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Power System loss minimization by using STATCOM placed at optimal location given by Artificial Bee Colony Algorithm

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Abstract: This study suggests an intuitive method-based strategy that uses one integrated electrical flow controller to reduce power system losses. In this case, the generator malfunction happens when the Artificial Bee Colony Algorithm (ABC) optimises the STATCOM's placement. Because the generator defect impacts power flow limitations that include voltage magnitude, power loss , reactive as well as real power, the ideal position gives or tells us about the loss of power at the bus. The least amount of power loss is achieved by utilising STATCOM at the ideal place. After that, STATCOM is positioned in the best possible way, and the resulting data is examined. The suggested approach is put into practice using the MATLAB/Simulink platform, and the comparison power loss under various scenarios is used to assess the performance. The comparative findings validate the suggested approach's capacity to address the problem and show how effective it is.

Index words: Power loss , Power flows ,ABC, STATCOM.

1. INTRODUCTION

Constraints on safety and stability place a limit on the maximum quantity of electricity that may be transferred between two locations via a broadcast network [1]. Environmental and financial constraints to establish new generating facilities and transmission lines have caused electric power networks all over the world to operate at almost full capacity [2] [3]. It is not advisable to let the power flow through the transformers and lines get so high that a random event might bring down the network due to cascading faults [4] [5]. Flexible Alternating Current Transmission System (FACTS) is a stationary device designed to manage the power transmission system [6] [7]. "Power system on based power electronics and additional stationary devices which allows command over one or more AC gearbox system characteristics to maximize the power transfer capabilities and create controllability" is the official definition of FACTS [8]. One FACTS device, STATCOM, has the ability to control the power flow in a transmission line by putting an reactive and component of active voltage parallel to the transmission line[9].

A STATCOM device's ideal placement enables control over its power streams for a network that is connected, increasing the system load capacity [10]. One barrier to combinatorial revision is the ideal placement and capacity of a specific number of FACTS in a power system [11]. This kind of problem has been tackled using a variety of optimisation techniques, including tabu search, genetic algorithms, and repeated annealing [12].This study offers a methodology or a technique to minimize the loss of power in the power system while making use of STATCOM. The novel suggested approach, which uses the Artificial Bee Colony Algorithm, which helps to chooses a particular location for STATCOM in the occurrence of a generator failure. How do power flow restraints like reactive and real power ,voltage and loss of power change when a generator fails? To improve the performance of the given system, a STATCOM is placed in the optimal location as determined by the ABC algorithm. Increasing power flows and reducing power loss are the goals of this work. The remaining of the document is structured as follows: Section 2 discusses exploration projects from the past to the present. The structure, issue formulation, and algorithm of STATCOM are covered in Section 3. The results are presented in Section 4, and the paper is shortly concluded in Section 5.

2.NEW RESEARCH: A SHORT SUMMARY

There are several relevant publications in the literature that focus on enhancing the power system's capacity for power transfer. This page reviews a few of them. In order to improve the safety measures for the electric power system, Husam I. Shaheen et al. has suggested a process based on the distinct evolutionary path methodology in terms of single line dependencies. This method aims to discover the ideal placement and parameter setting coupled using UPFC. [13] On IEEE 14-bus and 30-bus test systems, they ran simulations.

In order to minimise the overall cost of generators for producing active and reactive electricity and to lower the cost of UPFC installation, Seyed Abbas Taher et al. established this requirement related to the hybrid immune algorithm [14]. They used IEEE 14-bus and 30-bus test systems for their simulation.

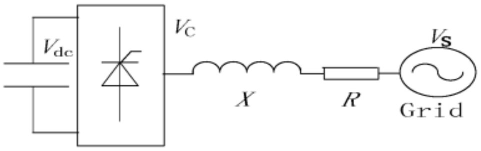
Real Coded Genetic Algorithm and fuzzy logic are two methods proposed by A.R. Phadke et al. [15] For the sizing and engagement of shunt FACTS controllers. A fuzzy appearance index is suggested that takes into account the capacity of the Shunt FACTS controller, voltage profile, and distance to prevent node bifurcation. IEEE 14-bus and IEEE 57-bus test systems have both been utilised using the suggested approach.

Sanjeev Kumar et al. [16] Developed a capable and trustworthy evolutionary-based method for solving optimum power flow (OPF) issues. By Combining Particle Swarm Optimisation (PSO) and Genetic Algorithm (GA) with Fuzzy Systems to get the best OPF issue control variable settings.

B.Vijay kumar *et al* have also tried to solve the issue of where to put the UPFC optimally to increase power system stability of voltage using the Artificial Bee Colony method [17]. Simulation studies were tested out using the IEEE 14 bus system.

3. Static Synchronous Compensator (STATCOM):

Basic Principle: A voltage-source converter called STATCOM incorporates or preserves voltage stability by absorbing reactive power. It provides immediate correction for variations in reactive power demand by functioning as a shunt-connected device and connecting simultaneously to the wind power plant.



Equivalent circuit of STATCOM

Modelling: The STATCOM model includes the representation of the voltage-source converter, control algorithms, and feedback loops. The mathematical equations describe the relationship between the control signals, converter output, and reactive power injection. The output active power and reactive power of STATCOM are

$$P = -YU_cU_s\sin\delta \qquad (6)$$

$$Q = Y(U_cU_s\cos\delta - U_s^2) \qquad (7)$$

In accordance with the above equation, the STATCOM device draws reactive power from the network when the voltage of output is lower than the voltage of input, or when Uc < Us; in contrast, when its voltage of output is higher than the mains voltage or when Uc > Us supplies reactive energy to the grid, the STATCOM device attracts reactive power from the network; The STATCOM device's reactive power is zero at that point we can tell that the voltage of output is equals the line voltage, or when Uc = Us.
By Calculating the actual power and phantom power at the buses *i* and *j* involves applying the load flow solution. Because the proportional features of the admission matrix will not be lost, the power injection representation is important.[18].
In section 3.1 that follows, the formulation of the loss reduction issue is briefly presented.

3.1 Formulation of the Problem

A nonlinear optimisation challenge is the minimising of power system loss. Control variables must be kept inside the safe bounds in order to do this. Different equality and inequality constraints relate to a certain goal function as the control variables. Equations (3.1), (3.2), and (3.3) provide a mathematical description of the necessary goal function.

$$Minimize\ \ F(t,u) \qquad (3.1)$$

$$Subject\ \ to\ g(t,u)=0 \qquad (3.2)$$

$$h(t,u)\leq 0 \qquad (3.3)$$

The term F(t,u) is the power system stability goal function that, in the event of a generator failure, minimises power system loss and voltage variation. The system's dynamic stability is impacted when a generator or generators fail because of increased power loss and voltage variations at the buses.

Two goal functions are taken into consideration here. The first is minimising system loss, and the second is minimising voltage variations across all of the power system's buses. Then, the constraints on equality are g(t,u), while the constraints on inequality are h(t,u). The restrictions on equality, inequality, and active power loss are described in the section that follows.

3.1.1 *Objective function*

Reducing the quantity of active loss of power is the aim here, The below mentioned formula explains about the loss of active power in the transmission network: [19]

$$P_{loss}=\sum_{k\in N_E} g_k(V_i^2+V_j^2-2V_iV_j\cos\theta_{ij}) \qquad (3.4)$$

Here the *k= (i,j)*; N_E is the collection of numerical network branches, g_k it is known as the branch of conductance *k*. θ_{ij} it is the difference between the voltage angles bus *i* and *j*.

3.1.2 *Equality limitations*

The limitations on equality of the power system are explained in this section. Here, the generators in the power system must guarantee both the transmission loss and the whole demand of the clients. It is often referred to as the power system's power balancing situation. The necessary equations for power balancing are shown below.

$$\sum_{i=1}^{N_B} P_G^i = P_D + \sum_{i=1}^{N_B}(P_L^i) \qquad (3.5)$$

Where, P_G^i it is the generating of power by the i^{th} bus, P_D it is the demand in power by the network, P_L^i it is the losses of the actual power of the bus number i^{th}.

The section that follows provides an explanation of the inequality limitations.

3.1.3 *Inequality Limitations*

The actual and phantom power, voltage , and transformer tap limits—limited by inequality [19]—are explained in this portion of the power system. For thesystem to be in stable condition , these restrictions must be kept within reasonable bounds. Since voltage stability at each node is a key component of power system stability, bus voltage restrictions are principally considered in the issue. To operate the electricity network with stable voltage of the bus could be in the limit $V_i^{\min} \leq V_i \leq V_i^{\max}$. The normal voltage limit of each bus node can be *0.95 to 1.05 pu*. Below are some more inequality limitations.

$V_i^{min} \leq V_i \leq V_i^{max}$ Bus voltage limits (3.6)

$T_i^{min} \leq T_i \leq T_i^{max}$ Tap position limits (3.7)

$Q_i^{min} \leq Q_i \leq Q_i^{max}$ Generation of reactive power (3.8)

$P_i^{min} \leq P_i \leq P_i^{max}$ Generation of the active power (3.9)

In typical, steady conditions, these limitations are met. There is an increase in power loss when there is a generator fault state because it affects power flow limitations. Connecting a UPFC at the ideal position will reduce the power system loss under these circumstances. Using the suggested ABC method, this is feasible.

3.2 The ABC algorithm is used for identifying the best site for STATCOM C.

N-R load flows are used to discover normal power flows in the first stage of the suggested heuristic approach. After introducing a generator malfunction, the Newton-Raphson (N-R) method is used to calculate power flows and power loss. With the desired goal function—minimizing the system power loss—the ideal position of the UPFC is now found with the ABC algorithm. In the next part, you will find the algorithmic procedures to optimise location.

3.2.1 How to apply the ABC algorithm to find the best spot for a STATCOM

Step1: Set the line power loss and voltage populations at each bus to their initial values.

Step 2: Provide the unpredictable input voltage as well as power loss in the population.

Step 3: The population's fitness is assessed in the employ bee phase, and The measure of fitness required is given in equation (3.10) [20].

$$P_{loss} = \sum_{k \in N_E} g_k (V_i^2 + V_j^2 - 2V_i V_j \cos\theta_{ij}) \qquad (3.10)$$

Step 4: Set the number of iterations to 1, such that iteration I=1.

Step 5: Now perform the process/method again.

Step 6: Using the following formula (3.11), the observer bee achieves the bus system's elite fitness function and increases population velocity.

$$v_{i,j} = x_{i,j} + \Phi_{i,j}(x_{i,j} - x_{k,j}) \qquad (3.11)$$

In which, k represents the resolution in the vicinity of i, ψ it is the arbitrary digit taken from the extent mentioned i.e., [-1, 1], $k = (1,2,3\ldots n)$ and $j = (1,2,3\ldots n)$, these are some numbers chosen randomly and v_{ij} it is the solution presented for neighborhood of x_i.

Step 7: Utilise the choosing procedure to ascertain the likelihood and identify which of the new solutions has the higher fitness.

$$probability = \frac{\Phi}{\sum_{i=1}^{n} \Phi} \qquad (3.12)$$

Step 8: Should further satisfactory answers not be obtained, give up and use the following equation (3.13) to generate a random number of scout bee solutions.

$$x_i^j = x_{\min}^j + rand[0,1](x_{\max}^j - x_{\min}^j) \qquad (3.13)$$

Step 9: Remember the finest solution that has been found by this step.

Step 10: Review the range of iterations.

if it is not reached the peak extent, either raise the count of iterations by (count) I=I+1 or end the procedure.

At the designated generator bus fault state, the system is prepared to generate the utmost power loss of the bus when the aforementioned procedure is complete. The following section determines the STATCOM's ideal sizing.

The power system is prepared to provide the best location for the STATCOM after the aforementioned procedure is finished. The MATLAB platform is used to develop the suggested ABC method, and a range of operating circumstances are used to evaluate its performance. It is provided in the section that follows.

3.3. Findings and Conversations Regarding ABC Algorithm

In the MATLAB platform, the suggested ABC method is put into practice. This section presents and discusses the suggested ABC algorithm's numerical findings. A comparison is made between the outcomes achieved using several individual methods. The IEEE 30 bus technology is utilised in this application of the ABC method. The following are the talks on the two systems.

3.3.1 Results validation using the ABC technique for the IEEE 30 bus system

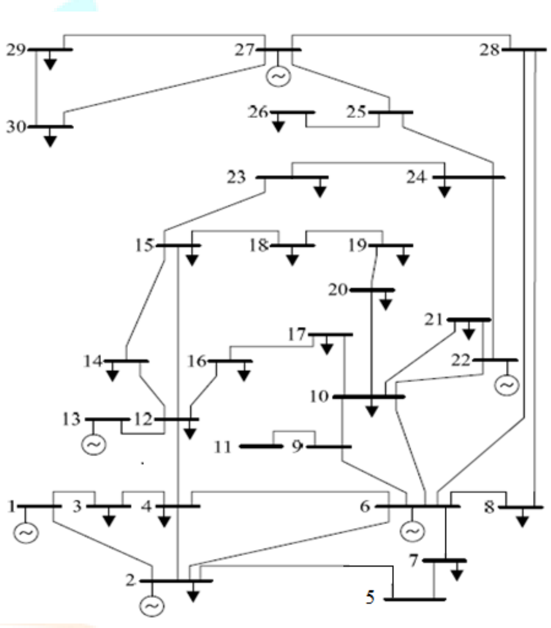


Figure 1 This the structure of IEEE 30 bus system

Figure 1 depicts the IEEE 30 bus system's structure. This picture examines the IEEE-30 bus standard system, which consists of 42 transmission lines, 21 load buses with 6 generating buses. The traditional Newton-Raphson (N-R) technique which is initially used to perform the system initial-case load flow analysis. The IEEE 30 bus system standard data is employed in this instance. The faults of generators which can be from double or single are then added, and the associated flow of power is examined. The power system losses or power losses rise as a result of generator problems. Higher Connecting STATCOM at the ideal location—which the suggested ABC algorithm can determine—will reduce power loss.

- **Single generator fault**

  In this instance, a single generator is given a flaw at a time, and the stability that results is examined.

Table 1 displays power flows under normal circumstances, during a generator fault, and following the connection of a STATCOM that is positioned optimally for various single generator failure scenarios. Here, it is seen that connecting STATCOM—whose position is established by the ABC algorithm—improves electricity flows.

Table 2 displays power loss under normal circumstances, generator failure conditions, and the appropriate STATCOM size and placement following connection many fault circumstances for a single generator. Here, it is noted that the system's power loss is decreased by attaching STATCOM. In this instance, it is evident that when a single generator fails, power loss increases to 11.903 MW; however, after attaching STATCOM, the position of which is determined by the suggested ABC method, power loss decreases to 9.233 MW.

Table 1 shows the flow of power analysis for an individual generator malfunction scenario using the ABC approach.

Fault of generator at bus no.	Ideal spot of STATCOM		Power flow					
			In general condition		In the generator fault condition		Using STATCOM at optimal location	
	From bus	To bus	P (MW)	Q (MVAR)	P (MW)	Q (MVAR)	P (MW)	Q (MVAR)
2	12	15	19.685	7.779	19.797	7.755	20.459	7.715
6	5	7	23.744	13.834	24.763	14.248	21.015	17.649
13	10	22	4.044	6.627	4.044	6.582	1.316	7.107
22	12	15	19.652	7.784	19.801	7.757	20.017	7.222
27	10	22	4.045	6.618	4.044	6.582	1.705	8.120

Table 2 shows the loss of power analysis using the ABC technique for an individual generator fault condition

Fault of generator at bus. no	Ideal spot of STATCOM		Power loss in MW		
	From bus	To bus	In the normal condition	In the generator fault condition	Using STATCOM at optimal location
2	12	15	10.809	12.766	9.219
6	5	7		12.553	8.370
13	10	22		12.794	8.346
22	12	15		11.885	8.671
27	10	22		11.910	9.229

Table 3 shows flow of power analysis for the dual generator failures using the ABC approach

Fault of generator at bus nos.	Ideal spot of STATCOM		Power flow					
	From bus	To bus	In the normal condition		In dual generator fault condition		Using a STATCOM placed at ideal spot	
			P (MW)	Q (MVAR)	P (MW)	Q (MVAR)	P (MW)	Q (MVAR)
2 and 6	10	22	1.051	6.517	4.044	6.581	4.035	6.471
2 and 13	5	7	23.846	13.807	24.763	14.248	21.938	13.077
6 and 13	2	5	72.827	2.551	71.715	2.681	78.743	1.916
22 and 27	12	15	19.636	7.768	19.797	7.760	22.475	6.498
13 and 27	10	22	1.042	6.617	4.044	6.579	2.389	6.892

Table 4 shows loss of power analysis using the ABC technique for double generator failures

Generator at which fault occurred and its bus nos.	Ideal spot of STATCOM		Loss of power in MW		
	From bus	To bus	In the general condition	In dual generator fault condition	Placing a STATCOM at ideal spot
2 and 6	10	22	10.809	14.729	9.212
2 and 13	5	7		15.018	8.995
6 and 13	2	5		14.833	9.598
22 and 27	12	15		13.049	8.706
13 and 27	10	22		14.005	9.896

- **Double generator fault condition**

In this instance, faults are applied to two generators simultaneously, and the resulting stability is examined.

Table 3 displays power flows under normal circumstances, in the event of a double generator malfunction, and following the connection of STATCOM, the best placement of which is chosen using the ABC method. Here, it is shown that attaching the STATCOM improves power flows.

Table 4 displays loss of power under normal circumstances, a dual generator fault scenario, and the ideal placement of the STATCOM connection—a site identified by the ABC method. Here, it is noted that the system's power loss is decreased by attaching STATCOM. In this case, it is evident that power loss increases to 14.005 MW after a double generator failure and decreases to 9.901 MW upon attaching STATCOM, the position of which is determined using the suggested ABC algorithm.

Tables 2 and 4 demonstrate the efficacy of the suggested technique for determining the best location for STATCOM to minimise system power loss.

3.5 CONCLUSION

This research presents the efficacy of the suggested ABC algorithm in locating the UPFC in the best possible way for minimising the loss of power of the given electrical system. The benefit of this suggested algorithm is its capacity for precise and efficient searching to identify the best answers. Here, the efficiency of the suggested approach is evaluated under various generator failure scenarios using the IEEE 30 bus benchmark system. Single generator faults are first introduced into the system at various buses, and then double generator faults are added.
The power flows and power loss are examined under each of these circumstances. A particular analysis has done base on the acquired data, it can be inferred that the suggested ABC algorithm is efficiant in reducing loss of power in the electrical system by enhancing power flows through the efficient identification of the ideal placement for the UPFC.

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