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GENETIC ALGORITHM OPTIMIZED TCSC LOCATION AND SIZING CONCERNING POWER SYSTEM SECURITY ENHANCEMENT

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ABSTRACT

It is expected that the power demand is presently increasing than the generation due to transformation of world which impacts loads heavily. Henceforth it is hard to operate the power system under stable conditions at all times which revealssome issues such as voltage instability and power losses, etc. considering that Steady-state security enhancement via Flexible AC Transmission System (FACTS) have been applied tothe power system is viable. The placing and sizing of these devices will yield better results concerning system security and stability. Thispaper emphasis that, the location and the ratings of FACTS devices that are optimized using Genetic Algorithm (GA). The main goal is to optimize the position and ratings of Thyristor controlled series capacitor (TCSC) device by considering these objectives such as the minimization of Voltage Security limit, minimization of line overloading limit. For optimizing these viable parameters, A genetic algorithm (GA), basically an iterative method delivers an optimal solution by solving multi-objective concerns.Simulation trials Reveal that much-demanded location and level ofTCSC parametersare optimized Using GAwith astandard IEEE 6 bus system.

KEYWORDS: FACTS Devices, Genetic Algorithm (GA), Multi-Objective Optimization, Power system Security Enhancement, Thyristor controlled series capacitor (TCSC).

INTRODUCTION

Security deliberations have long been accustomed as an indispensable part of power system expansion and control, also adapts the load variation without exceeding their system operating constraints. Due to economic reasons and uncertainties in the forecast of loads and emerge of new facilities, Power supply reliability does not attain the 100% level. Consequently, Grid maintenance becomes a big annoyance to ensure that all customers are satisfied minimally. Hence, there has been a significant consideration in developing tools to identify, predict and control these security constraints. [1-2]. For understanding the static security evaluation, the system should be designed to operate within normal operating ranges for credible load and generation patterns for base case operation and be designed to withstand the more probable contingencies without widespread system failure and instability, maintaining power quality within specified voltage and frequency fluctuation ranges and maintaining voltage and thermal loadings within operating limits [3].

A quick security evaluation of the power system will forewarn the Grid operators that the system is insecure under a certain condition which leads to follow appropriate precautions or actions should be taken quickly. So, there is a pressing in further for security enhancement of power systems [4]. The Present work mainly focuses on steady-state security enhancement via FACTS. Many conventional approaches have been investigated earlier to solve the problem of security enhancement. The current work primarily hearts on steady-state security enhancement via Facts devices. FACTS devices [1-5] structured by power electronics technological updateprovides an active tool for the control of active power as well as reactive power and voltage control. Good management involving optimal location and sizing of FACTS devices will operate the power system more secure and economical. This work mainly focuses on optimal place and optimal setting of Thyristor Controlled Series Compensation (TCSC) for security enhancement applicable to the following objectives such as minimization **of voltage magnitude (Vmag) violations and 130% of line overloading limit (S_{MVA}).** A Genetic Algorithm (GA) [6] is proposed for solving the multi-objective security optimization problem. Here, dual objectives are considered also assumes multi-objective optimization problem which isensued via a fitness mission scheme that prefers non-dominated results and by using a sharing approach that conserves multiplicity among solutions of each non-dominated front [7]

Thus, the proposed GA Optimized TCSC location and sizing which concerns Power system static security enhancementis executed with the IEEE 6-bus system by using software MATLAB 7.1 Demo version with addon package MATPOWER- Opensource Power system Analysis toolbox [8].

SECURITY ENHANCEMENT

A power flow is sternly governed by the electric system equations [9]. The flow pattern depends mainly on the load and the generation distributions and the network configuration. The amount of power generated by each unit is constrained by its capacity. The power flowing in each line is limited by its rating and so is that handled by each transformer. For system security function constrictions may inflict on the bus voltage angle across the lines. Voltage levels are to be within a satisfactory range. All the preceding conditions may be expressed in the following mathematical equalities and inequalities [10].

$$P_{G\,i} - P_{L\,i} = V_i \sum_{J=1}^{n} V_j \,.\, Y_{i\,j} \,.\cos(\delta_i - \delta_j - \theta_{i\,j}) \quad (1)$$

$$Q_{G\,i} - Q_{L\,i} = V_i \sum_{J=1}^{n} V_j \,.\, Y_{i\,j} \,.\sin(\delta_i - \delta_j - \theta_{i\,j}) \quad (2)$$

$$P_{G_{Max\ i}} \geq P_{G\,i} \geq P_{G_{Min\ i}} \quad (3)$$

$$Q_{G_{Max\ i}} \geq Q_{G_{\,i}} \geq Q_{G_{Min\ i}} \quad (4)$$

$$V_{Max\ i} \geq V_{i} \geq V_{Min\ i} \quad (5)$$

$$\alpha_{i\,j} \geq |\delta_{i\,j}| = |\delta_i - \delta_j|, \quad i = 1, 2 \ldots n \ \ / j = i+1 \ldots n \quad (6)$$

The above equalities and inequalities (1)-(6), may be expressed in compact form,

$$g(x, u) = 0 \ \ \& \ \ h(x, u) \leq 0 \quad (7)$$

where $u$is a set of independent variables and$x$is a set of dependent variables, while all the equality and inequality constraints $g\,(x, u) = 0$ and $h\,(x, u) \leq 0$, are satisfied, the power system is said to be in the normal operating state. If anyone its equality and inequality constraints are not satisfied once at a time which conceives different operating modes such as normal, alert, restorative. This concept has been utilized to understand the security status of the power system models.Security enhancement procedure must be originated when the system proves sufficient success in the static security Assessment process.

FACTS DEVICES

A Power electronics-based Flexible Alternating Current Transmission System (FACTS) is inert equipment used for the AC transmission of the electrical system [11]. The FACTS controllers suggest a grand prospect to control the Transmission of alternating current (AC), rising or failing the power flow in exact lines and responding roundabout right away to the Stability Problems.

Based on the several literatures, The FACTS devices can be identified into several groups, reliant on their switching phenomenon such as i.) mechanically switched (like PST), ii.) thyristor switched or rapid switched, via IGBTs iii.) Phase-shifting transformers (PST) iv.) static VAR compensator (SVC). Based on the various studies which reveal that SVCs and STATCOM devices are finely matched to give ancillary services (such as voltage control) to the grid which proven fault clear through capabilities, decreases oscillations in the grid even though renewable energy resources involved. Functioning of FACTS has mainly defined a point that there are principally three main variables that can be directly controlled in the power system to impact its performance such as 1.Voltage, 2. Angle, 3. Impedance.

List of few Facts devices and their predominant features

Here some important FACTS devices and their predominant features are explained

- Static Synchronous Compensator (STATCOM) -Controls voltage
- Static VAR Compensator (SVC) -Controls voltage
- Unified Power Flow Controller (UPFC) -Control's voltage impedance, angle and power.
- Convertible Series Compensator (CSC) -Control's voltage impedance, angle and power.

• Inter-phase Power Flow Controller (IPFC) -Control's voltage impedance, angle and power.
• Static Synchronous Series Controller (SSSC) -Control's voltage impedance, angle and power.
• Thyristor Controlled Series Compensator (TCSC)-Control's impedance
• Thyristor Controlled Phase Shifting Transformer (TCPST)-Controls angle
• Super Conducting Magnetic Energy Storage (SMES)-Control's voltage and power

In this paper, the proposedwork highlights on Thyristor controlled series capacitor (TCSC), whichis one of the effective FACTS devicesthat yields smooth and flexible control of transmission line impedance with faster response speed compared with traditional control devices.it is capable to improve stability, modernize the dynamic quality of the power system, and increasing the transfer capability of the transmission system by diminishing the transfer reactance between the buses to which the line is connected. By optimizing the crucial power parameters with GA to findsan optimal place and setting of TCSC under single contingency(n-1) with identified line overloads and the bus voltage violations will be described in further sections.

OPTIMAL LOCATION AND SETTING OF TCSC FOR SECURITY ENHANCEMENT USING GENETIC ALGORITHM

Objective function

$$F_t = \sum_{l-1}^{ntl} w_l \left(\frac{S_l}{S_{l\max}}\right)^{2q} + \sum_{m-1}^{nb} w_m \left(\frac{V_{mref} - V_m}{V_{mref}}\right)^{2r}, \quad (8)$$

where *Sl* and *Slmax* represent the current apparent power inline *l* and the maximum apparent power of line *l,* respectively; *Vm* represents the voltage magnitude at bus *m*; *Vmref* represents the nominal voltage at bus *m*;*wl*and*wm* represent two weighting factors which are determined to have the same index value for 10% voltage difference and 100% branch loading; *q* and *r* represent two coefficients which are used to fineapproximately overloads and voltage deviation, respectively (for the existing study, they are advised to be equal to and *ntl* and *nb*correspond to the number of lines and the number of buses in the structure.
The following steps are used to find the optimal location and setting of TCSC
Step 1: Initially create a population (NXtcsc, NLocation,)
Step 2: Perform a power flow program.
Step 3: For all the individual's fitness values are evaluated.
Step 4: Stand on the fitness value, thelatest population has been selected from the older population stand on the evaluation function as given.
Step5: Genetic operators (crossover and mutation) functional to the population that has been selected to make new solutions.
Step6: Fitness value is evaluated for new chromosomes and use in the population.
Step7: If it exceeds the time, stop the process and provide the best Individual if not, proceed from step 4.

Methodology: Optimal location and setting of TCSC for security enhancement using Genetic Algorithm
The process of using GA method can be expressed as follows:
Step 1: Firstly, declare the inputs of the optimization including the population size, the maximum number of creation, the associated parameters of GA (stopping condition, crossover way and its chance, mutation name and its chance) and the power flow records.

Step 2: After selecting the control parameters of GA such as the population size, the crossover probability, and the mutation probability, an initial population of floating individuals of finite length is haphazardly generated to regard as the variables that should be optimized (the place and the parameter setting of TCSC). Each of these individuals concatenated of two chromosomes (genes) represents a possibleresult to the optimization problem. The first chromosomes in the character correspond to the place of TCSC device in the system. This chromosome restrains the numbers of the lines where the TCSC should be situated and it is arbitrarily generated between one and ntl (where ntl is the total number of lines in the system) with the exception of the lines where the transformers are existed (It is assumed that no TCSC will be fitted in such lines). Whereas the next chromosome is interrelated to the parameter settings of the TCSC, that is the reactance of the TCSC and it is arbitrarily generated according to the operational range of TCSC which is considered as follows:

$0.5XL < X_{TCSC} < 0.5XL$ per unit

Where XTCSC is the reactance additional to the line by TCSC; XL is the reactance of the line where TCSC is located. Combinations of the above-mentioned two chromosomes (with the described generation mechanism of their elements) create the individual. By repeating these processes with a number of times equal to the selected population size, an entire initial population will be created.

Step 3: As the GA algorithm is originallyconsidered for searching the maximization problem solution and in the paper, the opposite of the objective function as fitness of GA shown in Eq. (1) is employed. The fitness for every individual in the population is calculated by taken the converse of the summation of the two terms of the objective function which are computed as follows: From the power flow solutions, the bus voltages and the line flows desired to calculate the two provisos of the objective function shown in Eq. (1) can be attained.

Step 4: A fresh population is formed with the elimination of worse performing individuals, even as the most very much fit members in a population are selected to get ahead of on information to the next generation. The genetic operations containing selection, crossover, and mutation are achieved. Basically, the selection method attempts to apply pressure upon the population in a wayrelated to that of the normal selection found in biological systems. The selection role called predetermined sampling selection is adopted in this effort, which guarantees that the bigger fitness individuals are remaindered into the after that generation. Theoretically, pairs of individuals are selected randomly from the population and the fit of each pair is permissible to mate. Every pair of mates generates a child having some combine of the two parents. The crossover may arise with a probability *Pc*commonly close to one. Crossover is the most important part of genetic operation, which promotes the exploration of freshsections in the search space using randomized method of switching information linking individuals. Two individuals previously placed in the mating pool throughimitation are arbitrarily selected. A crossover point is then randomly selected and information from one parent up to the crossover point is exchanged with the other parent. The mutation process is used to avoid losing main information at a particular position in the decisions. The mutation operator with a mutation probability Pm is applied to all the elements in the individual. Mutation is usually considered as a secondary operator to widen the search space and sourceget away from a local optimum when used sensibly with the selection and crossover schemes.

Step 5: Process of selection, crossover, and mutation are continual until the desired number of individuals for the fresh generation is created, and the objective function is premeditated again for all of the individuals in the new generation. The finest individual in the new generation according to its fitness (opposite of the objective function value) is kept to prolong to the next generation. This way guarantees that the fitness of the finest individual of the next generation will be the similar or higher than that of the finest individual in the earlier generation. Thus, the fitness of the whole population will be improved with the increase of generation.

Step 6: The stopping criterion is the maximum number of generations. If this number is reached, stop the process, publish the finest individual (optimal place and optimal parameter settings of TCSC).

SIMULATION RESULTS

System Data details

The design of proposed model for static security enhancement is implemented and tested on IEEE 6 bus standard test system [12] and the effectiveness of the proposed model has been demonstrated withOptimal location and setting of TCSC with Genetic algorithm. For static security assessment, The data set required for training and testing phases are obtained by off-line simulation performed using MATPOWER Toolbox with MATLAB 7.1[8]. This data set is obtained by varying the generation and load from 80% to 120% of their base case value with generation variation restricted to their minimum and maximum limits.

The IEEE-6 bus sample system has 3 generators, 6 buses and11 lines as shown in Table 1,2, &3. One at a time, outage studies are performed and form the set of disturbances to be utilized for steady state security in the Power system. The patterns or variables are generated through the load flow analysis using newton Raphson method. The generated variable set consists of 6 numbers of voltage magnitude variables (Vi), 6 numbers of voltage angle (δi), 3 numbers of real power generation variables (Pgi), 3 numbers of real power demand variables (PDi), 3 numbers of reactive power demand variables (QDi), 11 numbers of active real power flow variables (Pi-j) ,11 numbers of reactive power flow variables (Qi–j) and 11 numbers of line MVA variables (Si-j). All feasible parameters are subjected to static security check with voltage limit and line flow limit.

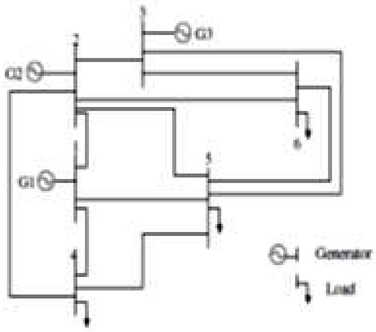

Fig 1: IEEE 6 Bus System

Table 1: Bus data of IEEE 6 bus system

Bus_i	Type	Pd	Qd	Vm	Basekv	Vmax	Vmin
1	3	0	0	1.05	230	1.05	1.05
2	2	0	0	1.05	230	1.05	1.05
3	2	0	0	1.07	230	1.07	1.07
4	1	70	70	1	230	1.05	0.95
5	1	70	70	1	230	1.05	0.95
6	1	70	70	1	230	1.05	0.95

Table 2: Generator data of IEEE 6 bus system

Bus	Pg	Qg	Qmax	Qmin	Vg	Mva base	Pmax	Pmin
1	0	0	100	-100	1.05	100	200	50
2	50	0	100	-100	1.05	100	150	37.5
3	60	0	100	-100	1.07	100	180	45

Case study 1: Simulation results expose Security Assessment and checking violations

The IEEE 6 bus model has been implemented using MATLAB with Matpower and the load flow analysis was performed with Newton Rapson method. From the load flow results, the below power system parameters are tabulated shown in table 4 and 5. From the simulation result voltage magnitude at bus 4 is violated. Even though there is a small fluctuation that will be considered for security evolution likewise line MVA also verified whether the values are within the limits or not.

Table 3: Line data of IEEE 6 bus system

FBUS	TBUS	R	X	B	MVA LIMIT	FBUS	TBUS	R	X	B	MVA LIMIT
1	**2**	0.1	0.2	0.04	40	**2**	**6**	0.07	0.2	0.05	90
1	**4**	0.05	0.2	0.04	60	**3**	**5**	0.12	0.26	0.05	70

1	**5**	0.08	0.3	0.06	40	**3**	**6**	0.02	0.1	0.02	80
2	**3**	0.05	0.25	0.06	40	**4**	**5**	0.2	0.4	0.08	20
2	**4**	0.05	0.1	0.02	60	**5**	**6**	0.1	0.3	0.06	40
2	**5**	0.1	0.3	0.04	30						

Table 4: Load flow results of Base case Phase1

V	1.050	1.050	1.070	0.952	0.983	1.004
Del	0.000	-6.272	-6.349	-8.067	-6.603	-8.040
Pg	113.36	50.00	60.00	0	0	0
Qg	-13.86	116.04	90.87	0	0	0
PD	0	0	0	0	70.00	70
QD	0	0	0	0	70.00	70

Table 5: Load flow results of Base case Phase2

Pline	49.50	63.86	-0.66	66.56	8.86	22.10	15.16	44.16	-7.70	5.36	8.36
Qline	-23.66	9.79	-10.27	69.44	18.42	13.91	26.10	61.11	-7.08	-11.57	-7.86
MVA(S)	54.86	64.60	10.29	96.19	20.44	26.11	30.18	75.40	10.46	12.75	11.65

The simulation result proves and that the number of voltage magnitude among 6 buses are predicted as safe or unsafe that is whether lines are violated or not. If violate 0 is assigned for its corresponding bus magnitude and if not violate, 1 is assigned for its corresponding bus magnitude of the buses.

Table 6: Checking the Limits of V magnitude and Line MVA

<table>
<tr><th colspan="2">V Check</th><th colspan="2">Line MVA Check</th></tr>
<tr><td>Limit imposed</td><td>0.955 - 1.05 (for load buses)</td><td>Limit imposed</td><td>130 percentage of its base value</td></tr>
<tr><td rowspan="3">V magnitude violation check (1,0) if violated-0 not violated-1</td><td rowspan="3">1 1 0 0 1 1</td><td>Line MVA limit</td><td>52, 52 ,52, 78, 39, 117, 91, 104, 26, 52 ,52</td></tr>
<tr><td>Line MVA overload in %</td><td>105.5038, 124.2394, 19.7835, 123.3238, 52.4196, 22.3184,33.1656, 72.4979, 40.2445, 24.5273</td></tr>
<tr><td>Line MVA index (if violated-0 not violated-1)</td><td>0 0 1 0 1 1 1 1 1 1 1</td></tr>
</table>

Under static security evolution considering n-1 outage, most overload lines and bus voltages with line MVA and bus voltage violation are recorded. Table 6 shown the limitation of Vmag& MVA Check

Case study 2: Simulation results exposes Security enhancement

Security enhancement procedure must be originated when the system proves sufficient success in the static security Assessment process. To identifying the most demanded line is separated optimized can be called to find the exact location and size of the FACT devices

Table 7: Overloading and Violations before placing of TCSC

Contingency Ranking (manual method)	
Overloaded lines:	1-5, 1-2, 2-4 (3)
% Over loading:	126.6598, 106.0548, 124.8578 (3)
Voltage violation at buses:	4 (1)

Table 8: Parameters of GA

Parameters of GA	
Number of variables:	*2*
Length of individual:	*3*
Population size (np) of individuals:	*30*
Maximum number of generations (gmax):	*100*
Number of offspring per pair of parents:	*1*
Crossover fraction:	*0.8*
Selection function:	*Stochastic uniform*
Crossover function:	*Scattered*

This GA-based multi-objective optimization is applied with overload lines with its limits, Voltage violation at buses on the IEEE test case. GA-based optimization parameters and the process of a random population of the reactance of Xtcsc are tabulated that shown in table 7, 8, and 9. Simulation results reveals that the optimal placement of TCSC given by GA is branch number 5 [Line between bus no 2 & 4] and optimal setting of TCSC given by GA is -0.0393.

Table 9: Optimal placement and setting of TCSC

OPTIMAL PLACEMENT OF TCSC BY GA	*BRANCH 5(2-4)*
OPTIMAL SETTING OF TCSC BY GA	*-0.0393 (0.5 <xTcsc<=_0.5)*
OVERLOADED LINES	*1-2, (1)*
% OVER LOADING	*123.2848*
VOLTAGE VIOLATION AT BUSES	*NIL*

Table 10: Random population of Xtcsc Generated by GA

Population size (np)	**Xtcsc**	**Population size (np)**	**Xtcsc**	**Population size (np)**	**Xtcsc**
10.0000	-0.4674	7.0000	-0.3794	1.0000	-0.1237
9.0000	0.0612	7.0000	0.0895	6.0000	-0.3091
9.0000	0.3819	1.0000	-0.2738	5.0000	-0.0717
3.0000	0.1692	1.0000	-0.1154	7.0000	-0.018
6.0000	-0.3096	4.0000	0.083	6.0000	0.2302
1.0000	-0.1311	6.0000	-0.2482	4.0000	-0.1561
5.0000	-0.0393	7.0000	-0.2096	2.0000	0.0841
4.0000	0.4816	5.0000	0.1171	7.0000	-0.3922
2.0000	-0.3436	9.0000	-0.2347	2.0000	0.3555
5.0000	0.1448	8.0000	0.3244	10.0000	0.4827

CONCLUSION

This paper has presented a model based on Multi objective optimization using GA.This optimizer helps to enhance the security of the power system with ***n-1*** contingency and attains optimal place and size of TCSC. There are two main contributions have been achieved from its simulation results. First, we characterize for security assessment of IEEE 6 bus system that can be easily processed by load flow analysis using Newton Rapson method and it acknowledges that the safe and unsafe operating points exactly. Secondly, security enhancement process has been carried out with and without TCSC implementations and its results are compared. from the simulation results, seen that voltage violation at the buses and overloading percentage atall the lines, so as to bear optimal setting and placement of FACT device successfully. In future, this work will be extended with the implementations of different FACT devices, new methodologies proposed for place and sizing of FACT devices is possible.

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