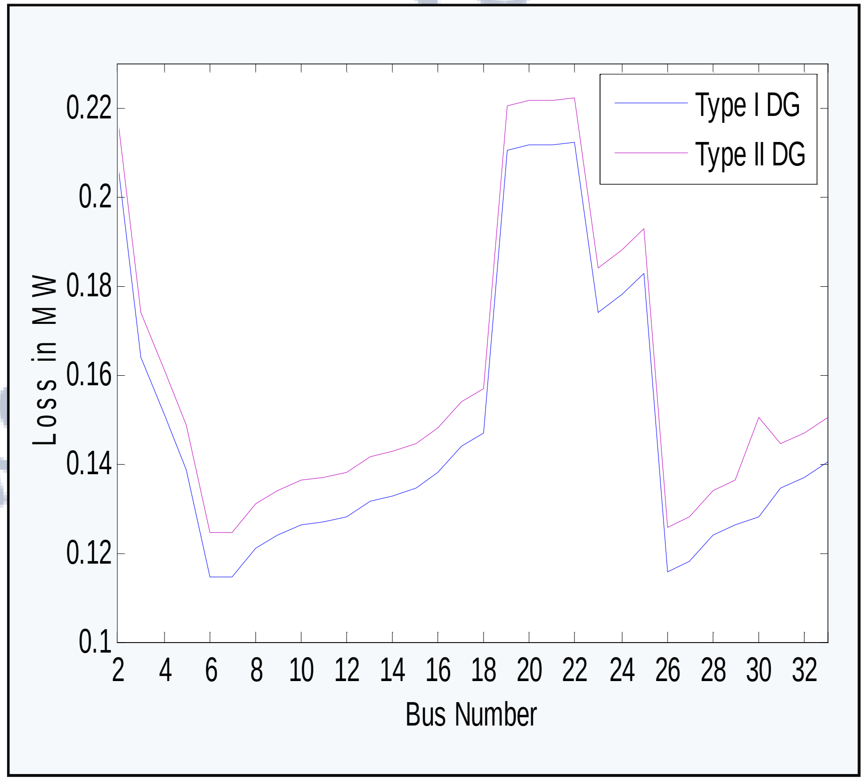
Table I: Optimization of different type of DG with sizes and loss reduction in IEEE 33 bus distribution system using PSO technique.

DG Type	DG Installation		Losses	
	DG Size	Location	Value(kW)	Reduction (%)
No DG	_	_	211.0	_
I st	2.61 MW	6	114.3	45.838
II nd	1.23 MVAr	30	150.3	28.782

Size of DG and loss associated with it at each bus of IEEE 33 bus distribution system



Size of different types of DG at various locations for IEEE-33 bus distribution system.



Total Real Power Loss at different buses for IEEE-33 bus distribution system

Table II: Results for IEEE 33 bus system reconfiguration with Type I DG penetration.

Algorithms	Loading conditions	Switches	Loss	
			Value	Decline (%)
Initial configuration	_	33 34 35 36 37	211 kW	_
RBFNN	Base	13 17 20 35 37	89.0955	57.77
	Light	14 20 35 36 37	79.9614	62.1
	Medium	10 17 20 36 37	98.7553	53.19
	Heavy	13 17 20 36 37	108.45	48.6
Genetic Algorithm[94]	Base	07 14 17 20 37	108.5535	48.55
	Light	07 09 35 36 37	90.79	56.97
	Medium	07 17 20 34 37	118.675	43.75
	Heavy	10 13 34 35 36	117.345	44.38
Tabu Search[95]	Base	13 14 35 36 37	110.29	47.72
	Light	9 17 33 34 37	92.45	56.18
	Medium	10 14 20 33 35	119.234	43.49
	Heavy	07 14 17 34 37	118.24	43.96

Table III: Results for IEEE 33 bus system reconfiguration with type II DG penetration.

Algorithms	Loading conditions	Switches	Loss	
			Value	Decline (%)
Initial configuration	_	33 34 35 36 37	211 kW	_
RBFNN	Base	13 15 20 22 35	131.45	33.7
	Light	13 17 20 22 35	117.57	44.27
	Medium	13 14 20 33 35	145.85	30.87
	Heavy	13 15 20 22 35	161.34	23.53
Genetic Algorithm[94]	Base	14 17 33 35 37	129.67	38.54
	Light	17 20 35 36 37	119.23	43.49
	Medium	14 20 34 35 37	143.34	32.06
	Heavy	14 15 20 36 37	161.45	23.48
Tabu Search[95]	Base	14 17 34 36 37	133.68	36.64
	Light	20 22 34 35 36	118.034	44.05
	Medium	13 20 33 36 37	144.37	31.57
	Heavy	14 20 35 36 37	162.97	22.76

Active power loss for type I and type II DG penetrated IEEE 33 bus system

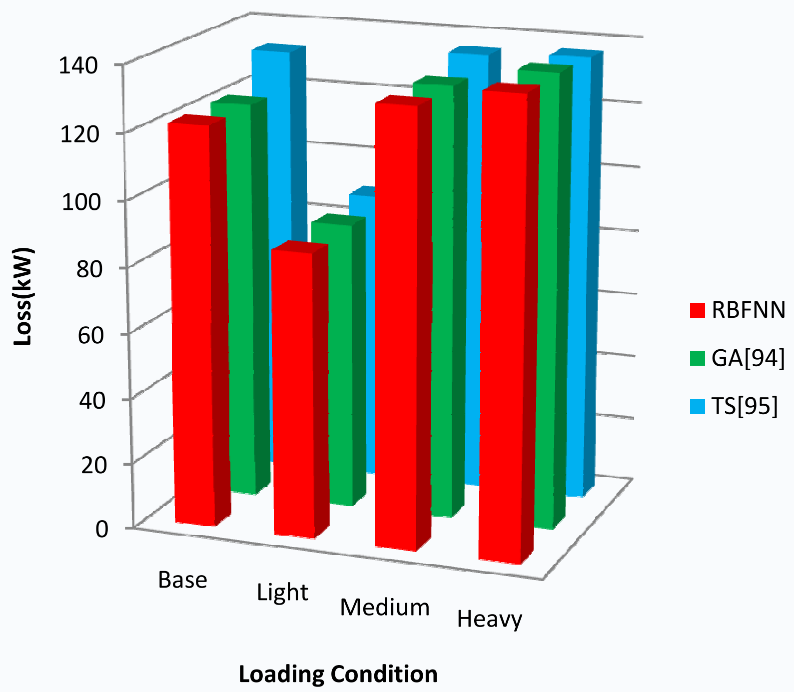


Fig: Active power loss for type I DG penetrated IEEE 33 bus system

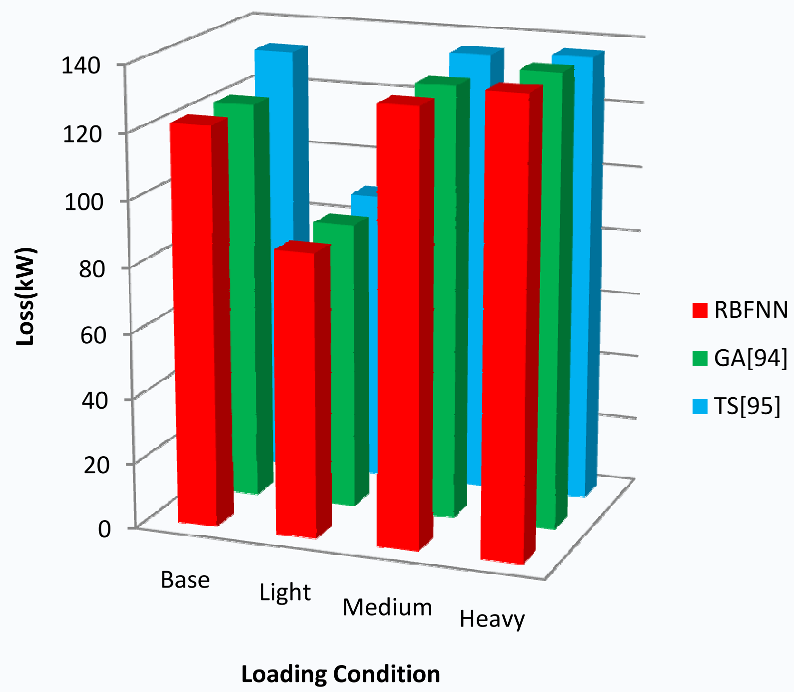


Fig : Active power loss for type II DG penetrated IEEE 33 bus system

Results

IEEE-69 Bus radial distribution system

Optimal placement, sizing of DG and system reconfiguration for IEEE 69 bus distribution system

Table IV: Optimization of different type of DG with sizes and loss reduction in IEEE 69 bus distribution system using PSO technique.

	DG Installation		Losses	
DG Type	DG Size	Location	Value(kW)	Reduction (%)
No DG	_	_	225.00	_
I st	1.8078 MW	61	85.00	62.222
II nd	1.29 MVAr		152.14	32.382

Size of type I DG and type II DG at all buses for IEEE 69 bus distribution system

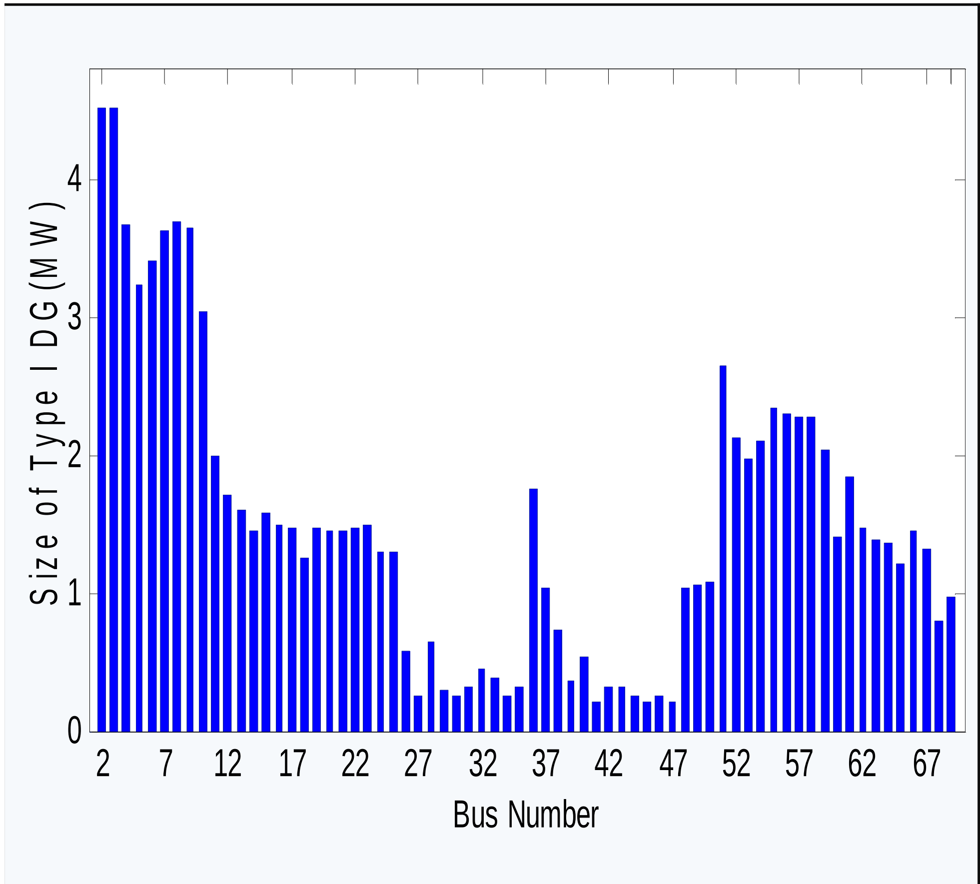


Fig: Size of type I DG at all buses for IEEE 69 bus distribution system

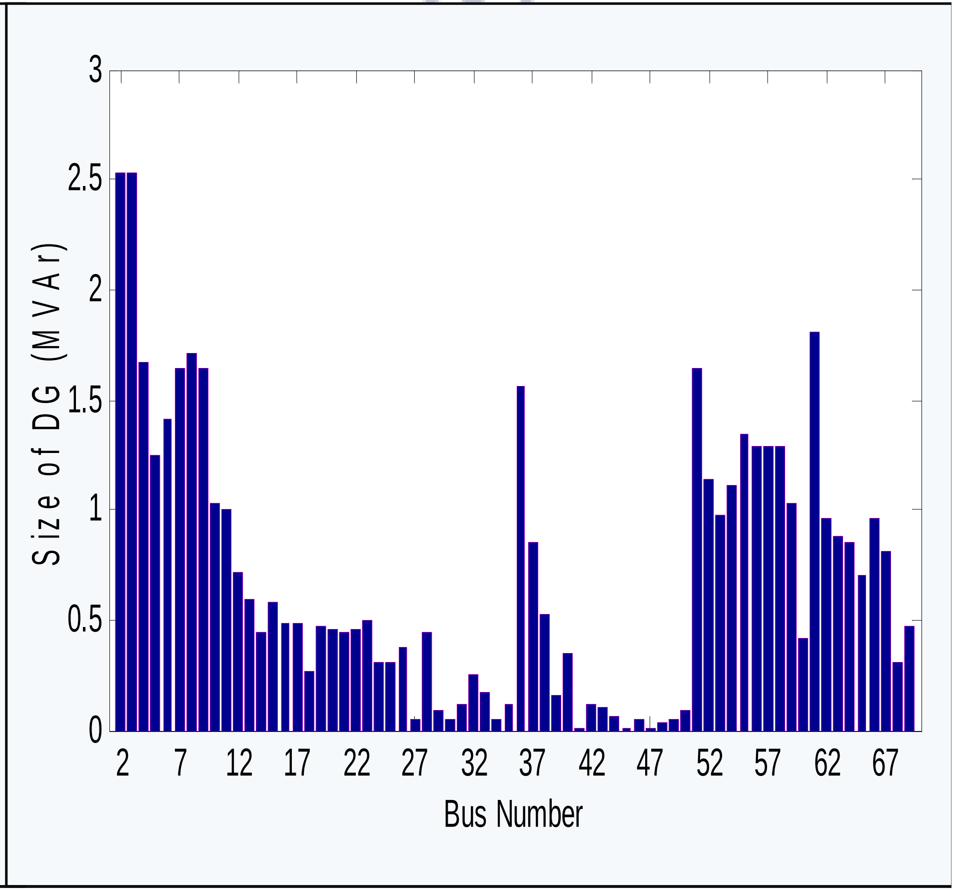


Fig: Size of type II DG at all buses for IEEE 69 bus distribution system

Total Real Power Loss at different buses for IEEE-69 bus distribution system

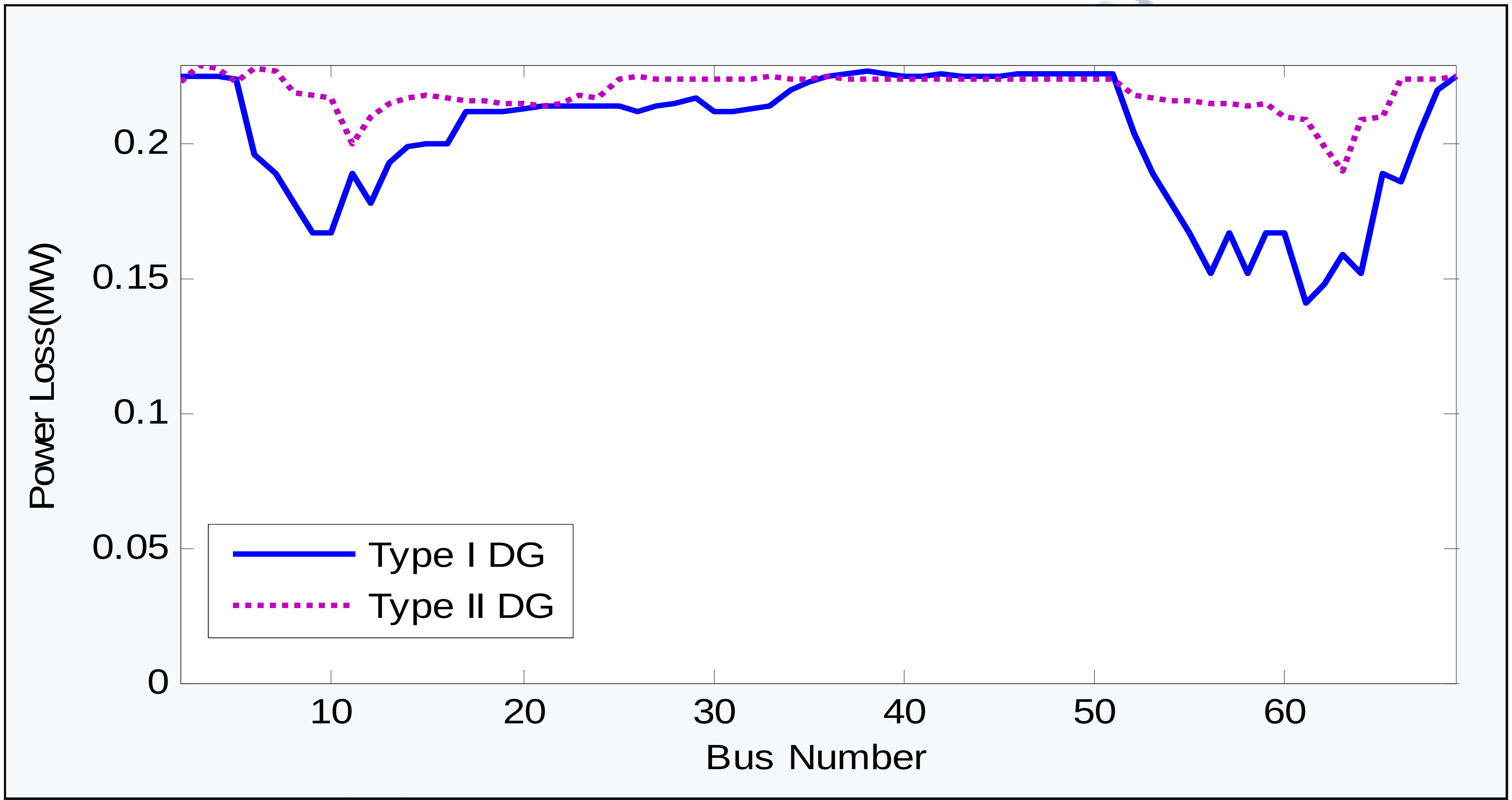


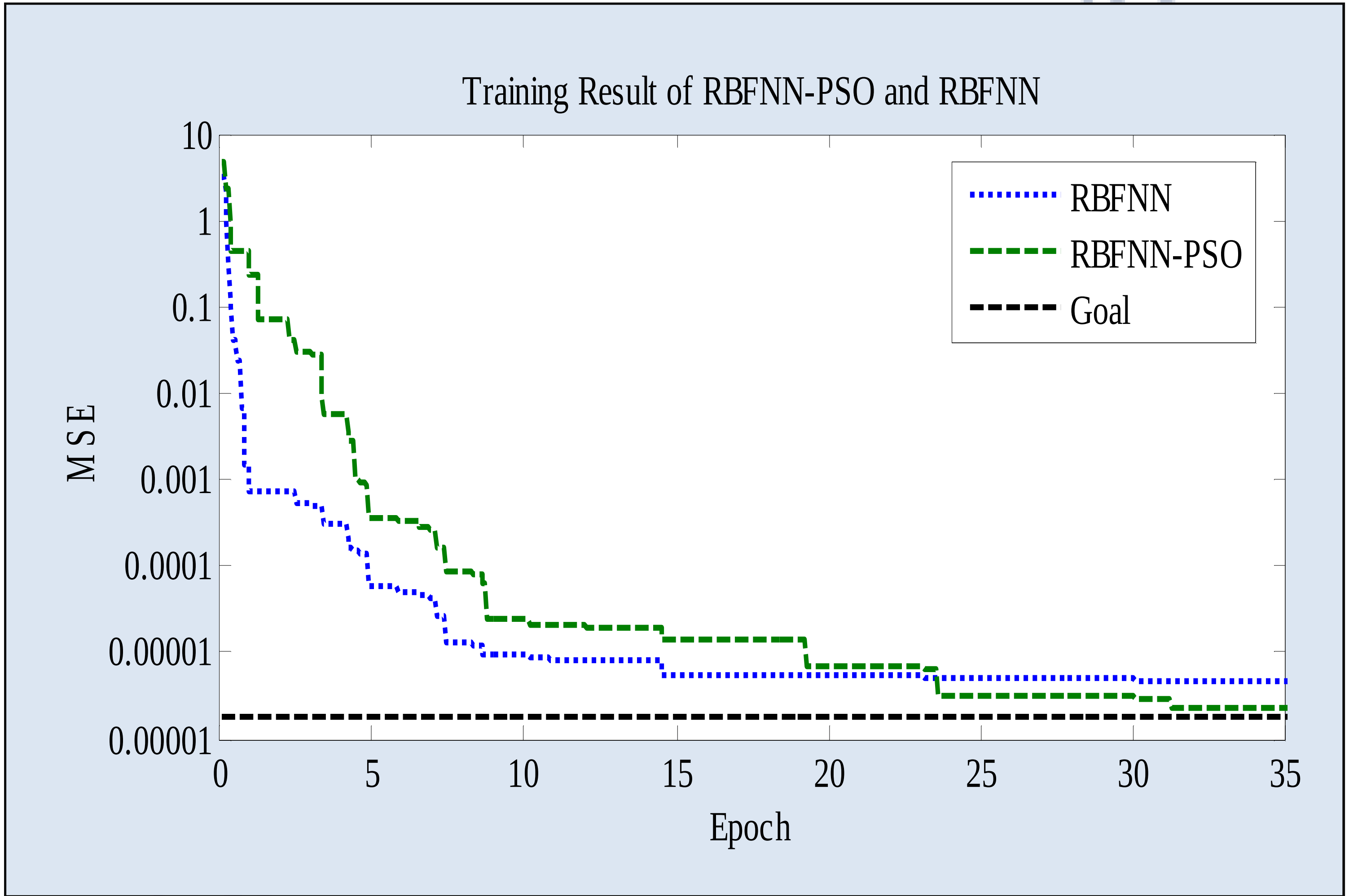
Table V: Results for IEEE 69 bus system reconfiguration with Type I DG penetration

Algorithms	Loading conditions	Switches	Loss	
			Value	Decline (%)
Initial configuration	_	69,70,71,72,73	225 kW	_
RBFNN	Base	4,13,20,21,69	77.9137	65.37
	Light	4,13,18,21,69	66.6312	70.38
	Medium	4,13,20,21,69	81.891	63.60
	Heavy	5,14,20,21,69	97.7679	56.54
Genetic Algorithm[94]	Base	4,18,20,69,72	78.23	65.23
	Light	5,18,20,69,72	67.097	70.17
	Medium	4,13,18,21,69	81.97	63.56
	Heavy	4, 5, 13,18,21	97.846	56.51
Tabu Search[95]	Base	5,13,18,20,21	78.45	65.13
	Light	4,13,18,20,21	67.945	69.80
	Medium	5,13,14,18,20	83.245	63.00
	Heavy	4, 5 ,20,21,69	99.856	55.61

Table VI illustrates the comparative analysis of results obtained from the three approaches implemented to type II DG penetrated IEEE 69 bus distribution system.

Algorithms	Loading conditions	Switches	Loss	
			Value	Decline (%)
Initial configuration	_	69,70,71,72,73	225 kW	_
RBFNN	Base	3,08,14,18,21	121.92	45.81
	Light	4,14,20,21,69	86.6717	61.47
	Medium	4,13,20,21,69	131.891	41.38
	Heavy	5,13,20,21,69	137.6815	38.8
Genetic Algorithm[94]	Base	4,13,20,21,69	121.96	45.79
	Light	5,13,20,21,69	87.68	61.03
	Medium	4,5 ,20,21,69	131.934	41.36
	Heavy	4,13,18,21,69	137.89	38.71
Tabu Search[95]	Base	4,13,20,21,69	132.56	41.08
	Light	3,8,13,19,21	89.46	60.24
	Medium	4,13,14,18,21	135.594	39.73
	Heavy	5,13,18,21,69	136.783	39.2

Convergence characteristics



Values of parameters assumed

- Swarm size = 80
- Number of iterations = 100
- $c_1 = c_2 = 2$
- $\omega_{min} = 0.4$
- $\omega_{max} = 0.9$.

Conclusion

- This dissertation presents the optimal allocation of different types of DGs using PSO technique for active and reactive power compensation to minimize the real power losses in the primary distribution networks.
- PSO approach for optimal placement of multiple types of DGs not only reduces the line losses but also minimizes the sizes of DGs.
- In this dissertation a new RBFNN based methodology for optimization of network reconfiguration in distribution systems has been proposed.
- This work that if network is reconfigured in presence of DG more loss reduction can be achieved.

List of publications

- S.Gupta, A.Saxena, B.P.Soni, “A Radial Basis Function Neural Network based Optimal Placement of Distributed generation sources in Distribution Networks”, Journal of automation and system engineering, Vol.8 (4), pp 175-186,December 2014.
- S.Gupta, A.Saxena, B.P.Soni, “Optimal Placement Strategy of Distributed Generators based on Radial Basis Function Neural Network in Distribution Networks”, Elsevier proceedia.(presented and to be published in coming edition).
- S.Gupta, A.Saxena, “Implementation of loss minimization strategies in modern distribution system”, Taylor & Francis.(under communication)
- S.Gupta, A.Saxena, “Adaptive strategy for loss minimization through network reconfiguration in a DG penetrated distribution system”, Ain Shams Engineering Journal(Elsevier).(under communication)
- S.Gupta, A.Saxena, “ RBFNN based optimization of the system configuration for system loss mitigation ”,human centric computing and information sciences.(Springer).(would be intimated by June 1’st)

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Thank you