Optimal Location and Sizing of Multi Type Facts Devices using Grey Wolf Optimization Technique

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Abstract— In this paper, Flexible AC Transmission System (FACTS) devices are optimally located in a power network to reduce the transmission line losses. FACTS devices are used in transmission system to control the system performance. The location of FACTS devices and the setting of their control parameters are optimized by Grey Wolf Optimization Technique (GWO) to improve the performance of the power network. The FACTS devices namely SVC (Static VAR Compensator) and TCSC (Thyristor Controlled Series Compensator) are considered to reduce transmission line losses. The proposed system is used to control the main parameters namely voltage, phase angle and impedance, which is affecting AC power transmission. Proposed algorithm is tested on IEEE 118 bus system for optical location & sizing of multi type FACTS devices & the system loadability gets improved and the transmission line losses are reduced.

Key words: Grey Wolf Optimization Technique (GWO), Optimal Power Flow, Static VAR Compensator (SVC), System Loadability Limits, Thyristor Controlled Series Compensator (TCSC), voltage stability margin

I. INTRODUCTION

Nowadays power systems are developed and widely interconnected, the operation of power system becomes more complex because of increasing load demand. In many cases, generation is far away from the load and critical to transmit a power to huge loads on long distance [1,2]. Enhancement of transmission line loadability is essential, because of stable power supply for many industries in daily operation. The development of power electronics, Flexible AC Transmission System (FACTS) devices has been implemented in power systems [3, 4, 5]. FACTS devices namely Thyristor Controlled Series Compensator (TCSC), Static VAR Compensator (SVC), Static Compensator (STATCOM), Unified Power Flow Controller (UPFC), etc. These devices can provide more flexible operation of power system[6,7,8].

Series compensation device namely Thyristor Controlled Series Compensator (TCSC) and shunt compensation devices such as Static VAR Compensator (SVC) and Static Synchronous Compensator (STATCOM). Unified Power Flow Controller (UPFC) can provide both series and shunt compensation [9, 10, 11]. The FACTS devices are optimally located by using optimization techniques. The system loadability can be improved by optimal location & sizing of FACTS devices [12, 13, 14]

In this paper, GWO technique is used to find the optimal location & sizing of multi type FACTS devices. SVC & TCSC devices are considered to improve the transmission line loadability. TCSC can change the line resistance by connecting a variable resistance in series with the line. It may reduces the real power losses. The Static VAR Compensator (SVC) can inject or generate the reactive power on the transmission line. Simulations are carried out on IEEE 118-bus systems and the results are discussed.

II. MODELLING OF FACTS DEVICES

The two types of FACTS devices are considered namely static VAR compensator (SVC) and thyristor controlled series capacitor (TCSC).

A. Static Var Compensator (SVC):

SVC consists of a Thyristor Controlled Rectifier (TCR) in parallel with a bank of capacitor. It regulates voltage terminals by controlling the amount of reactive power injection or absorption. The reactive power generation or absorption depends on the system voltage level low or high respectively.

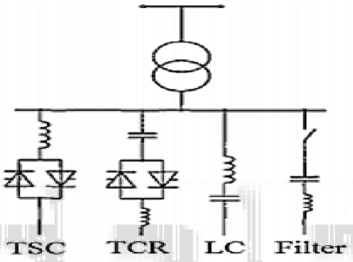

Fig. 1: Static Var Compensator

B. Thyristor Controlled Series Capacitor (TCSC):

Thyristor Controlled Series Capacitor (TCSC) is a series compensation device, which control the reactacnce in the transmission line. The TCSC have two characteristics such as capacitive or inductive, corresponding to the reactance of the line, $X_{line,}$ decreasing or increasing, respectively. The capacitance or inductance value of the TCSC is denoted as X_{TCSC}.

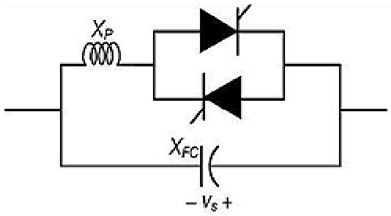

Fig. 2: Thyristor Controlled Series Capacitor

$$X_{ij}=X_{line}+X_{TCSC} \qquad (1)$$

Where,

X^{TCSC} = compensation factor of TCSC.
X^{line} = reactance of transmission lines.

Where X_{line} is reactance of transmission line. Rating of TCSC is depended on transmission line where it is located.

III. PROBLEM FORMULATION

A. Objective Function:

The objective function is to maximize system loadability. It can be achieved by load factor (λ) of the system will be increased in an iterative process. Initial condition load factor is equal to 1(λ_0=1).

$$g(x,v)=0 \qquad (2)$$

Where,

x= System Variable Vector

$$x=[V\ \theta]^T \qquad (3)$$

v=Control Variable Vector

$$v=[P_g\ C_f\ F]^T \qquad (4)$$

Subject to the both equality & inequality constraints:

1) Equality Constraints:

The equality constraints g(x,u) are the nonlinear power flow equations,

$$P_{G_i} = P_{D_i} + V_i \sum_{j=1}^{N_i} V_j (G_{ij}\cos\theta_{ij} + B_{ij}\sin\theta_{ij}) \quad i = 1, \cdots, N_0, \qquad (5)$$

$$Q_{G_i} = Q_{D_i} + V_i \sum_{j=1}^{N_i} V_j (G_{ij}\sin\theta_{ij} + B_{ij}\cos\theta_{ij}) \quad i = 1, \cdots, N_{PQ}, \qquad (6)$$

2) Inequality Constraints:

The inequality constraints h(x,u) are limits of control variables and state variables.

$$P^{min}_{Gi} \leq P_{Gi} \leq P^{max}_{Gi} \qquad (7)$$

$$Q^{min}_{Gi} \leq Q_{Gi} \leq Q^{max}_{Gi} \qquad (8)$$

$$V^{min}_{Gi} \leq V_{Gi} \leq V^{max}_{Gi} \qquad (9)$$

Where,

P_{Gi}= Real power generation at bus i.

Q_{Gi}= Reactive power generation at bus i.

V_{Gi}= Voltage at generator bus i

B. Optimal Location & Sizing of SVC:

The SVC can be used to control reactive power in the system. It may be installed at midpoint of the transmission interconnections or in load areas. It can be used for both inductive and capacitive compensation.

$$lo_{min} \leq lo_{svc} \leq lo_{max} \qquad (10)$$

$$Q_{min} \leq Q_{svc} \leq Q_{max} \quad ; \quad -100 \leq Qsvc \leq 100 \qquad (11)$$

Where,

Qmin= minimum reactive power of svc

Qmax= maximum reactive power of svc

lo_{svc}= Optimal location of svc to be place

Q_{SVC} = Optimal size of SVC

C. Optimal Location & Sizing of TCSC:

The TCSC can allow rapid & continous changes of the transmission line impedance. It can provide continuous control of power on the ac line over a wide range. The line reactance values between -0.8 to 0.2.

$$lo_{min} \leq lo_{tcsc} \leq lo_{max} \qquad (12)$$

$$X_{min} \leq X_{tcsc} \leq X_{max} \qquad -0.8 \leq Xtcsc \leq 0.2 \qquad (13)$$

Where,

Xmin = minimum value of tcsc reactance

Xmax = maximum value of tcsc reactance

lo_{tcsc} = optimal location of TCSC to be place

X_{tcsc} = optimal size of TCSC

IV. GREY WOLF OPTIMIZATION TECHNIQUE

The GWO technique was proposed by Mirjalili et al. in 2014 [1]. This algorithm based on hunting mechanism of grey wolves in nature. It prefer to live in a pack. The size of the pack is 5-12 on average.

Steps for hunting:

Searching for prey:

It mostly search according to the position of the alpha, beta & delta. It vary from each other to search for prey & covered to attack prey.

1) Encircling Prey:

During hunting it encircling the prey. The behavior of the encircling is

$$D = |c.\ X_p(t) - X(t)| \qquad (14)$$

$$X(t+1) = X_p(t) - A.\ D \qquad (15)$$

where,

t - current iteration

A & D - co-efficient vectors

X_p - Position vector of the prey

X - Position vector of the grey wolf

A & C are calculated by

$$A= 2a.\ r_1 - a \qquad (16)$$

$$C=2.\ r_2 \qquad (17)$$

Where,

r_1, r_2 - random vectors

a - linearly decreased from 2 to 0

2) Attacking prey:

The prey will decrease the value of a after the hunting is finished. The variation range of A is also decreased by a.

Types of Grey wolves are:

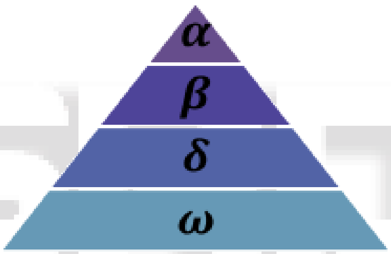

Fig 1: Types of Grey Wolf

1) Alpha: Alpha is the leader of the pack, it may be male or female. It is the responsible for making decisions about hunting, sleeping, place & time to wake. It is not necessary to be a strongest member of the pack but it must have the capability of managing the pack.
2) Beta: It helps the alpha to make decision making or other pack activities.It can be either male or female. When one of the alpha wolf passes away or becomes very old the best candidates of the beta to be an alpha. It should respect the alpha command and passes throughout the pack & given feedback to the alpha.
3) Delta: Delta wolves have to obey the alphas & betas command, but they dominate the omega. Scouts, sentinels, elders, hunters & caretakers belong to this category.
4) Omega: Omega is not an important individuals in the pack. It always have to submit to all the other dominant wolves. It helps to satisfy the entire pack & maintain the structure. Some cases omega is the babysitter in the pack.

V. SIMULATION RESULT AND DISCUSSIONS

The proposed algorithm is tested on IEEE 118 bus system. The system contains 186 branches, 91 load sides & 54 thermal units. SVC can be placed on the bus through the shunt connection. The location & sizing of SVC & TCSC have been found by using GWO.

For IEEE118 bus system has 26 control variables, such as location & sizing of SVC & TCSC (L1 to L26).

A. Comparison of Power Losses before and After Compensation:

Power losses are tabulated and compared with before and after compensations that can be seen in following table.

SI.NO	**DEVICE**	**REAL POWER LOSS (MW)**	**REACTIVE POWER LOSS (MVAR)**
1	WITHOUT FACTS DEVICE	277.483	802.44
2	WITH FACTS DEVICE	238.045	778.62

Table 1: Real & Reactive Power Losses Without & With FACTS Devices

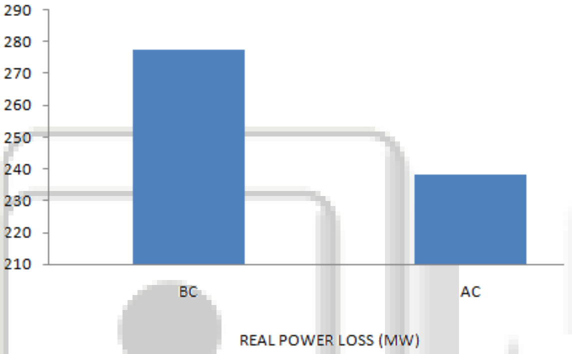

Fig. 2: Comparison of Real Power Loss

The real power losses have been reduced to 238.045MW from 277.483MW, after the devices are located at appropriate place.

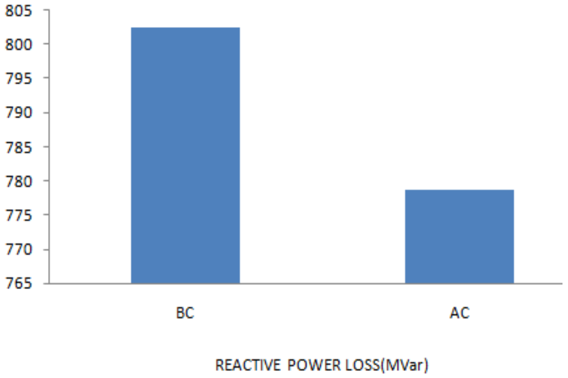

Fig. 3: Comparison of Reactive Power Loss

Thus same, the reactive power losses are reduced to 778.62 MVar from 802.44 MVar, the devices have been located at the appropriate place.

B. Optimal Location And Size Of Multi Type Facts Devices:

The optimal location & sizing of multi type FACTS devices have been achieved by GWO. TCSC is a series controller, have been placed on branch 19-21 with optimal size of -0.2020 (reactance in p.u) and branch 25-26 with optimal size of 0.2887 (reactance in p.u). SVC is a shunt controller & have been placed on 107, 3 5 & 6 bus.

FACTS DEVICES	OPTIMAL LOCATON	OPTIMAL SIZING(P.U)
SVC1	Bus 107	0.4585 (MVAR)
SVC2	Bus 3	-0.1417 (MVAR)
SVC3	Bus 5	1.3349(MVAR)
SVC4	Bus 6	5.0928(MVAR)
TCSC1	Branch55-56	0.0420 (Reactance)
TCSC2	Branch 9-10	0.4624 (Reactance)
TCSC3	Branch 4-11	0.0619 (Reactance)

Table 2: Optimal Location and Size Data of Multi Type Facts Device

C. Voltage Level Comparison With And Without Facts Devices:

The multi-type FACTS devices are located at their appropriate locations, voltage profile has been improved.

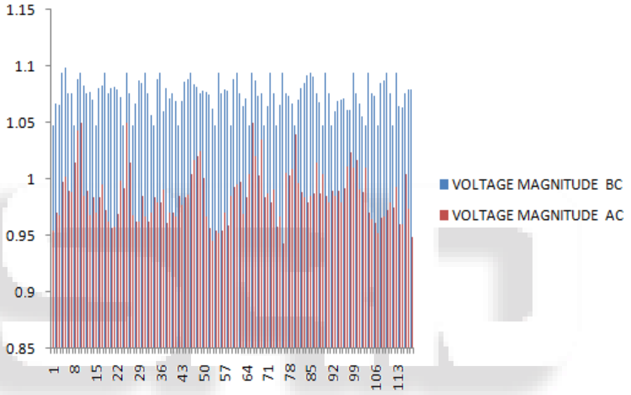

Fig. 4: Voltage Magnitude BC & AC

VI. CONCLUSION

This paper made to find the optimal location & sizing of SVC and TCSC devices to reduce the transmission line losses on the power network. SVC can improve the voltage profile & TCSC can reduces the real power losses. By using the GWO, the given devices can be located at optimal place & sizing on the power system to reduce power losses and to maintain system voltage at rated level. The proposed method has been tested for IEEE 118 bus system under different loading conditions.

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