AN EFFECTIVE HSA APPROACH FOR OPTIMAL PLACEMENT OF SVC

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ABSTRACT

Voltage stability problems have been one of the major concerns for electric utilities as a result of which systems are subjected to heavy loading. Because of this heavy loading, power systems are closer to their stability margins and voltage collapse. Voltage instability is a major problem that usually occurs in the heavy loading electric power systems and causes voltages to decline. Voltage collapse may lead to the blackout if suitable monitoring is not done and appropriate preventive control methods are not used. In this project a new method of optimal placement of Static Var Compensator (SVC) based on Harmony Search algorithm (HAS) is presented and effectively implemented. A comparison has been made for the Fast Voltage Stability Index (FVSI) with and without placing SVC. The MATLAB simulations are performed on IEEE 30 bus test system. It was found that, the efficiency of FVSI has been considerably increased. The simulations results show that there is reduction in the total SVC cost, and also there is reduction in total power loss. With increase in the fitness value function there is improvement in the power system voltage stability.

Keywords - Fast Voltage Stability Index, SVC, Harmonic Search Algorithm

I INTRODUCTION

Power systems operated close to their thermal and stability limits due to the some of constraint such as right-of-way, cost problems for power transmission network expansion and environmental concerns [1]. Difficulties encountered in building new lines and the cost of transmission lines would often limit the available transmission capacity. This limitation is important because there are many cases where economic energy or reserve sharing is constrained by transmission capacity. Besides, in a deregulated electric service environment, the competitive environment of reliable electric service is highly dependent on effectiveness the electric grid [1]. Increasing demands, and the growing need to provide open access electricity market for Generating Companies and utility customers, have created tendencies toward reduced quality of supply and less security. Flexible AC Transmission Systems (FACTS) devices can be introduced as an appropriate tool to overcome this problem without the drawbacks of the electromechanical devices such as slowness and mechanical loss. FACTS devices can improve the performance of the network in some areas, such as transient and small signal stability, reduce the power flow of heavily loaded lines and support voltages. This improvement is done by controlling these devices parameters including series impedance shunt impedance, current, voltage amplitude and phase angle. Controlling power flow in the network leads to balanced load sharing among the lines, less system loss and improved the system security. On account of considerable costs of FACTS devices, it is important to place them in optimal location in the power system for their efficient usage. There are several papers presented in the literatures, which deal with the optimal placement of FACTS devices in the power system with meta-heuristic methods [1, 3].In this paper, the Harmony Search Algorithm (HSA) has been used to find the optimal location of the shunt FACTS device (i.e. SVC) to keep the power system voltage stability index in a desired margin.

The SVC ***(Static Var Compensator)*** may have two character inductive or capacitive, respectively to absorb or provide reactive power. The SVC is represented by a shunt Variable susceptance inserted in the bus or at the mid-point of the line. It may take values characterized by the reactive power *Qsvc* injected or absorbed at the voltage of 1 p.u.fig 1 show circuit diagram of svc connected to infinite bus

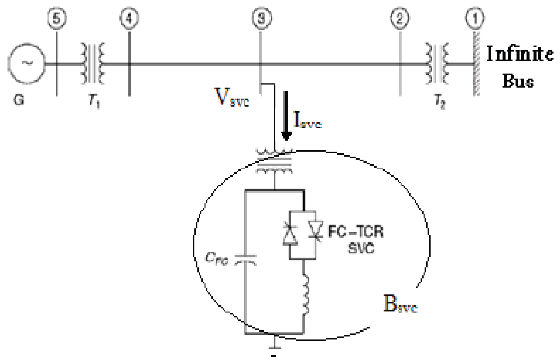

Fig.1. Circuit Diagram of SVC Connected To an Infinite Bus

II FAST VOLTAGE STABILITY INDEX (FVSI)

It is formulated as a predicting index of the voltage stability condition in the system. The mathematical formulation is very simple that could speed up the computation. The proposed index is based on the same concept as the existing ones in which discriminant is set to be greater than or equal to zero to achieve stability[6]. If the discriminant is smaller than zero, the roots of voltage or power quadratic equations will have imaginary part that could cause instability in the system. The condition of voltage stability in a power system can be characterized by the use of the voltage stability index. This index can rather be referred to a bus or a line. The voltage stability index developed in this study is referred to a line. Generally, it starts with the current equation to form the power or voltage quadratic equations. The criterion employed in this paper is to set the discriminant of the roots of voltage or power quadratic equation to be larger than zero. When the discriminant is less than zero, it causes the roots of quadratic equations to be imaginary which in turn causes voltage instability that may lead to voltage collapse in the system.

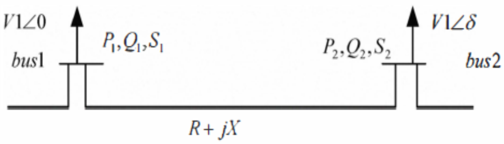

Fig 2 2-bus power system model

The line index that is evaluated close to 1.00 will indicate the limit of voltage instability Fig 2 illustrates a 2-bus power system model that the proposed FVSI is derived from. Taking the symbol “I” as the sending bus and "j” as the receiving bus, the fast voltage stability index, FVSI can be defined by:

$$\mathrm{FVSI}_{ij} = \frac{4Z^2 Q_j}{V_1^2\ X}$$

A value close to 1.0 for FVSI indicates that the particular line is close to its instability point which may lead to voltage collapse in the entire the power system. To maintain a secure condition the value of FVSI should be maintained well below 1.0. In the two bus system shown in fig. 1,the FVSI can decrease by using reactive compensator in the bus 2 that leads to increase in Vi and decrease in Q2 and in turn results in lower FVSI. In the large and specially interconnected power system the location and amount of reactive compensation cannot be easily determined and the place of installing the compensator and the amount of reactive power generation should be determined by solving the optimization problem that try to minimize the FVSI by changing the place and amount of reactive compensation in different buses. Lower FVSI shows the more stable system.

Minimize the investment cost

The total SVC cost in US$/kVAr are given as

$\mathbf{C}_{\mathbf{SVC}}=\sum_{k=1}^{n} 0.0003Q_k^2-0.3051Q_k+127.38$

Where Qk is the reactive power capacity of kth installed SVC, in MVar.

III HARMONIC SEARCH ALGORITHM

The harmony search algorithm (HSA) has been developed in an analogy with the music improvisation process where music players improvise the pitches of their instruments to obtain better harmony .

The steps in the procedure of harmony are as follows;

Step 1: Initialize the problem and algorithm parameters. The optimization problem is specified as:

Min $\{f(x)\backslash x\in X\}$ subject to $g(x)\geq 0$ and $h(x) = 0$. (3.1)

Where f(x) is the objective function,

g(x) is the inequality constraint function and

h(x) is the equality constraint function.

x is the set of each decision variable,

x_i , and X is the set of the possible range of values for each decision variable, that is $X_{i,min}\leq x_i\leq X_{i,max}$ where $X_{i,min}$, and $X_{i,max}$, are the lower and upper bounds for each decision variable, respectively.

The HAS algorithm parameters are also specified in this step. These are the

1. Harmony memory size (HMS),
2. Harmony memory considering rate (HMCR);
3. pitch adjusting rate (PAR); number of decision Variables (N) and the
4. Number of improvisations (NI), or stopping criterion.
5. The harmony memory (HM) here HMCR and PAR are parameters that are used to improve the solution vector both of them are defined in Step 3.

Step 2: Initialize the harmony memory

In Step 2, the HM matrix will be filled with as many randomly generated solution vectors as the HMS.

$$HM = \begin{bmatrix} x_1^1 & x_2^1 & \cdots & x_{N-1}^1 & x_N^1 \\ x_1^2 & x_2^2 & \cdots & x_{N-1}^2 & x_N^2 \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ x_1^{HMS-1} & x_2^{HMS-1} & \cdots & x_{N-1}^{HMS-1} & x_N^{HMS-1} \\ x_1^{HMS} & x_2^{HMS} & \cdots & x_{N-1}^{HMS} & x_N^{HMS} \end{bmatrix} \quad (3.2)$$

Step 3: Improvise a new harmony

A New Harmony vector, xl = (x'1, x'2... x'N), is generated based on three rules:

(1) Memory consideration,

(2) Pitch adjustment and

(3) Random solution generation.

Creating a new harmony is called 'improvisation'

Xi'← {xi' ∈ {xi^1,xi^2… xi^HMS} with probability HMCR (3.3)

{xi' ∈ Xi with probability (1-HMCR)

Pitch adjusting decision for:

xi' ← {Yes with probability PA R (3.4)

{ No with probability (1 -PAR)

The value of (1 - PAR) sets the rate of doing nothing with the decision variable value. If the pitch adjustment decision for xi' is Yes, xi' is replaced as follows:

xi'← xi'± rand()^*b_w (3.5)

Where b_w is the distance bandwidth that is set in step 1, rand () is a random number between 0 and 1.

In Step 3, HM consideration, pitch adjustment or random selection is applied to each variable of the New Harmony vector in turn.

Step 4: Update harmony memory

If the new harmony vector, xI '= (xI ',x2',. .. ,x'N) is better than the worst harmony in the HM, that is judged in terms of the objective function value, the new harmony is included in the HM and the existing worst harmony is excluded from it.

Step 5: Check stopping criterion

If the maximum number of improvisations is reached, computation is terminated. Otherwise, Steps 3 and 4 are repeated. Fig 3 gives the flow chart of HSA

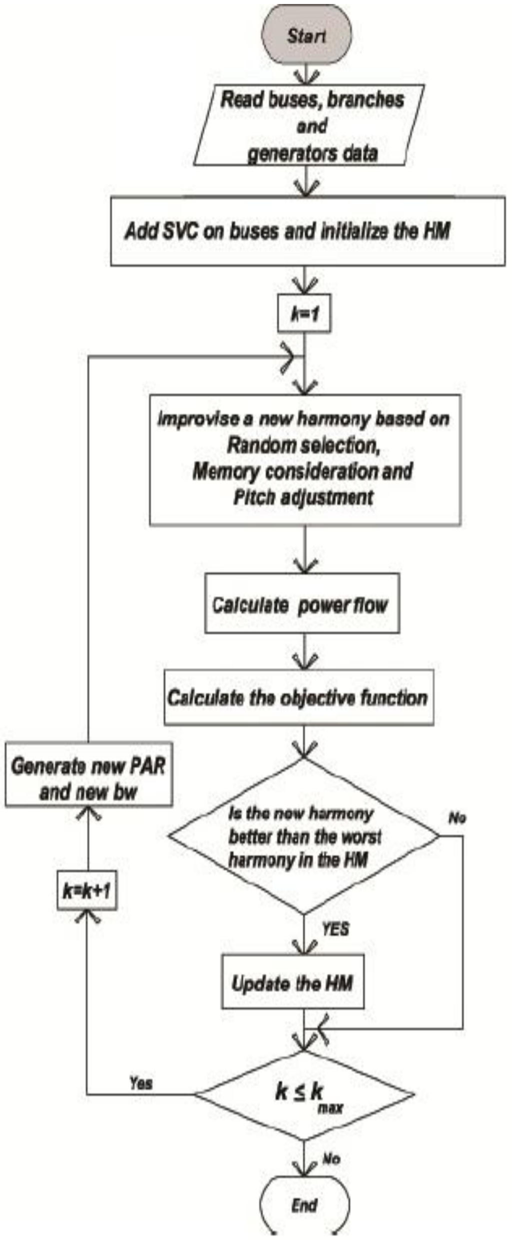

Fig 3: HSA Flow Chart for Placing SVC

IV SIMULATION RESULTS

Optimal allocation of SVC shunt compensator in a bus has been solved by the harmony search algorithm (HSA) on the IEEE 30-bus standard test case (Fig. 4).

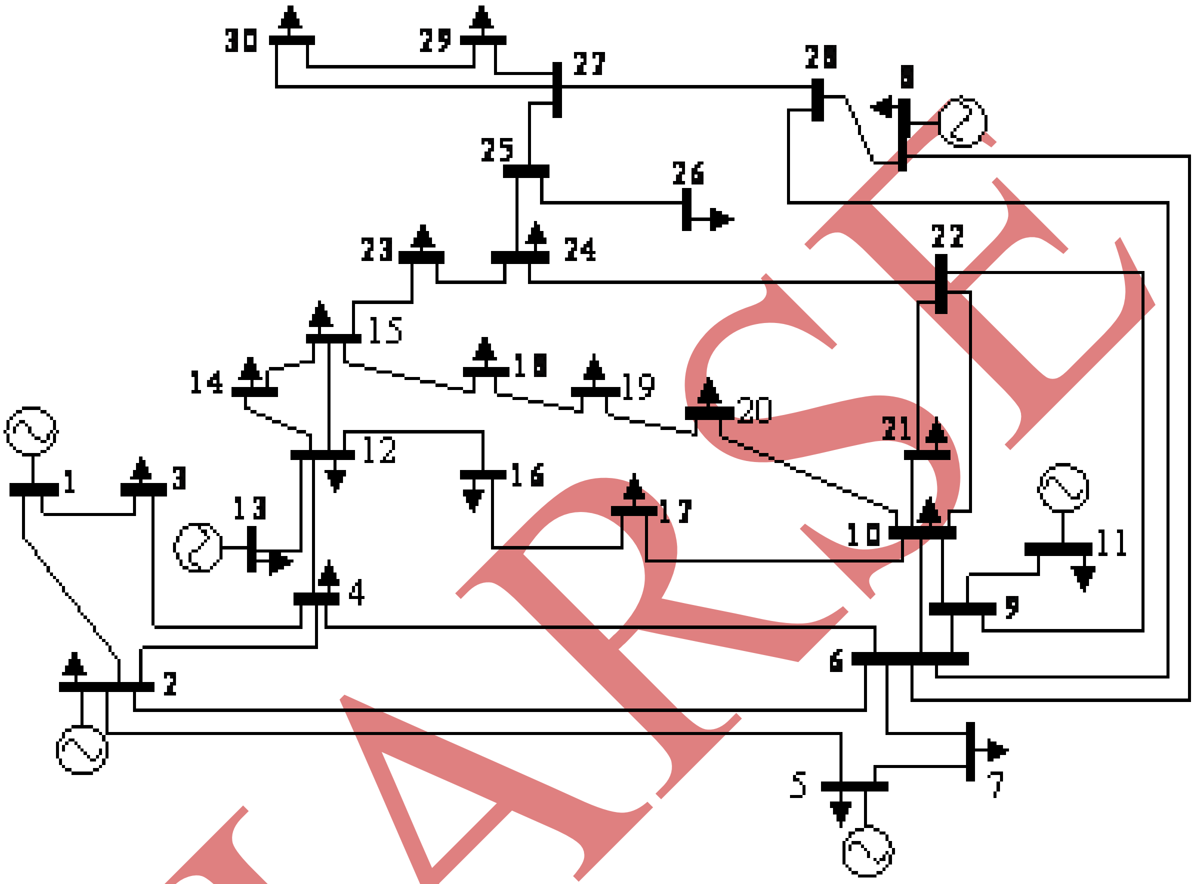

Fig. 4: IEEE 30 Bus Standard Test Cases

In order to consider voltage stability margins and also injected reactive power, the objective function has been defined as follows:

OBJECTIVE FUNCTION = $C_1 \sum_{i=1}^{Nline} FVSI_i^2 + C_2 \sum_{i=1}^{Nbus} Q_2(injected)$

0.95 p.u.$\leq V_i \leq 1.05$p.u.$(1 \leq i \leq 30)$

The test case is IEEE 30-bus network, so Nbus=30 and NLine = 41. Cl and C2 are weighting

This determines which of the Objectives have greater priority in a multi objective problem. These parameters have been set to 1 and 2 respectively because we prefer minimization of the injected reactive power because of its cost.

Fig 5: The compensators should be placed at buses 15, 25, 26, 27, 29 and 30 graph plotted the bus number verus voltage in pu. It shown in figure6.5. Here voltage stability index comparsion is made before and after placing SVC. It was found without placing SVC for 30 bus system voltage at bus 7 is nearly to 1 p.u.then we can see rise in upto maximum voltage upto 1.08 p.u.and then sudden drop in voltage. Therefore after placing SVC we can see efficiency in voltage stability index upto 1p.u respectively

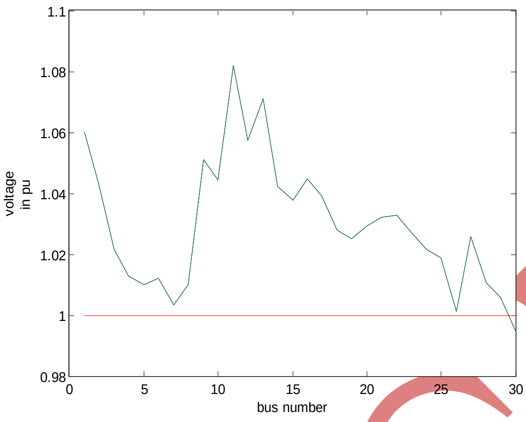

Fig: 5: Stabilized Voltage Profile

Table:1 According to table below the compensators should be placed in these buses and setting of FVSI

BUS NUMBER	QSVC	FVSI
15	0.8003	1
25	0.6787	1
26	0.7577	1
27	0.7431	1
29	0.6555	1
30	0.1712	2

OBJECTIVE FUNCTION	AFTER INSTALLING SVC USING HSA
Total Economic cost($)	892.874
Total power Loss (kW)	0.6472
Fitness value function	0.001000

Table 1: Final Values of HSA Findings

Table 2: Objective Function After Installing SVC

V CONCLUSION

In this project a new method of optimal placement of SVC based on HSA is presented and implemented for a standard IEEE 30 bus system. Simulation results shows that fast voltage stability index is improved to 1p.u after placing the SVC. A comparision is done for fast voltage stability index with and without placing SVC for 30 bus system. From the result it is observerd total real power loss is reduced to 17.59MW to 0.6472Kw and it minimize total SVC cost to 892.87$ after placing SVC. This algorithm is practical and easy to implement with view of future in large scale power system.

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