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Optimal placement and sizing of D-STATCOMs devices in distribution network using Bacterial Foraging Algorithm and coordinated control of these devices with OLTC and Distributed Generation

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ABSTRACT: This paper presentsan optimal approachand technique for voltage and power regulations of Radial Distribution Systems (RDS) in presence of Distributed Generation (DG) units.First, it presents an optimal technique of coordination action between on-load tap changer (OLTC) and reactive power compensation by Distribution STATicCOMpensator (D-STATCOM). In a second step,it suggests a bio-inspiredapproach based on Bacterial Foraging optimisation, to identify optimal size and placement ofD-STATCOM in RDS. Algorithm and method proposed are tested on modified IEEE 34-bus (68-bus) system and on a real distribution network of JIRAMA (Malagasy electricity utility).Simulation results in MATLAB reveal that the proposed control method is capable of maintaining the system voltage within the permitted range and minimize power losses in the worst scenarios of the test system.

KEYWORDS:BFA, D-STATCOM,OLTC coordinationRadial Distribution Systems, Optimal Location, OptimalSize.

I. INTRODUCTION

Development of power supply system has been based on large power plants, at a small number of locations. Faced with problem of rapid growth in energy demand, these large power plants can no longer meet demands. Usually, to reinforce conventional power generation, new centralized generation units are inserted into transmission grid. However, in recent years, a number of influences have been combined to lead and to increased interest in the use of small renewable energy power plants, connected to local distribution systems, commonly known as "Distributed Generation" (DG).Implementation of these productions posed new difficulties for the operator since current network was not designed for this change. Indeed, when the penetration of DG is high, generated power modify energy flow in distribution network. As a result, connecting DG to grid may have impacts on operation and control of power grid.Some of the impacts are on control and voltage stability in the systems. Voltage control devices in conventional distribution systems (distribution systems without DG) are mainly operated on basis that the voltage decreases along distributor from substation to the sending end. Presence of DG makes this characteristic invalid.In fact, over voltage at the DG's Point of CommonCoupling (PCC) may occur [9].

Power utilitiesusedconventional control such as OLTCto provide customers a stable and near-rated voltage. It principle is to adjust the

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secondary voltage by changing the transformer turn ratio, which in reality is achieved by automatic moving the tap position based on the detected bus voltage.However, OLTC cannot be used for voltage regulation of long radial distribution feeders as it changes the sending point voltage of the feeder. Also, it could prove to be too slow and insufficient to respond effectively to the problems of grid instability, in particular given the new constraints. It will therefore be necessary to complete their action by implementing power electronic devices with short response times, like D-STATCOM.

Most of the loads on the main distribution network are inductive in nature. So the network power factor will belagging in nature. It leads to increasing the power losses [5].Power electronics based controllers such as STATCOM has led to improved ways of reducing losses in power networks [1]. Considering the fact that most electric loads draw lagging current, there is an increase in the demand for reactive power in distribution networks.

Nevertheless, its inappropriate placement for a nodeand/or inadequate sizing can limit its technicalperformance and more weaken the operation ofthe network in which it would be installed[1].

The purpose of this paper isto proposemethodsof:(i) voltageregulation byOLTC-DSTATCOM coordination control and (ii) sizing and placement of D-STATCOM in RDS. Toshow the effectiveness of the proposed method, it has beenapplied on modified IEEE test radial distribution system.

II. PROBLEM FORMULATION

2.1. Load Flow Analysis.

Load flow analysis of distribution system differs from the transmission system. The conventional method is used for transmission systems and their use in distribution system usually does not provide good results and very often solution diverges. The efficient power flow analysis named the backward/forward sweep (BFS) algorithm has been used to find power losses and voltage levels across buses [7]. This method has unique features such as fast computation, requires less memory, and is very simple to use with accurate results, as well as robust convergence [4][8].

The diagram line of a sampledistribution system is shown in Figure 1.Branch currents IB5, IB4, IB3, IB2, and IB1 can be expressed as follows:

$$\begin{bmatrix} IB_1 \\ IB_2 \\ IB_3 \\ IB_4 \\ IB_5 \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 & 1 & 1 \\ 0 & 1 & 1 & 1 & 1 \\ 0 & 0 & 1 & 1 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \\ I_3 \\ I_4 \\ I_5 \end{bmatrix} \quad (1)$$

$$[IB] = [BIBC][I] \quad (2)$$

whereIB is the branch current. BIBC is the bus current injection to branch current matrix.

The network node voltage can be expressed as a function of node currents, line parameters, and main substation voltage.

$$\begin{bmatrix} V_1 \\ V_1 \\ V_1 \\ V_1 \\ V_1 \end{bmatrix} - \begin{bmatrix} V_2 \\ V_3 \\ V_4 \\ V_5 \\ V_6 \end{bmatrix} = \quad (3)$$

3)

$$[\Delta V] = [BCBV][IB] \quad (4)$$

Where BCBV is the Branch Current to Bus Voltage

$$[BCBV] = [BIBC][ZD] \quad (5)$$

$$[\Delta V] = [DLF][I] \quad (6)$$

$$[DLF] = [BCBV][BIBC] \quad (7)$$

Where DLF is theDistribution Load Flowmatrix
The iterative solution for the power flow of the distribution system can be obtained by solving the equations 8 and 9

$$I_i^k = I_i^r(V_i^k) + jI_i^i(V_i^k) = \left(\frac{P_i + jQ_i}{V_i^k}\right)^* \quad (8)$$

$$[V^{k+1}] = [V^0][\Delta V^{k+1}] \quad (9)$$

Where $[\Delta V^{k+1}] = [DLF][I^k]$

The active and reactive power losses of the i,k branch are calculated using the equations 10 and 11.

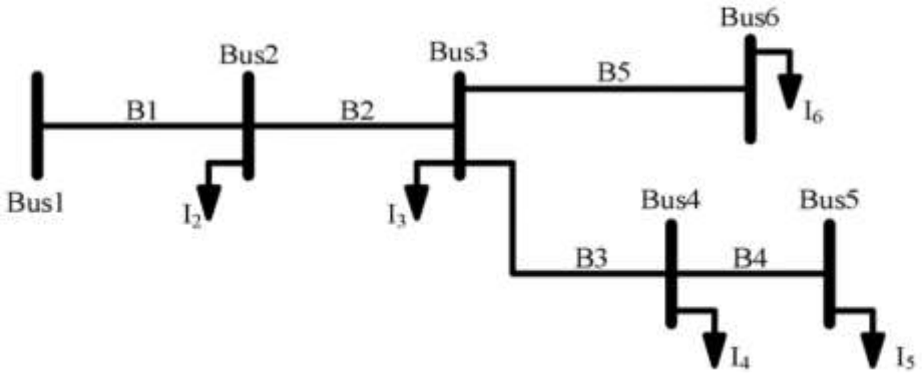

Figure 1 : Simple Radial Distribution system

$$P_{i,k\ Losses} = \left|I_{B\ \ i,k}\right|^2 * \mathcal{R}(\overline{Z_{B\ \ i,k}}) \quad (10)$$

$$Q_{i,k\ Losses} = \left|I_{B\ \ i,k}\right|^2 * \Im(\overline{Z_{B\ \ i,k}}) \quad (11)$$

Suppose a single-source RDS with a number of N_L branches and a DG must be placed at node i and α is a set of branches connected between the source and node i.

$$P_{D\_i}^{with\ DG} = P_{D\_i}^{no\ DG} - P_{G\_i}^{DG} \quad (12)$$

$$Q_{D\_i}^{with\ DG} = Q_{D\_i}^{no\ DG} - Q_{G\_i}^{DG} \quad (13)$$

Where P_{D_i} and Q_{D_i} are the active and reactive power demanded at the node to which a DG unit is placed. $P_{G_i}$is the active power supplied and $Q_{G_i}$is the reactive power supplied or withdrawn from the systems by the DG

2.2. Coordinated control of OLTC and D-STATCOM

a- OLTC action

Figure 2.a shows the working ranges of the OLTC action. OLTC action is offered as a method of controlling the main voltage in steady state. It handles 0.05 p.u of the voltage violation and the rest of the voltage violation is suppressed by D-STATCOM

b- D-STATCOMaction

D-STATCOM regulates the system voltage based on a defined reference voltage (Vref) and maintains the voltage at this value as shown in Figure2.b. Within the allowed range of voltage variations, there is no need for a D-STATCOM response, two different reference voltages must be defined for the D-STATCOM according to the upper and lower voltage limits (1.05 and 0 , 95 pu). However, in this situation, there is no chance for the participation of the OLTC action because D-STATCOM always removes voltage violations quickly and OLTC cannot work. In order to solve this problem, another reference voltage must be considered for the D-STATCOM.

When the voltage of the regulated point (Vt) is between the predefined limits, then Vref of D-STATCOM is considered to be equal to the voltage of the regulated point. In this way, the D-STATCOM keeps its exchanged reactive power unchanged and since there is no fixed reference value for the D-STATCOM, the OLTC with its timer can start to act in order to decrease the output of the D -STATCOM.

The operating conditions of D-STATCOM based on the proposed reference voltages are summarized below:

$$\text{if } V_t > 1.05 \text{Then} V_{réf} = 1.05 \quad (14)$$

$$\text{if} 0.95 \leq V_t \leq 1.05 \text{then} V_{réf} = V_T \quad (15)$$

$$\text{if} V_t < 0.95 \text{then} V_{réf} = 0.95 \quad (16)$$

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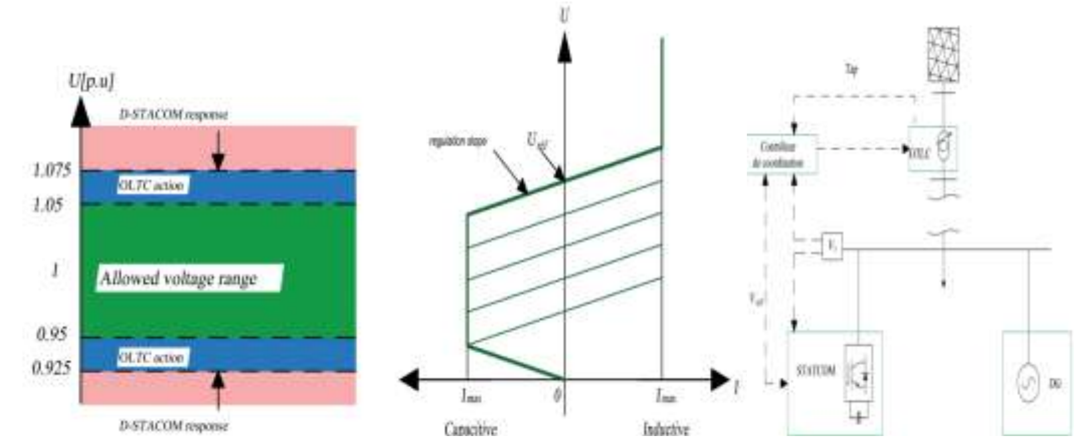

(a) (b) (c)

Figure 2: Coordination controller signal diagram

c- OLTC operating condition and dead band

The OLTC action starts when Vt> 1.05 or Vt<0.95 and stops when Vt increases to 0.952 or Ut falls to 1.048 pu. As can be understood, when the voltage exceeds the allowable range, D-STATCOM and OLTC are triggered to act at the same time but with different response times. After completing the rapid response of D-STATCOM, the working conditions of the OLTC are still kept because its starting condition is when Ut is equal to or greater (or less) than the allowed limits. Thus, the OLTC can continue to operate in order to reduce the output of D-STATCOM until such time as its shutdown conditions are triggered.

The dead band of the OLTC action is considered equal to the allowed voltage range (± 0.05 p.u). Thus, if the voltage of the connected bus DG is within the authorized range, the OLTC will not act. When the voltage of the regulated point exceeds the allowable range, with the forced limitation (because it is not really the normal limitation of the OLTC mechanism) of the OLTC (± 2.5%), it changes the voltage of the point of send in order to adjust the end point voltage of the start.

2.3 OBJECTIVES FUNCTIONS

Here, the objective is to accomplish two objectives:
1. Minimize the total loss of active power, $P_{Tlosses}$;
2. Minimize the voltage deviation, VD.

The total active power loss function of the network is given by:

$$P_{Tplosse} = \sum_{i,k=1}^{N_B} \left|I_{B\ i,k}\right|^2 * \mathcal{R}(\overline{Z_{B\ i,k}}) \quad (17)$$

The voltage deviation function is expressed as:

$$V_D = \sum_{k=1}^{N_B} V_k - V_k^{ref\ 2} \quad (18)$$

Where V_k and V_k^{ref} are the voltage values in per unit (p.u) to the k bus and the reference bus respectively.
The multi objective function J can be formulated mathematically:

$$min\, J = min(\omega_1 P_{Tlosse} + \omega_2 V_D) \quad (19)$$

Constraints:

(i)Equality constraints

$$\sum_{k=1}^{N_B} (P_{Gk} - P_{Dk}) = P_l \quad (20)$$

$$\sum_{k=1}^{N_B} (Q_{Gk} - Q_{Dk}) = Q_l \quad (21)$$

Where indices **Gk**, **Dk** and **l** denote respectively the power generated, requested and the losses at the bus k,

(ii) Inequality constraints

$$V_k^{min} \le V_k \le V_k^{max} \quad (22)$$

$$Q_n^{min} \le Q_n \le Q_n^{max} \quad (23)$$

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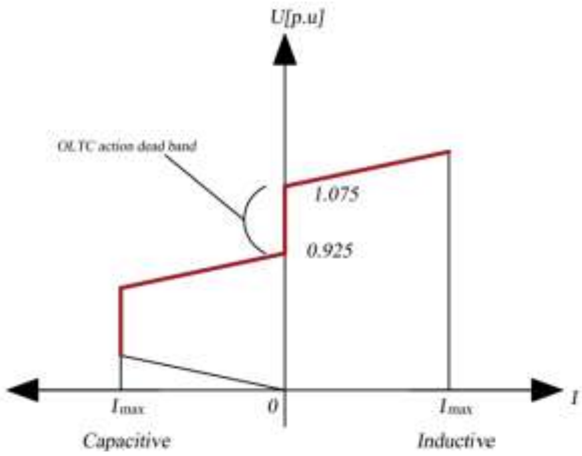

Figure 3 : Proposed V-I characteristic of D-STATCOM

III. BASIC CONCEPTS

3.1 BACTERIAL FORAGING ALGORITHM (BFA)

The BFA is nature inspired algorithm developed based on four principal behaviours of Escherichia Coli (E. Coli) bacteria [10].

(1) Chemotaxis:

It explains the procedure in which the bacteria conduct their movements over alandscape of nutrients. The i-th bacterium movement is performed by:

$$\boldsymbol{\theta^i}_{\mathbf{j+1,k,l}} = \boldsymbol{\theta^i}_{\mathbf{j,k,l}} + \mathbf{C_i}\boldsymbol{\emptyset}_{\mathbf{i}} \qquad (24)$$

Where:

$\boldsymbol{\theta^i}_{\mathbf{j,k,l}}$: location of the i-th bacterium at the j-th chemotactic step, k-th reproductive, l-th elimination and dispersion,

$\mathbf{C_i}$: length of the walking unit

$\boldsymbol{\emptyset}_{\mathbf{i}}$: angle of direction of the y-th step

The fitness function of the i-th bacterium is determined based on its position and is represented by J= J i, j, k, l. The direction angle ϕi describes the tumble of the bacteria as:

$$\boldsymbol{\emptyset}_{\mathbf{i}} = \frac{\boldsymbol{\Delta}_{\mathbf{i}}}{\sqrt{\boldsymbol{\Delta^T}_{\mathbf{i}}\boldsymbol{\Delta}_{\mathbf{i}}}} \qquad (25)$$

$\boldsymbol{\Delta}_{\mathbf{i}}$: is a randomly generated vector with elements in the interval [-1,1]

$\mathbf{T}$:transposition

(2) Swarming:

The attractive and repellent effects of each bacterium are used as a means of communication with the others. Bacteria in stressful circumstances release attractants to signal bacteria to gather, while repellents are released to signal others to keep a minimum distance. Cell-to-cell signalling of bacteria can be represented by

$$\mathbf{J_{cc}} = \left(\boldsymbol{\theta}, \mathbf{P}(\mathbf{j}, \mathbf{k}, \mathbf{l})\right)$$

$$\mathbf{J_{cc}} = \sum_{\mathbf{i=1}}^{\mathbf{S}}\left[-\mathbf{d_{attract}}\mathbf{exp}\left(-\boldsymbol{\omega}_{\mathbf{attract}}\sum_{\mathbf{m=1}}^{\mathbf{p}}(\boldsymbol{\theta}_{\mathbf{m}} - \boldsymbol{\theta^i}_{\mathbf{m}})^2\right)\right] + \sum_{\mathbf{i=1}}^{\mathbf{S}}\left[-\mathbf{h_{repellant}}\mathbf{exp}\left(-\boldsymbol{\omega}_{\mathbf{repellant}}\sum_{\mathbf{m=1}}^{\mathbf{p}}(\boldsymbol{\theta}_{\mathbf{m}} - \boldsymbol{\theta^i}_{\mathbf{m}})^2\right)\right] \qquad (26)$$

whereJcc = (0, P (j, k, l)) is the fitness function to be added to the actual fitness function, S is the number of bacteria, p is the number of variables to be optimized. 0 = [01 02 ... 0p] T represents a point in the dimensional research field, d- attract and w- attract are the depth and width of the released attractant respectively, while h-repellent and w-repellent represent the height and width of the repellent respectively. The suitability of each position is determined using:

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$$\mathbf{J}(\mathbf{i},\mathbf{j},\mathbf{k},\mathbf{l}) = \mathbf{J}(\mathbf{i},\mathbf{j},\mathbf{k},\mathbf{l}) + \mathbf{J}_{\mathbf{cc}}\big(\boldsymbol{\theta},\mathbf{P}(\mathbf{j},\mathbf{k},\mathbf{l})\big) \quad (27)$$

(3) Reproduction:

The idea behind reproduction in E. coli bacteria is that nature tends to eliminate animals with poor feeding strategies and retain those with better strategies. After the Nc chemotaxis steps, the reproduction step should be performed by sorting the health of all bacteria according to the physical form described by a fitness function:

$$\mathbf{J}^{\mathbf{i}}{}_{\mathbf{sant\acute{e}}} = \sum_{\mathbf{j}}^{\mathbf{N_c+1}} \mathbf{J}(\mathbf{i},\mathbf{j},\mathbf{k},\mathbf{l}) \quad (28)$$

Sr bacteria (the population of bacteria divided into two equal halves) with the least health due to insufficient nutrient eventually die due to insufficient food die by following, leaving the healthiest to divide into two similar bacteria and position in the same place.

(4) Disposal and dispersion

The process of elimination and dispersion is carried out after N_{re} stages of reproduction; this in order to avoid being involved in local optimums. Each bacterium is subject to elimination and dispersion in the environment according to a P_{ed} probability.

N_{el} is the number of elimination and dispersion steps. If a bacterium is then eliminated, it is dispersed to a new (random) location in the nutrient environment in order to maintain the original population of bacteria

3.2 ORGANIZATIONAL CHART AND STRUCTURING OF BFA

The flowchart for the execution of the BFA presented by [2] is set out below.

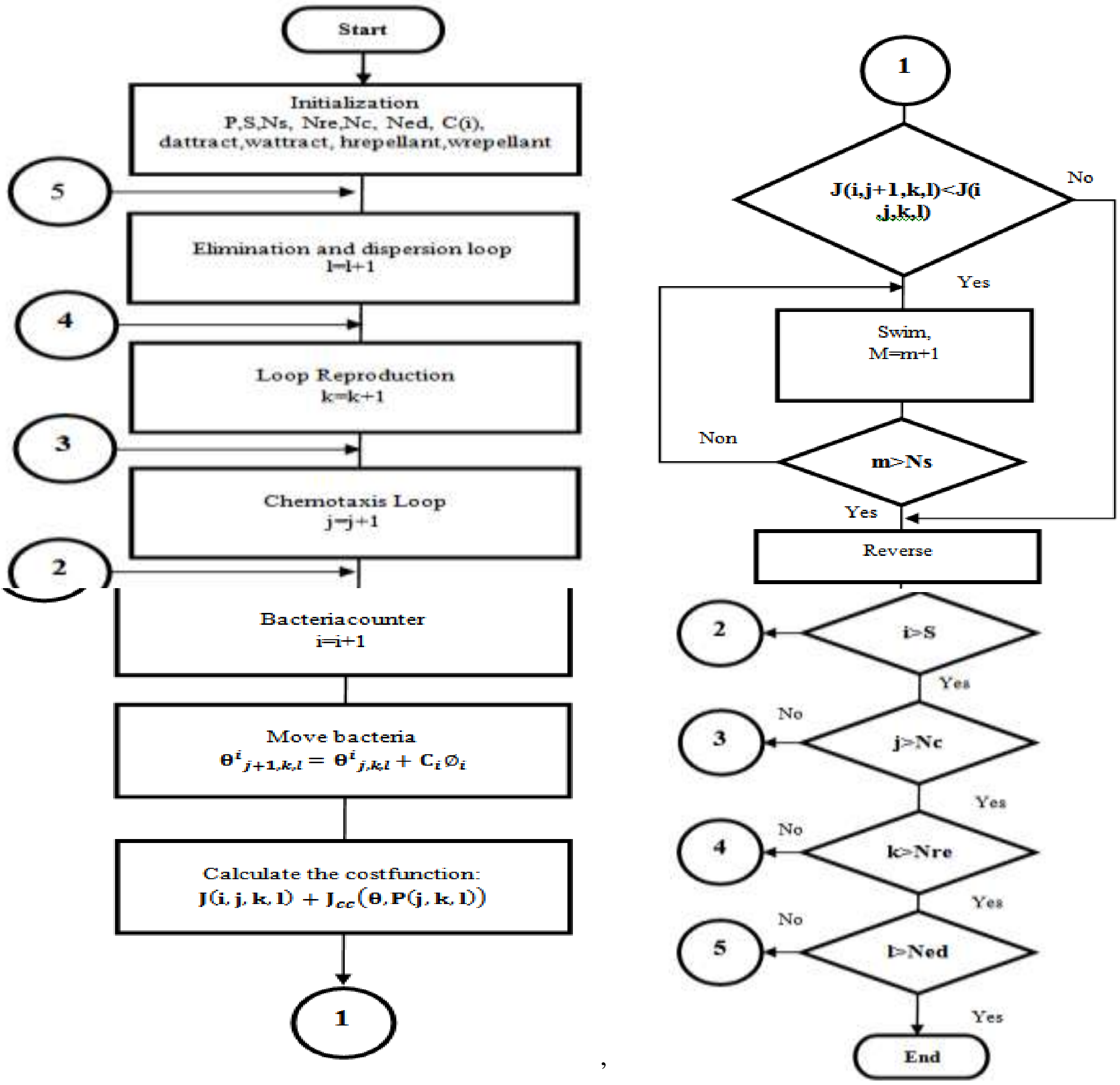

Figure 4 : BFA flow chart

3.3 Improved BFA.

The literatures have proposed several improvements to the BFA in order to improve its performance by reducing the complexity of the algorithm and the computational time. This publication uses the IBFA as proposed by [2].

To mitigate the inconvenience of complexity and high compute time associated with BFA, two parameters should be considered:

1. Unit of journey length Ci; and
2. Cell-to-cell signaling mechanism Jcc Θ, P j, k,l used for swarming.

The quadratic adaptive BFA (QABFA) uses the quadratic function to update the journey length unit. The unit of runway length is therefore formulated as follows [2]:

$$C_q(i) = \frac{C_{max}}{1 + \frac{\alpha}{\beta|J(i)|^2 + |J(i)|}} \tag{29}$$

$C_q(i)$ is a quadratic adaptive path length for each bacterium

3.4 Optimization of Placement and Sizing of D-STATCOMs by IBFA

This section presents the application of IBFA for the placement of D-STATCOM through a step-by-step methodology. Indeed, the placement and the dimensioning of the device is a problem of optimization of nonlinear system.Figure 5 shows the algorithm flowchart of the steps involved in the implementation of IBFA.

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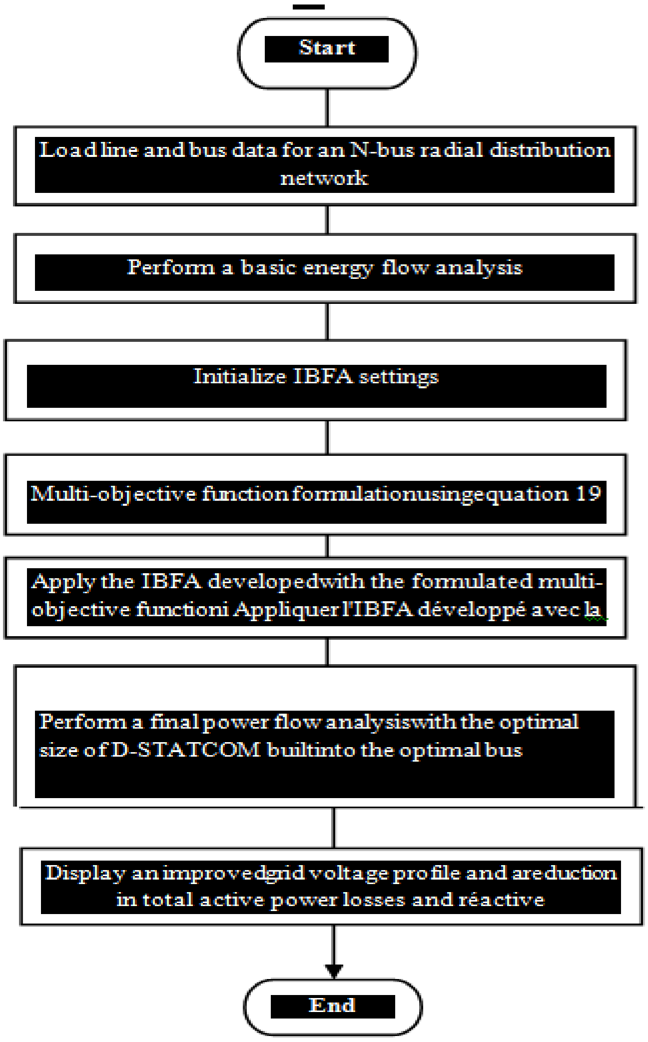

Figure 5 : Flow chart of power flow with incorporation of D-STATCOM

IV. MATERIALS AND METHODS

4.1 Test Network

(1)In order to verify and validate the coordinated control of the OLTC, and STATCOM, the standard 5 node RDR has been reduced to a simplified system which is shown in Figure 6a. The OLTC mechanism is installed on the secondary side of the secondary. The DG produces intermittent energy with a unity power factor. It is assumed that there is no exchange of reactive power between the DG and the network. The parameters of the system are as follows:

- Conductor impedance of each section: 0.5 + j 0.5
-Nominal value of each load: 1 MW, with a deceleration power factor equal to 0.9.
- DG rated power: 5.1 MW
- Nominal system voltage: 5 kV

(2)In order to evaluate the effectiveness of the BFA for optimal placement and sizing of D-STATCOM in RDS, the distribution network derived from the IEEE standard 34-bus x 2 is used (figure 6b). Part of the Antananarivo Interconnected Network (RIA) distribution network, reduced to 50-bus, in the Antananarivo Atsimondrano area was considered for the implementation of the proposed technique (Figure 6c).

4.2 Typeof Decentralized Production Used

Type 0: DGs which do not participate in the P and Q adjustment
Type 1: the DGs which only contribute to the adjustment of the active power P,

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Type 2: DGs which only contribute to the reactive power Q adjustment,
Type 3: DGs that can contribute to both P and Q

4.3 SCENARIO AND NETWORK CONFIGURATION TESTED

To avoid saturating the study, since there are 64 possible disposition cases if the DGs participate in the adjustments, the scenarios are limited to 04 representative cases (Table 2):

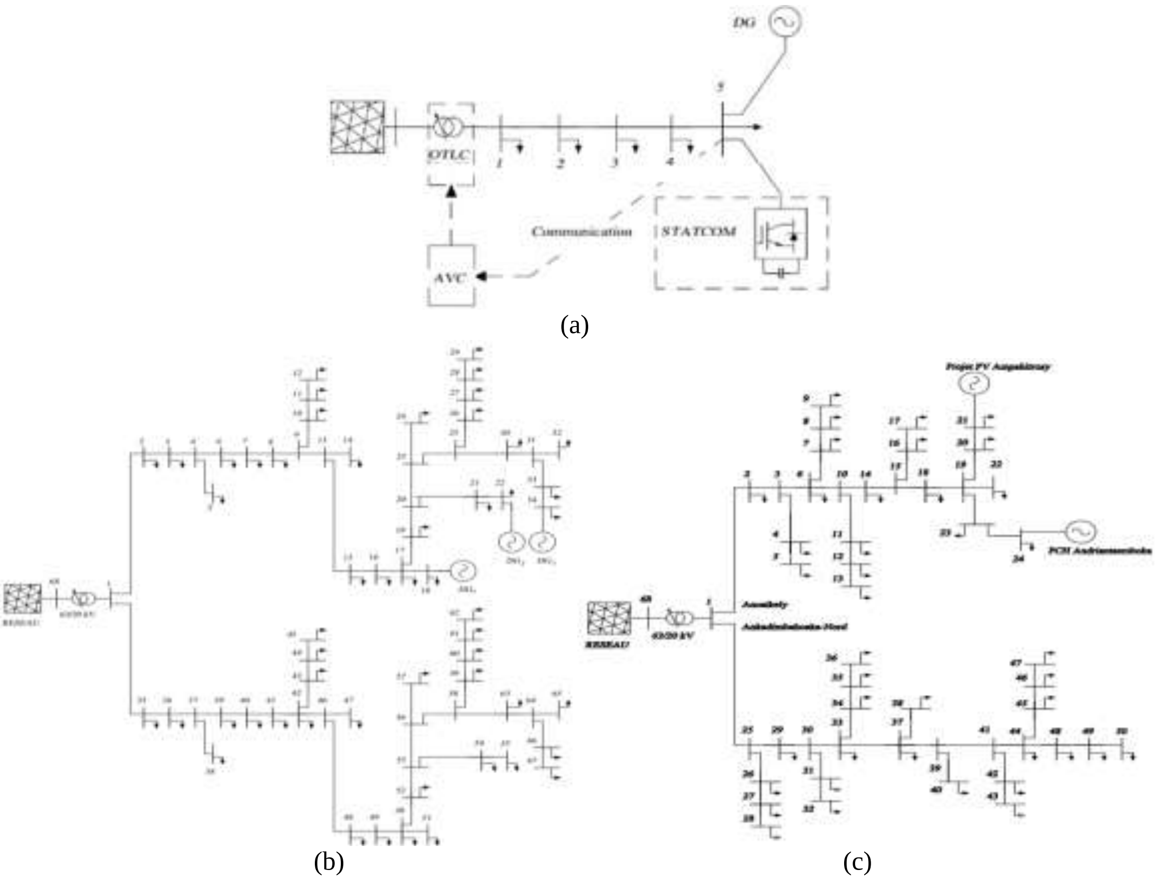

Figure 6 : Test Network

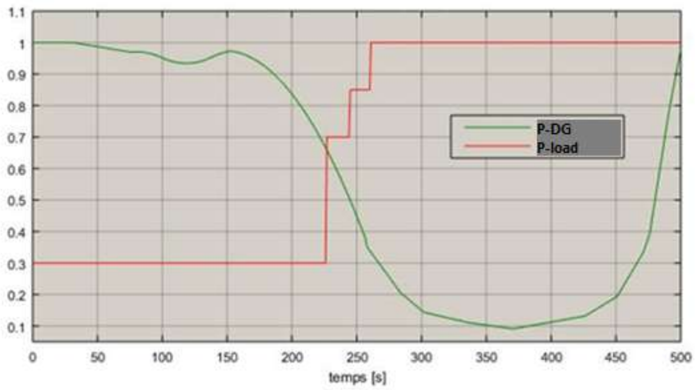

Figure 7 : Power produced and load in p.u.

Table 1 : Characteristic of DGs in 68-bus network test

	Technology	Location bus	Pmax (Peak) in MW

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DG1	Wind farm	18	3
DG2	Solar power plant	22	2
DG3	Small hydroelectric power station	34	4

Table 2 : Configuration scenario and combination of DGs in 68-bus network test

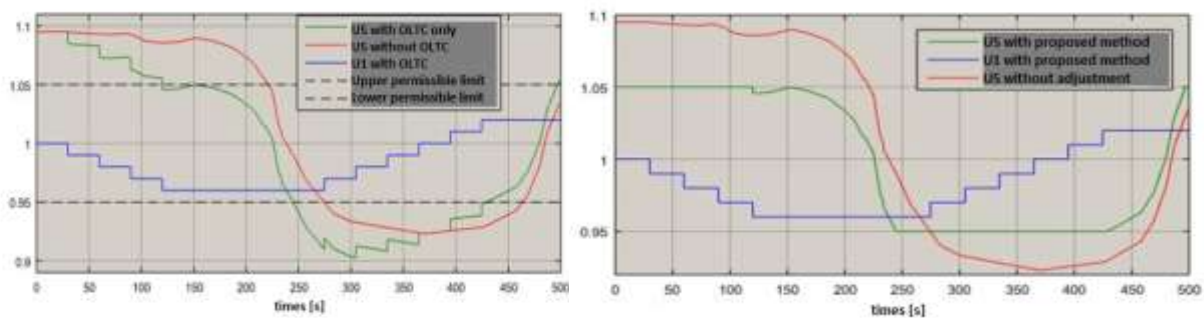
Scenarios		**Sub-scenario**	**DG1**	**DG2**	**DG3**
Sc.0	Without adjustment		Type 0	Type 0	Type 0
Sc.1	OLTC+D-STATCOM adjustment		Type 0	Type 0	Type 0
Sc.2	OLTC+D-STATCOMs+DGsadjustment	Cas 1	Type 1	Type 0	Type 0
		Cas 2	Type 2	Type 1	Type 1
		Cas 3	Type 3	Type 0	Type 2
		Cas 4	Type 3	Type 3	Type 3

Table 3 : IBFA settings

Parameters.	**Value**
Dimension of the researchspace, p	2
Number of bacteria, S	10
Number of chemotacticsteps, Nc	4
Number of swimmingsteps, Nc	4
Number of breedingsteps, Nre	4
Number of elimination-dispersion steps, Ned	3
Stroke length unit, C i	0,1
Number of reproductions of bacteria (splits) per generation. Sr	S / 2
Probabilitythateachbacteriumwillbeeliminated / dispersed, Ped	0,25
Depth of attraction, dattarct	0,1
Attraction width, ωattract	0,2
Repellentheight, h plump	0,1
Repellentwidth, ωrepul	10
Tunable factor, α	1
Scale factor, β	0,01

V. TEST RESULT

5.1 Coordinated control of OLTCandSTATCOM



(a) **(b)**

Figure 8 : Voltage at bus 01 and 05 (a)with OLTC setting only, (b)with coordinated adjustment

5.2D-STATCOM size and Location

Table 4 : Location and size of D-STATCOM, Power losses in the 68-bus network, MP: Proposed method, CF: Ant colonies optimization, PSO: Particle swarms' optimization.

Scenarios	**Location D-STATCOM (bus)**			**D-STATCOM size (MVAr)**			**Total losses. P [kW]**			**Q [kVAr]**			**iterations times [second]**		
	PM	AC	PSO	PM	AC	PSO	PM	AC	PSO	PM	AC	PSO	PM	AC	PSO
Sc.0	-	-	-	-	-	-	**253,00**	253,00	253,00	**171,50**	171,50	171,50	**-**	-	-
	18	18	18	**1,453**	1,497	1,504									
	22	22	22	**1,925**	1,973	1,983									
Sc.1	**34**	34	34	**1,937**	1,976	1,985	**121,23**	127,72	123,52	**42,92**	45,33	43,72	**1 490**	1 475	1 440
	52	53	50	**0,854**	0,885	0,871									
	63	64	63	**0,985**	1,017	0,990									
	18	18	18	**1,307**	1,346	1,353									
	22	22	22	**1,925**	1,973	1,983									
Sc.2 / Cas 1	**34**	34	34	**1,937**	1,976	1,985	**30,54**	32,17	31,12	**21,60**	22,81	22,00	**2 160**	2 080	1 980
	52	53	50	**0,854**	0,885	0,871									
	63	64	63	**0,985**	1,017	0,990									
	18	18	18	**0,871**	0,897	0,901									
	22	22	22	**1,732**	1,775	1,784									
Sc.2 / Cas 2	**34**	34	34	**1,743**	1,778	1,787	**29,01**	30,56	29,56	**21,36**	22,56	21,75	**2 280**	2 190	2 100
	52	53	50	**0,854**	0,885	0,871									
	63	64	63	**0,98**	1,0	0,99									

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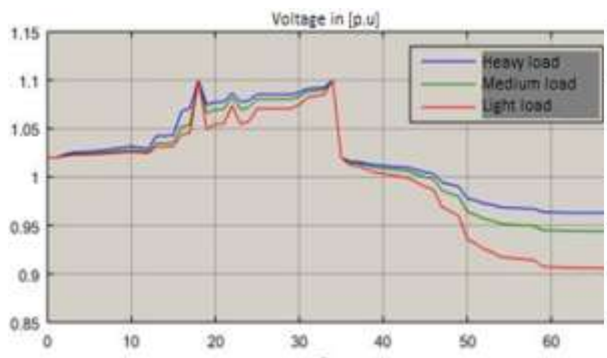
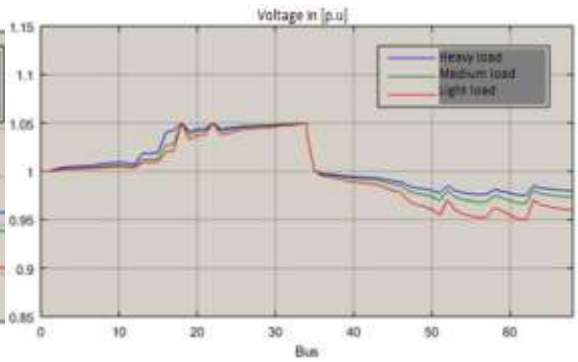
				5	17	0									
	18	18	18	**0,784**	0,808	0,811									
	22	22	22	**1,925**	1,973	1,983									
Sc.2 / Cas 3	**34**	34	34	**1,162**	1,185	1,191	**24,80**	26,13	25,27	**18,26**	19,28	18,60	**2 340**	2 310	2 160
	52	53	50	**0,854**	0,885	0,871									
	63	64	63	**0,985**	1,017	0,990									
	18	18	18	**0,653**	0,673	0,676									
	22	22	22	**0,885**	0,907	0,912									
Sc.2 / Cas 4	**34**	34	34	**0,910**	0,928	0,933	**19,84**	20,90	20,21	**14,61**	15,43	14,88	**2 520**	2 485	2 280
	52	53	50	**0,854**	0,885	0,871									
	63	64	63	**0,985**	1,017	0,990									



(a)



(b)

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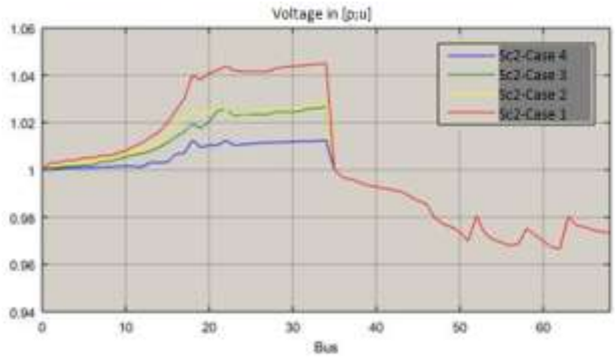


(c)

Figure 9 : Voltage profile in the 68-bus system: (a) without adjustment, (b) OLTC and DSTATCOM only (c) OLTC, DSTATCOM and DGs coordination adjustment with different DG type cases

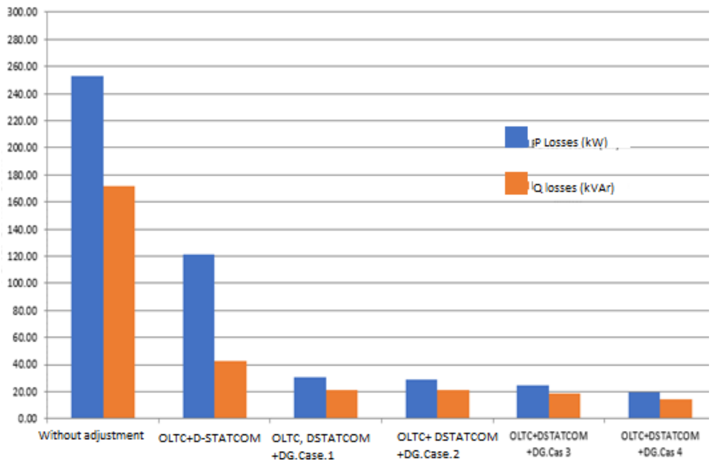
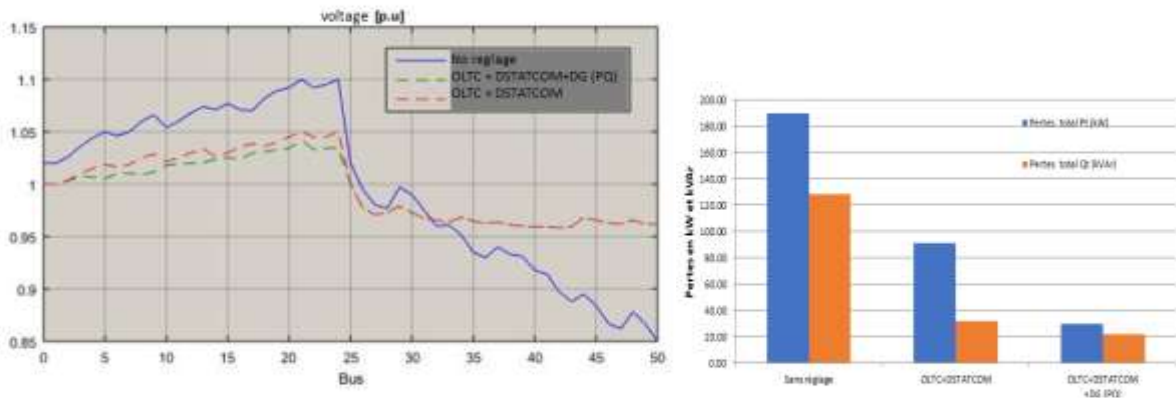


Figure 10 : Loss in the 68-bus system with different cases



(a) **(b)**

Figure 11 : JIRAMA 50-bus tests results: (a) without adjustment, (b) OLTC and DSTATCOM only

From the test results, first of all, it is observed that the sizes and the locations of DSTATCOM on 68 buses the networks are roughly identical and confused for the 03 compared methods. Second, it is clearly shown that the system voltage magnitudes have been improved; losses are reduced with inclusion of D-STATCOM. With regard to modified IEEE 34-bus system, BFA obtains 5,35% loss reduction compared to AC value reported [1] for the same test system and

1,89% loss reduction compared to PSO value reported [11],for the same test system.

VI. CONCLUSION

In this paper, first,a coordination method of OLTC and D-STATCOM for the regulation of voltages in an RDS has been developed. The coordination method was developed on the basis of the combination of the reference voltage, the dead band and the time delay. The proposed coordination method provides a reasonable recovery time for the system voltage while minimizing the number of operations. The results proved that the proposed method is flexible to coordinate the control actions of different regulators and DGs to control the supply voltage.

Second, we solve the problem of sizing and optimal location of DSTATCOM in radial power distribution networks. The allocation and sizing of DSTATCOM in the RDS is used to compensate active and reactive power, which helps to reduce system power loss and improve the voltage profile.It is essential to place DGs and DSTATCOMs in ideal locations with optimal sizes to ensure proper functioning of the system. In this work, a new approach using the BFA was used to find the optimal DSTATCOM locations in the RDS.

The proposed method is applied to the IEEE 2x34-bus modified radial distribution system as well as to an existing 50-bus RDS of the Malagasy Electricity Company (JIRAMA), with different cases. The simulated results obtained using BFA were compared to other existing AC and PSO techniques, and the results show that the performance of the proposed method for minimizing power loss and maximizing voltage profile is better than other existing methods even if the computation time is slightly longer than the other two methods. it can be concluded that the proposed method can be easily applied for any real system.

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