Allocation Of The DSTATCOM In The Distribution System

Aliasghar Baziar, Mehdi Nafar, Khodakhast Esapour, Mahsa Yazdani, Mohammad-Reza Akbari-Zadeh

Abstract: Through this article, a novel random structure is depicted to shape the uncertainty result of the active and reactive loads in the DSTATCOM allocation and problem in sizing. The planned technique has 2m+1 point approximation method (PEM) to capture the random associated with the anticipated fault of the loads. The aims are minimization of the entire active power losses which lessen the voltage nonconformity of the buses. A new optimization procedure on the root of the bat algorithm (BA) is confirmed to explore the problem galaxy universally. In addition, the clue of interactive fuzzy sufficient method is useful in the multi-objective preparation in providing a suitable stability between the optimization of the objective roles. Lastly, the proposed method will be examed on the 69-bus IEEE distribution system to settle its likelihood and effective presentation.

Keywords: DSTATCOM Allocation, Uncertainty, Multi-Objective Optimization, 2*m*+1 Point Estimate Method.

1. Preface

The distribution systems have noteworthy purpose in the failure statistics or inaccessibility of power at consumer's clearance. Hence, the viable markets growth the request of plans or methods which can advance the total condition of the distribution systems. Thus, so that to maximize the obtained efficiency and revenue; any options should be inspected correctly. In this issue, fresh procedures are under examination by the utilities to advance the total system electrical services from both operation and planning perspectives. The most noticeable and popular techniques can be recognized as: the best management of the shunt capacitors, push apparatuses, automatic voltage device, series capacitors or freshly spreading network elastic AC diffusion system (D.F.A.C.T.S) skills such as scattering static compensator (DSTATCOM) [1]. In the vigorous educations, swapping in the structure causes some effective issues such as echo or provisional harmonics in certain typical reactive power loots structures like plunge capacitor settlement policy or series capacitors while the DSTATCOM is free from these types of operational grades. DSTATCOM will expand the worth of the electrical facilities by successful the sparkle stoppage, voltage parameter and voltage matching in the power quality [2]. Other useful properties for example short power deprivations, high governing skill and minor scope, low melodious output, make DSTATCOM a superior trick among other irritable power compensation devices [3]. Likewise, DSTATCOM is intelligent to washing up the voltage from any distort or melodious falsification [4]. Truly, as the cargo claim varies in the system, the DSTATCOM is proficient to reimburse the cargo claim locally and it is measured robotically. As the years go by, with growth of the whole load consumption in power systems, the efficiency of the DSTATCOM to magnify the power method loadability, solidity and responsive power recompense is more showed too. Simply, it is drawn deduction from the overhead argument that the DSTATCOM maneuver has a important key role in the optimum operation and organization of the imminent dispersal networks. One of the most vital subjects in the efficacy zone is to decline the capacity of M.W control harms by diminishing the resisting harms [5-8]. We witness an enhancement in the network control value by refining the voltage of the buses, which can progress the electrical services by shrinking the charge of destructive delicate electrical strategies and also sinking the number of disruptions in the system. In several papers the significance of this dispassionate purpose can be seen [9-11]. Clarifications which can be depicted from what are covered above; there is a bit of effort existing in the field of DSTATCOM provision to demonstrate its outcomes on the scattering network from numerous facts of view. By taking the independent functions of vigorous control harms and voltage profile into attention concurrently, the author judged the DSTATCOM distribution problematic in [12]. Nevertheless, overlooking the hesitation with the vigorous and responsive loads, clues to reduction in the constancy of the final results is a vast shortage of the examinations [14]. To decline the effect of the voltage variations in the network, maximum production of the DSTATCOM sharing and sizing is under examination. Coextensive effects of the spreading generation (D.G) on the optimum DSTATCOM distribution are evaluated while the hesitation of the accidental variables is overlooked in this paper. Further, paper expressions a new stochastic construction according to 2m+1 point approximation method (P.E.M) to capture the indecision connected rendering the active and irritable heaps in the examination. The stochastic DSTATCOM distribution tricky is renewed into 2*m*+1 same deterministic difficulties with unlike possibilities in the optional stochastic process. The proposed process mockups the vagueness of the loads by seeing the ordinary spreading meaning with zero means value. The entire active power victims and the voltage outline are measured as the impartial functions in the examination. Regardless of, a fresh cooperative fuzzy sufficient process recommends dealing with mutually of the objective meanings. Attention of the hesitation of the active and reactive lots lead to composite and nonlinear maximum production problem which increase the necessity of more influential instrument to drip deceiving in local optima and also early union. Therefore, a fresh optimization scheme based on revised bat algorithm (M.B.A) is suggested to discover the pursuit zone in a universal method. The recommended technique is experienced on the 69-bus IEEE circular spreading classification to validate its effectiveness and adequate ultimate. The rest of this paper is prepared as follows: sector 2 defines the objective

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functions and the related restraints. In sector 3, the DSTATCOM modeling is being categorized. In sector 4 defines the 2*m*+1 PEM totally. In sector 5, the optimization method and the multi-objective origination are being defined. The simulation consequences are designated in sector 6. Finally, sector 7 discourses the core observations and conclusions.

2. Disputable Preparation: Formulation

The objective purposes and the associated equivalence and difference restrictions will represent in this sector entirely.

2.1 - Independent Purposes

-**Minimization of the voltage nonconformity:** weakening the supreme voltage aberration of the buses from the minimal voltage value can root an development in the voltage profile of the system as follows:

$$f_1(X) = d_{volt}(X) = \max\{|1-V_{\min}|, |1-V_{\max}|\} \quad (1)$$

Which $V_{\min}$ and $V_{\max}$ are the lowest and the maximum cost of voltage size of i^{th} bus individually.

- Reduction of the vigorous power losses: By outline of the opposed power damages of the network divisions the vigorous power damages objective role can calculate as under:

$$f_2(X) = P_{loss}(X) = \sum_{i=1}^{N_{br}} R_i \times |I_i|^2 \quad (2)$$

In the overhead comparison, *X* is the regulator vector, R_i is the confrontation of i^{th} division, I_i is the current of i^{th} division and N_{br} is the amount of divisions.

1.2- Limits and Restraints

- Supreme transmission control: Limits related to the supreme power transmission ability of the distribution lines are stated as survey:

$$|P_{ij}^{Line}| < P_{ij,\max}^{Line} \quad (3)$$

Which P_{ij}^{Line} is the active control stream over the spreading lines of buses *i* and *j* and $P_{ij,\max}^{Line}$ is the supreme active control stream that is acceptable to flow among the buses *i* besides *j*.

-Power flow equivalences: This limitation contains of dual power stream calculations which can be engaged into attention as an equivalence limitation.

$$P_i = \sum_{i=1}^{N_{bus}} V_i V_j Y_{ij} \cos(\theta_{ij} - \delta_i + \delta_j)$$
$$Q_i = \sum_{i=1}^{N_{bus}} V_i V_j Y_{ij} \sin(\theta_{ij} - \delta_i + \delta_j) \quad (4)$$

In the limitations, V_i determines the voltage magnitude of i^{th} bus, θ_{ij} appearances the admission angle among the buses *i* besides *j*, δ_i means the voltage angle of i^{th} bus, Y_{ij} is the admission magnitude between the buses *i* and *j*, N_{bus} is the number of buses. P_i and Q_i is the net active and reactive power instillation to the i^{th} bus.

- Feeder existing restriction: The main feeders Provide a maximum recent cost in the network as under:

$$|I_{f,i}| \le I_{f,i}^{\max} \quad ; \quad i = 1, 2, ..., N_f \quad (5)$$

Which $I_{f,i}$ is the recent of the i^{th} feeder, $I_{f,i}^{\max}$ is the maximum recent of the i^{th} feeder then N_f means the quantity of feeders.

- Bus voltage limitations: During the optimization progression, the voltage near of the buses has to stay in the prearranged restricted interlude as monitors:

$$V_{\min} \le V_i \le V_{\max} \quad (6)$$

3. DSTATCOM Modeling

The Static Synchronous Compensator (STATCOM) is a portion of the Flexible AC Transmission Systems (FACTS) devices. This maneuver is a power controller value which is linked to the power system in shunt manner. As the DSTATCOM is being utilized in the voltage rank of spreading system, it should be entitled Spreading D.S.T.A.T.C.O.M. The DSTATCOM device functions below the control electronic voltage basis converters. In addition it can both consume and produce the reactive power of the electrical network at the coupling point. Also it can provide active power in the case of using a power source. In the D.S.T.A.T.C.O.M, a DC capacitor generates the voltage level. Accordingly, the degree of the voltage basis regulates the route and sum of reactive power. If the extent of the voltage source is higher than that of the joining point, the DSTATCOM can produce reactive power and work as a variable capacitor. Despite that, the DSTATCOM can exertion as a reactor and absorb reactive power while the magnitude of the voltage source is lesser than the voltage of the connection point. In the stable state examination, the inverter and the modernizer damages are balanced for D.S.T.A.T.C.O.M. theoretically, it is imaginary in the works that the load flow classical of the STATCOM is correct for the DSTATCOM device [12]. Moreover, the DSTATCOM is supposed to make a fresh power-voltage (PV) bus *j* through continuous voltage level. As an outcome of supposing no power source devoted to the D.S.T.A.T.C.O.M, it can just supply reactive power in the network. This intends that, the quantity of active power creation is theoretical to be zero. The series reactance and resistance R_T+jX_T are put to use to model the vigorous power losses of the transformer connection and the inverter [2]. Fig. 1 validates the diagrammatic figure of the model.

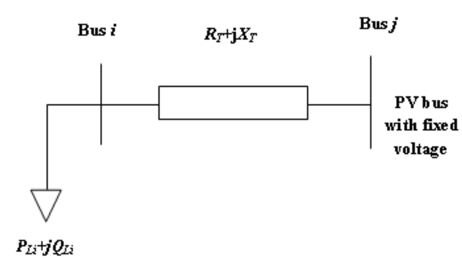

Fig. 1. *The schematic diagram of the DSTATCOM model connected to bus i [12]*

4. Improbability modeling by 2*m*+1

4.1. Background

To spot the engineering harms under vagueness, P.E.M is a resourceful recommendation which will entail a lesser computational load as opposed to Monte Carlo Simulation (MCS). In [13], the original P.E.M is a function of *m* accidental variables and involves 2^m procedures to guess the statistical moments of an accidental number. In [16], Hong tried to broaden the presentation of the original P.E.M method and obtainable the *Km* and *Km+1* scheme by dropping the digit of computations from 2^m to *Km* and *Km*+1 (The type of Hong's P.E.M scheme is firmed by the limitation K). This adjustment causes P.E.M to be an effective tool to handle the engineering problems with numerous accidental variables. In [15], Su approaches the power flow problem as a probabilistic problem by the use of the Hong's *2m* scheme for the first time. At later times, Morales [18] and Acromia [17] used 2*m*, 2*m*+1 and 4*m*+1 PEM schemes to find a technique for the probabilistic power stream difficult. Consequently, it can be derived that the *2m*+1 scheme awards the best answer from the correctness and computational exertions.

4.2. 2m+1 PEM Scheme

In Mathematic method, the deterministic power stream is labeled as below:

$$S = F(z) \qquad (7)$$

Which *S* is the set of yield variables? which is computed through the power flow function *F*(.) and *z* is the set of input variables comprising the network conformation, weight and scattered power generation.The main purpose in using the P.E.M is to estimate the moments of the production variables of attention (S_i) through the explanation of only a few deterministic power streams. This work affects the answer such that only rare numerical moments of input accidental variables are essential. Since *m* input random variables in the system, (7) can be changed as follows:

$$S_i = F_i(z_1, z_2, \ldots, z_m) \qquad (8)$$

Which z_l is a random variable with probability density function fz_l. The above equation must be calculated *2m+1* times where this reiteration is the consequence of *2m+1*schemes. It is clear from (7) that the *2 m +1* scheme uses the first four central moments of each random variable z_l which approaches its distribution by the means of three points named concentrations. The concept of *2m+1* PEM scheme is demonstrated in Fig. 2. As it is drawn in Fig. 1, the information of the variables $z_{l,1}$, $z_{l,2}$ and $z_{l,3}$ are altered into the variables $S_{l,1}$, $S_{l,2}$, and $S_{l,3}$ through the functional equation *S*=*F*(*z*). Moreover, to scale the three estimates of *S* variants ($S_{l,1}$, $S_{l,2}$, and $S_{l,3}$), the three weighting factors $\omega_{l,1}$, $\omega_{l,2}$ and $\omega_{l,3}$ are utilized. Each point or concentration consists of three pairs ($z_{l,k}$,$\omega_{l,k}$), *k*=1, 2, 3 where $z_{l,k}$ is the location factor and $\omega_{l,k}$ is the weighting factor. By taking the advantage of the mean ($\mu_{z,l}$) and variance ($\sigma_{z,l}$) of z_l, the three locations are calculated for each random variable z_l.

$$z_{l,k} = \mu_{z_l} + \xi_{z_{l,k}} . \sigma_{z_l} ; \quad k = 1,2,3 \qquad (9)$$

In the defined construction, $\zeta_{l,k}$ is the typical location measured as:

$$\xi_{l,k} = \frac{\lambda_{z_l,3}}{2} + (-1)^{3-k} \sqrt{(\lambda_{z_{l,4}} - \frac{3}{4}\lambda^2_{z_l,3})} , \quad k = 1,2 \qquad (10)$$
$$\xi_{z_l,3} = 0$$

Which $\lambda_{z_l,3}$ and $\lambda_{z_l,4}$ are the third and the fourth central moments of z_l individually. These parameters are distinct as coefficients of skewness and kurtosis as surveys:

$$\lambda_{z_l,3} = \frac{E[(z_l - \mu_{z_l})^3]}{(\sigma_{z_l})^3} , \lambda_{z_l,4} = \frac{E[(z_l - \mu_{z_l})^4]}{(\sigma_{z_l})^4} \qquad (11)$$

E is the anticipation operator.

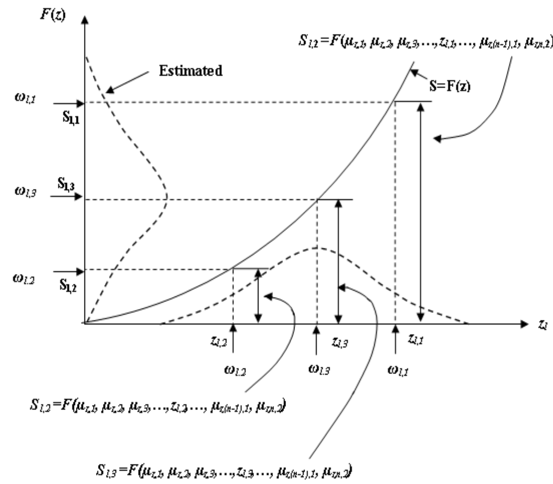

Fig. 2. *The concept of the 2m+1 PEM scheme*

The following formulation computes the weighting aspect $\omega_{l,k}$ related with the position $p_{l,k}$:

$$\omega_{l,k} = \frac{(-1)^{3-k}}{\xi_{l,k}(\xi_{l,1} - \xi_{l,2})} , \ k = 1,2$$
$$\omega_{l,3} = \frac{1}{m} - \frac{1}{\lambda_{z_{l,4}} - \lambda^2_{z_{l,3}}} \qquad (12)$$

IN each point, two couples of locations and weights ($z_{l,k}$,$\omega_{l,k}$,*k*=1,2) are calculated by putting (8) to (12) in use. Assuming that other variables are set at their mean cost, then the power stream is calculated for two places.

$$S_i(l,1) = F(\mu_{z1}, \mu_{z2}, .., z_{l,1}, ..., \mu_{zm}) \qquad (13)$$
$$S_i(l,2) = F(\mu_{z1}, \mu_{z2}, .., z_{l,2}, ..., \mu_{zm})$$

According to (9), the third place $z_{l,3}$ has zero standard location ($\xi_{z_l,3} = 0$). Essentially running power flow using the input variables set at their mean values.

$$S_\mu = F(\mu_{z1}, \mu_{z2}, .., \mu_{zl}, ..., \mu_{zm}) \qquad (14)$$

At this point that the key of the 3*m* power flow is explored using (13) and (14), the r^{th} order raw moment of S_i can be obtained as below:

$$E(S_i^r) = \sum_{l=1}^{m}\sum_{k=1}^{3}\omega_{l,k}.(S_{i(l,k)})^r = \sum_{l=1}^{m}\sum_{k=1}^{3}\omega_{l,k}.[F(\mu_{z1},\mu_{z2},..,z_{l,k},...,\mu_{zm})] \quad (15)$$

The certain clear point in (15) is that the m number of $3m$ places have the same point ($\mu_{z1},\mu_{z2},\ldots,\mu_{zm}$) which cause oversimplification of (15) as follow:

$$E(S_i^r) = \sum_{l=1}^{m}\sum_{k=1}^{3}\omega_{l,k}.(S_{i(l,k)})_r = \sum_{l=1}^{m}\sum_{k=1}^{2}\omega_{l,k}.(S_{i(l,k)})^r + [F(\mu_{z1},\mu_{z2},..,z_{l,3},...,\mu_{zm})^r]\sum_{l=1}^{m}\omega_{l,3} \quad (16)$$

Thus, $2m$ shots of power flow plus solitary one more run are required. Hence, in a system with m input accidental variables, the number of times to calculate power flow is $2m+1$ times. Once calculation of the mean and standard aberration of output accidental variables is ended through (16), the cumulative likelihood mass function can be obtained via Gram-Charlier series method [19].

5. Optimization Procedure

In recent years, several evolutionary created optimization procedures have been planned such as Particle Swarm Optimization (PSO) [20-21], teacher learning algorithm [22], cuckoo search procedure [23], shuffled frog leaping algorithm [24-25] and honey bee mating optimization algorithm [26-28]. Amongst this category, one of the most widespread procedures is BA.

5.1. Bat Algorithm

Xin-She Yang announced a innovative population grounded optimization procedure named bat algorithm (B.A) [29] in 2011. They (bats) have the talent of discovery food via the usage of echolocation. In fact, the process of transfer a hint to the atmosphere and getting its echo is definite as echolocation. The B.A simulates the probing actions of bat. This process is built on 3 key perceptions [29]:

I) The expanse is evaluated by the means of echolocation.

II) Each bat in probing galaxy is resulted by its position (X_i), flying speed of v_i, pointer occurrence fre_i, the wavelength λ_i and noise A_i;

III) The loudness A_i has the competency to change from the original large cost A_0 to its exact minimum value A_{min}. At first glance, the BA produces a random population. After that the objective meaning is estimated for each bat. Then, the whole population is updated and the updating process in each repetition k is expressed as follows:

$$fre_i = fre_{\min} + (fre_{\max} - fre_{\min})\rho$$
$$v_i^{k+1} = v_i^k + (X_i^k - X_{gbest})\, fre_i \quad (17)$$
$$X_i^{k+1} = X_i^k + v_i^{k+1}$$

Which ρ is a accidental number in the range [0,1], $fre_{\max}$ / $fre_{\min}$ are the maximum plus minimum values of the bat signal incidence correspondingly and v_i^k is the rate of the i^{th} bat in k^{th} reiteration. Likewise, there is additional method for apprising each bat. Hence, at first, a accidental value ($rand_i$) is caused for each bat such that a innovative test solution is utilized if $rand_i$ is bigger than the regularity ratio of the relevant bat r_i. The new solution is described as follows:

$$X_{new} = X_{old} + \varepsilon A^k \quad (18)$$

Which ε is a accidental number in the range [0,1]. The mentioned equation is similar to the particle cloud optimization (PSO) algorithm apprising process. So that if $rand_i$ has smaller amount in contrast to with r_i then a new test solution is generated randomly. However, the generated test solution is used under the following criteria:

$$[rand < A_i]\&[f(X_i) < f(X_{gbest})] \quad (19)$$

Which $rand$ is a random number in [0,1] and X_{gbest} is the bat with best objective function in the population. So that, in each of iterations, the process of apprising A_i^k besides r_i^k is as shadows:

$$A_i^{k+1} = \alpha A_i^k$$
$$r_i^{k+1} = r_i^0[1-\exp(-\gamma k)] \quad (20)$$

According to overhead preparations, α and γ are constant values for BA.

5.2. Modified BA (MFA)

Some advantages of the novel BA can be entitled as simple conception, cool operation, rapid conjunction, general claim, etc. The spite of that, in face of complex multi-objective optimization difficulties, an advance in the presentation of the process is required. This sector describes a fresh alteration on B.A which essentially purposes to increase the diversity of the B.A population. This method is simulated such that each bat transfers near the best global bat with its own speeding up. Farther, the nastiest bat in the population is confined through more acceleration than the bat with better position. Really, the factor parameter in discovery the acceleration drive of each bat is its distance from X_{gbest}. So, the suggested alteration is executed after updating the BA population. In each of reiterations, the Cartesian space for each bat X_i from the best bat in the populace X_{gbest} is considered as under:

$$D_{i,gbest} = \left\|X_{gbest} - X_i\right\| = \sqrt{\sum_{k=1}^{d}(x_{gbest,k} - x_{i,k})}$$
$$X_{gbest} = [x_{gbest,1}, x_{gbest,2}, .., x_{gbest,d}] \quad (21)$$
$$X_i = [x_{i,1}, x_{i,2}, .., x_{i,d}]$$

Which d is the distance of the regulator vector X. For X_{gbest}, an appeal parameter β is clarified as follows:

$$\beta = \beta_0 \exp(-D_{i,gbest}) \quad (22)$$

Where, β the appeal of a bat its distance is equivalent to zero. It is noticeable that the more distance of X_i since X_{gbest}, the lesser cost of the variable β is desirable. The monotonically reducing function of β is consequently. This construction conducts the updating method to scope a beneficial adjustment. Currently, the efficient place of the bat X_i is achieved as shadows:

$$X_{new} = \beta X_i + (1-\beta) X_{gbest} + u_k$$
$$u_k = \pi (rand(.) - \frac{1}{2}) \qquad (23)$$

The first two expressions are hired to mark a balance among the X_i besides X_{gbest} in the first design. In the pursuit space the, third word leads to a chance measure. Desirable, π , in the another balance, is the absorption factor which is used to confine the illumination lessening degree (light intensity).

5.3. Communicating fuzzy sustaining process

From what has been discussed, our examined difficult is a generous of multi-objective optimization tricky with several equivalence and inequality restraints. The environment conduct of the multi-objective optimization difficulties roots several developments in the objective purposes marks in extinguishing the optimum value of the other objective meaning. Now a enough multi-objective outline is documented upon communicating fuzzy sufficient process to handle together of the objective purposes subsequently. So that, the succeeding equation is working via the means of the fuzzy set theory:

$$F(X) = \min_{x \in \Omega} \left\{ \max_{i=1,\dots,n} \left| \mu_{ref,i} - \mu_{f,i}(X) \right| \right\} \qquad (24)$$

Which $\mu_{ref,i}$ is the sufficient step of $f_i(X)$, $\mu_{f,i}(X)$ is the fuzzy association function (trapezoidal membership function) and also the variable *n* shows the number of objective tasks. Using the overhead design will permit the workers to put on their favorites and skills to please each objective function separately.

6. Idea Process

In the following steps, the implementation of the proposed stochastic method on the DSTATCOM optimal distribution and sizing is clarified:

***Step* 1:** Fixed the idea data holding the network data, the DSTATCON data, the procedure data, etc.

***Step* 2:** Conversation the constrained Multi-objective optimization difficult via its equal unconstraint one.

***Step* 3:** Produce a random initial bat population. In the network each bat exposes a promising optimum place and scope for the DSTATCOM devices.

***Step* 4:** calculate the suitability role. In order to calculate the predictable assessment of the active power losses then the voltage deviation objective functions for each answer or bat, the stochastic load flow based on 2*m*+1 PEM is run in this step.

***Step* 5:** Appliance the collaborating fuzzy satisfying technique to alteration the multi-objective optimization problematic to the equal single objective one.
Besides, the involvement function worth of every objective role has been calculated now.

***Step* 6:** Classify the top bat in the population as X_{gbest}.

***Step* 7:** Apprise the bat populace as it was explicated in sector 5.1.

***Step* 8:** Put on the proposed modification as described and then apprise the whole population again in sector 5.2.

***Step* 9:** If the conclusion principle is pleased then stop, otherwise yield to step 6.

7. Simulation Results

In this sector refer to replication results of applying the planned scheme on the assessment system. From a part of P.G. &E distribution system which is nominated the suggested method is tested on the IEEE 69-bus radial distribution system. The token voltage of the system is 12.66 kV and the amounts of entire active and volatile loads which are supplied by the system are 3,802.19 kW and 2,694.59 kVar correspondingly. The sole line diagram of the test classification is shown in Fig. 3. The comprehensive data of the test structure can be found in [30]. Fifteen personalities are elected for the initial B.A populace. Due to, there is no development in the objective role charges after about 200 iterations, the termination criterion is fictional 200 iterations. To obligate well assessment the examination is functional for together the deterministic and stochastic frameworks.Also, 3 different states defined which are shown in the table:

State 1*:* *DSTATCOM assignment besides sizing for minimizing the active power losses.*

State 2*:* *DSTATCOM assignment besides sizing for minimizing the voltage deviation of buses.*

State* 3*: *DSTATCOM assignment besides sizing for minimizing in the proposed interactive fuzzy satisfying procedure*

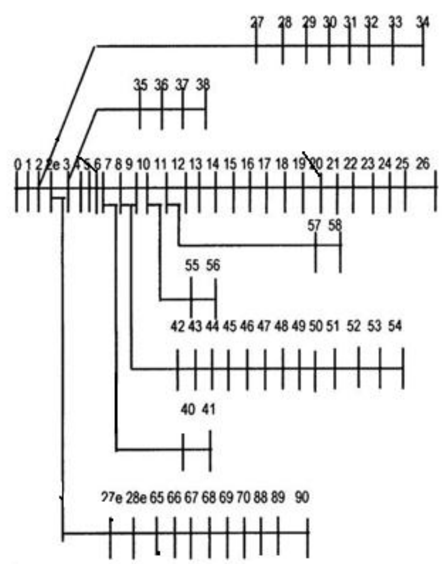

***Fig.3**. single line diagram of the test system*

So, two dissimilar operating conditions (OCs) are definite in the system to focus the positive effect of considering

DSTATCOM vividly. In the system, just one DSTATCOM is placed in the first OC while in the second OC two DSTATCOM s are assigned that the maximum bulk of each DSTATCOM is 3 MW. Table 1 demonstrates the results for the OC 1 as well as for all the three states in the deterministic agenda (neglecting the uncertainty effects).

***Table** 1: Results obtained by Optimal DSTATCOM allocation and sizing in the deterministic framework (OC 1)*

Items	Initial Condition	State 1	State 2	State 3
ActivePower losses (kW)	225.0	150.196936	269.204006	172.684083
Vmin (pu)	0.90944095	0.93092967	0.95514652	0.941715813
Vmax (pu)	1	1	1	1
Voltage Deviation (pu)		0.06907032	0.04485347	0.05828418
DSTATCOM size (MW)	……….	1.324	3	2.045
DSTATCOM Location	……….	61	63	62

According to the first state, Table 1 illustrates near 33% decrease in the quantity of active power losses in evaluation with initial power losses which is notable charge. The reducing resistive losses in the network impacts on the improvement of buses voltage profile, indirectly. The state 2 mainly intends to optimize the voltage deviation of the buses which consequences in expansion of the minimum voltage of the network. Now the amount of active power loss lessening is about 19 %. Lastly, the proposed interactive fuzzy satisfying process obtained proper trade-off between the active power losses and the voltage deviation in the third state. In fact, the planned multi-objective formulation has optimized both of the objective functions suitably which is observable in Table 1. Comparing the optimal extent of the DSTATCOM in dissimilar states clarifies that better voltage profile is attained for higher values of sensitive power compensation by the D.S.T.A.T.C.O.M. This progress is achieved with the cost of ascendant losses that shows the requirement of accurate sizing and allocating of the DSTATCOM in the system.The stochastic analysis is implemented in which the normal distribution system is supposed for all the active and reactive loads to model their uncertainty. As the typical deviation of the likelihood compactness functions is 0.05. The results of multi-objective optimization in both the deterministic and stochastic structures are shown in Table 1-2. It is brilliant that considering the uncertainty in the analysis has impact on incremental values in the objective functions. Nonetheless, the standard deviation values of the objectives in the stochastic basis are condensed. This drop shows more reliable optimum values nearby the real working points.

***Table 1-1:** Results obtained by Optimal DSTATCOM allocation and sizing in the stochastic framework (OC 1)*

Items	Item	Power losses	Voltage Deviation
Deterministic Framework	Objective Function	172.684083	0.05828418
	Standard Deviation	4.54322	0.001266
Stochastic Framework	Objective Function	173.948302	0.06028894
	Standard Deviation	3.98729	0.001123

In Fig. 4 and 5, the voltage profile development of the system earlier and after using 1 DSTATCOM is confirmed (case of multi-objective optimization).

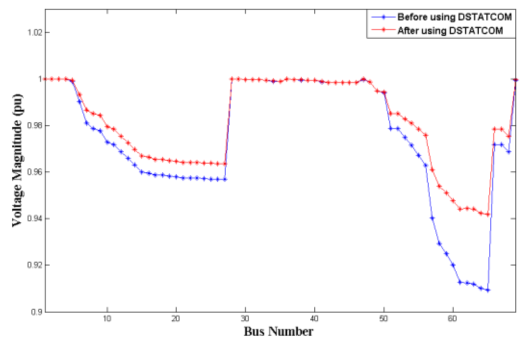

Fig. 4: *The voltage profile before and after using DSTATCOM in OC1 (multi-objective stochastic framework)*

Agreeing to Fig. 4, 1 DSTATCOM has an significant part in the development of the system control quality. It is time to run the second state so-called OC 2 where 2 DSTATCOM are utilized in the system. Now, the key purpose is to investigate the effect of by 1 more DSTATCOM on the optimal functioning opinion of the network. Table 1-3 exemplifies the simulation outcomes.

Table 1-3: *Results obtained by Optimal DSTATCOM allocation and sizing in the deterministic framework (OC 2)*

Items	Initial Condition	State 1		State 2		State 3	
Active Power losses (kW)	225.0	144.850511		653.0246131		172.474278	
Vmin (pu)	0.913090	0.93131951		0.973002854		0.9421118440	
Vmax (pu)	1	1		1.000239326		1	
Voltage Deviation(pu)	0.086909	0.06868048		0.026997145		0.05788815	
DSTATCOM size (MW)	……….	0.35	1.27	3	3	1.42	1.47
DSTATCOM Location	……….	17	61	57	61	54	64

Due to the survival of DSTATCOM in the system, an augmentation in all the objective functions can be seen from Table 1-3. Nevertheless, in contrast of the outcomes of Table 1 with Table 1-3, it is noticeable that the choice of using the second DSTATCOM would not enhance the capability to progress the values of the objective purposes. In fact, at the moment that just 1 DSTATCOM is used in O.C.1, an effective decrease in the total of both the power losses and voltage deviation occur. Also, the second DSTATCOM has just small outcome on extra enhancement of these objective purposes. Hence, due to the luxurious value of each DSTATCOM in the system, using the second DSTATCOM is not cheap and consequently not suggested. Table 1-4 displays the reproduction results of the stochastic construction. As it is clear, the proposed stochastic scheme has condensed the standard deviation values which lead to an increase in the dependability of the final solutions.

Table 1-4: *Results obtained by Optimal DSTATCOM allocation and sizing in the stochastic framework (OC 2)*

Items	Item	Power losses	Voltage Deviation
Deterministic Framework	Objective Function	144.85051	0.0269971
	Standard Deviation	4.00128	0.000539
Stochastic Framework	Objective Function	173.9483	0.06028894
	Standard Deviation	3.78351	0.000421

Ultimately the voltage profile beforehand and afterward using the OC 2 is exemplified in Fig. 1-5 in a comparative style.

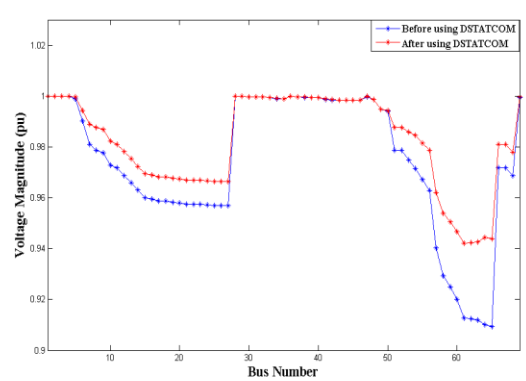

Fig. 1-5: *The voltage profile before and after using 2 DSTATCOM s in OC2 (multi-objective stochastic framework)*

8. Conclusion

In this paper we tried to present a fresh stochastic structure founded on 2*m*+1 PEM to consider the uncertainty results of active and reactive load forecast errors in the optimal DSTATCOM allocating and sizing. In this regard, a fresh alteration based on bat algorithm was planned to discover the examine galaxy universally. By taking the benefit of interactive fuzzy satisfying routine, two objective utilities including active power losses and the voltage deviation are handled. Consequently from simulation results that using the DSTATCOM as a illustrious FACTs device can advance the system state effectually. In spite of that, there is no shortest relationship which asserts that increase in the number of DSTATCOM in the system can variety an improvement in the objective utilities. Really, the simulation outcomes, in the 69--bus IEEE exam system, presented logically that the amount of growth in the objective functions values for using 2 DSTATCOM is not as greatly as just 1 D.S.T.A.T.C.O.M. From the uncertainty point of view, the proposed stochastic framework could reduce the standard deviation values and therefore the reliability of the optimal solutions increases progressively.

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