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# Best Power Surge Using Fuzzy Controlled Genetic Technique

K.Bhanu Kiran[1] & Dr.M.Ramkumar Prabhu[2]
[1]*Research Scholar, Bharath University, Chennai.*
[2]*Professor, Dhaanish Ahmed College of Engineering, Chennai.*

***Abstract:*** *This paper presents a novel method for optimal location of FACTS controllers in a multi machine power system using Fuzzy Controlled Genetic Algorithm (FCGA). Using the proposed method, the location of FACTS controller, their type and rated values are optimized simultaneously. Among the various FACTS controllers, Thyristor Controlled Series Compensator (TCSC) and Unified power Flow Controller (UPFC) are considered. The proposed algorithm is an effective method for finding the optimal choice and location of FACTS controller and also in minimizing the overall system cost, which comprises of generation cost and investment cost of FACTS controller using Genetic Algorithm, Fuzzy Logic and conventional NR power flow method.*
*Optimal Power Flow (OPF) is one of the most important processes in power system, which improves the performance of system by satisfying certain constraints. There are so many methods were used in the literature to solve the OPF problem. Furthermore, to solve the OPF problems, several heuristic algorithms such as evolutionary programming (EP), Tabu Search (TS), Hybrid Tabu Search and Simulated Annealing (TS/SA), Improved Tabu Search (ITS) and Improved Evolutionary Programming (IEP) have been already proposed. In this paper IEEE standard 14 & 30 bus systems taken as the reference bus systems to obtain the optimal solution. Here various FACTS devices (SVC, TCVR) were incorporated to obtain the feasible solution of OPF Problem. Simulation results shown that the obtained output is feasible and most accurate solution in the OPF solution. FACTS devices can direct the active and reactive power control and flexible to voltage-magnitude control simultaneously, because of their adaptability and fast control characteristics. With the aid of FACTS technology, namely Static Var Compensator (SVC), Thyristor Switched Capacitor Variable Reactor (TCVR) and Unified Power Flow Controller (UPFC) etc., the bus voltages, line impedances and phase angles in the power system can be controlled quickly and flexibly. In my paper IEEE standard 14 & 30 bus systems were taken for obtaining optimum solution.*

***Index Terms***: *OPF, EP, TS, SA, ITS, IEP, TCVR, FACTS controller,SVC, UPFC*

## I. Introduction

In present days with the deregulation of electricity market, the traditional practices of power system have been completely changed. Better utilization of the existing power system resources to increase capabilities by installing FACTS controllers with economic cost becomes essential. The parameters such as transmission line impedances, terminal voltages and voltage angle can be controlled by FACTS controllers in an efficient way. The benefits brought about FACTS include improvement of system dynamic behavior and enhancement of system reliability. However their main function is to control of power as ordered.

The objective of this thesis is to develop an algorithm to simultaneously find the real power allocation of generators and to choose the type and find the best location of FACTS controllers such that overall system cost which includes the generation cost of power plants and investment cost of FACTS are minimized using Genetic Algorithm and conventional

**NR power flow analysis.**

The possibility of operating power systems at the lower cost, while satisfying the given transmission and security constraints is one of the main current issues in elongating the transmission capacity through the use of FACTS devices. FACTS devices can direct the active and reactive power control and flexible to voltage-magnitude control simultaneously, because of their adaptability and fast control characteristics. With the aid of FACTS technology, namely Static Var Compensator (SVC), Static Synchronous Compensator (STATCOM), Static Synchronous Series Compensator (SSSC) and Unified Power Flow Controller (UPFC) etc., the bus voltages, line impedances and phase angles in the power system can be controlled quickly and flexibly.

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## II. Problem Formulation

### A. Optimal Placement of FACTS Devices

The essential idea of the proposed multi type FACTS devices, UPFC and TCSC placement approaches is to determine a branch which is most sensitive for the large list of single and multiple contingencies. This section will describe the definition and calculation of the contingency severity index CSI and the optimal placement procedure for the UPFC and TCSC.

### B. The participation matrix U

This is an (m x n) binary matrix, whose entries are “1” or “0” depending upon whether or not the corresponding branch is overloaded, where n is the total number of branches of interest, and m is the total number of single and multiple contingencies.

### C. The ratio matrix W

This is an (m x n) matrix of normalized excess (overload) branch flows. It’s (i, j)th element, wij is the normalized excess power flow (with respect to the base case flow) through branch

“j” during contingency “i” and is given by

$$W_{ij} = \frac{P_{ij,cont}}{P_{oj,Base}} - 1 \quad \text{-----------} \quad (1)$$

where,

$P_{ij,\,cont}$ - Power flow through branch “j” during Contingency “i”

$P_{oj,\,Base}$ - Base case power flow through branch “j”.

D.The Contingency probability array P

This is an (m x 1) array of branch outage probabilities. The probability of branch outage is calculated based on the historical data about the faults occurring along that particular branch in a specified duration of time. It will have the following form:

$$P_{mx1} = [p_1, p_2, p_3 .............. p_m]^T \quad (2)$$

**Pi -** Probability of occurrence for contingency “i” **m -** The number of contingencies.

Thus the CSI for branch “j” is defined as the sum of the sensitivities of branch “j” to all the considered single and multiple contingency, and is expressed as

$$SOL = \sum_{C=1}^{M} \sum_{k=1}^{n} a_k (P_k / P_{k\,max})^4 \quad .......... (4)$$

where,

**m-** Number of single contingency considered **n-** Number of lines

**ak-** weight factor=1.
**Pk-** real power transfer on branch k.

**$Pk^{max}$-** maximum real power transfer on branch k. **IC -** Installation cost of FACTS device

**SOL -** Represents the severity of overloading

$$C_{TCSC} = 0.0015S^2 - 0.71S + 153.75 (US\$/KVAR) \quad -(5)$$

$$C_{UPFC} = 0.0003S^2 - 0.2691S + 188.22 (US\$/KVAR) \quad -(6)$$

where, S - Operating range of UPFC in MVAR

$$S = |Q_2 - Q_1|$$

Q1 – MVAR flow through the branch before placing FACTS device.

Q2 - MVAR flow through branch after placing FACTS device. The objective function is solved with the following constraints:

**1. Voltage Stability Constraints**

VS includes voltage stability constraints in the objective function and is given by,

$$VS = \begin{cases} 0 & \text{if } 0.9<vb<1.1 \\ 0.9 - vb & \text{if } vb<0.9 \end{cases} \quad \text{-----------} \ (7)$$

$$CSI_j = \sum_{i=0}^{m} p_i u_{ij} w_{ij} \quad \text{.............} (3)$$

where $u_{ij}$ and $w_{ij}$ are elements of matrices U and W respectively. CSI values are calculated for every branch by using (3).

Branches are then ranked according to their corresponding CSI values. A branch has high value of CSI will be more sensitive for security system margin. The branch with the largest CSI is considered as the best location for FACTS device.

## III. Optimal Settings Of Facts Devices

In this paper UPFC is modeled as combination of a TCSC in series with the line and SVC connected across the corresponding buses between which the line is connected. After fixing the location, to determine the best possible settings of FACTS devices for all possible single and multiple contingencies, the optimization problem will have to be solved using Fuzzy Controlled Genetic Algorithm technique.

The objective function for this work is, Objective = minimize {SOL and IC}

Vb – 1.1 if vb> 1.1

**Vb -** Voltage at bus B

**2. FACTS Devices Constraints**

The FACTS device limit is given by,

$$-0.5 X_L < X_{TCSC} < 0.5 X_L$$

$$-200 \text{ MVAR} \le Q_{SVC} \le 200 \text{ MVAR} \ \text{-------} \ (8)$$

Where,

**$X_L$** - original line reactance in per unit

**$X_{TCSC}$** - reactance added to the line where UPFC is placed in per unit

**Qsvc-** reactive power injected at SVC placed bus in MVAR

**3. Power Balance Constraints**

While solving the optimization problem, power balance equations are taken as equality constraints. The power balance equations are given by,

$\Sigma P_G = \Sigma P_D + P_L$---------- (9) Where, $\Sigma P_G$– Total power generation $\Sigma P_D$– Total power demand
**PL** – Losses in the transmission network

$P_i = \Sigma / E_i / / E_k / [G_{ik} \cos(\theta_i - \theta_k) + B_{ik} \sin(\theta_i - \theta_k)$ ------ (10) $Q_i = \Sigma / E_i / / E_k / [G_{ik} \sin(\theta_i - \theta_k) + B_{ik} \cos(\theta_i - \theta_k)$ ------ (11)
where

**Pi** – Real power injected at bus i. **Qi**– Reactive power injected at bus i.
$\theta_i$ ,$\theta_k$– The phase angles at buses i and k respectively. $E_i$,$E_k$– Voltage magnitudes at bus i and k respectively. $G_{ik}$, $B_{ik}$– Elements of Y – bus matrix.

## IV. Fuzzy Controller And Its Operation

The collection of rules is called a rule base. The rules are in the familiar if-then format, andformally the if-side is called the conditionand the then-side is called the conclusion (more often, perhaps, the pair is called antecedent - consequent or premise -Conclusion ).

A preprocessor, the first block in the structure conditions the measurements before they enter the controller.The first block inside the controller is fuzzification, which converts each piece of input data to degrees of membership by lookup in one or several membership functions. The rules may use several variables both in the condition and exclusion of the rules. The controllers can therefore be applied to both multi-input-multi-output (MIMO) problems and single-input-single-output (SISO) problems.

## V. Opf With Facts Controller Using Simulation

Optimal power flow is one of the important methods used to increase the power flow between the buses. OPF is not only to increase the power flow in the system, but also to generate power based on the requirement with low cost. The power flow between the buses can also be increased by connecting FACTS controller in suitable places. By considering the above problems, here a new method for OPF with FACTS controller using MATLAB Simulation was proposed. Initially, the load flow between the buses is calculated using Newton raphson method and then the amount of power to be generated by each generator is computed using PSO. Finally, the FACTS controller is placed in a suitable location using PSO and Fuzzy Controller to increase the power flow between the buses. The process that takes place in the proposed method is explained briefly in the below sections.

## VI. Load Flow Calculation

The load flow calculation is important to compute the power flow between the buses. In our method Newton raphson method is used for load flow calculation. Newton raphson method is commonly used technique for load flow calculation. The real and reactive power in each bus is computed using equation 1 & 2.

$^{Gik}$ & $^{Bik}$ are the conductance and susceptance value respectively.

After computing the power flow between the lines, the amount of power to be generated for the corresponding load with low cost is identified using PSO. In our method, there are two stages of PSO and a neural network is used. Here, PSO is used for generating training dataset to train the neural network. In the first stage, the amount of power generated by each generator for a particular load is computed using PSO and in the second stage, the bus where the FACTS controller is to be connected is identified and using this data, the neural network is trained. From the output of neural network, the amount of power to be generated by each generator for the given load and the location of FACTS controller to be connected are obtained.

## VII. Identifying Upfc Connecting Bus

In the testing stage, if a bus number except the slack bus given as input, it checks the lines which are connected in that bus and based on the reduce in cost and increase in power flow, the next bus where the UPFC is to be connected and the corresponding voltage and angle to be injected in that bus are obtained as output by the neural network.

By injecting the voltage and angle value to the line that are identified by the network, and using the amount of power generated by each generator that are obtained as an output from the first stage of PSO, the power flow is optimal and reduce in line losses.

## VIII. Result And Discussions

The proposed technique was implemented in the working platform of MATLAB 7.11 and tested using IEEE 30 bus system. The IEEE 30 bus system used in our proposed method is shown in figure 1.

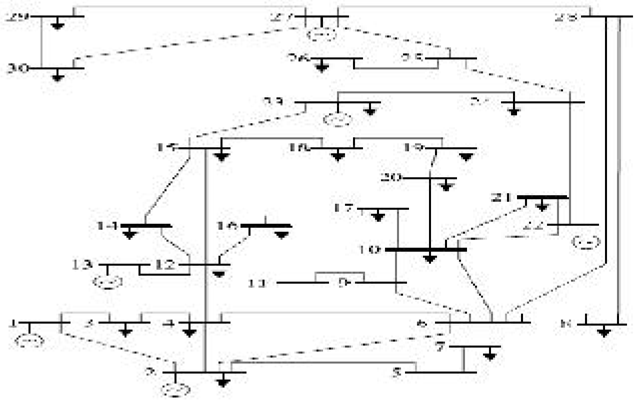


Figure 1: IEEE 30 bus system

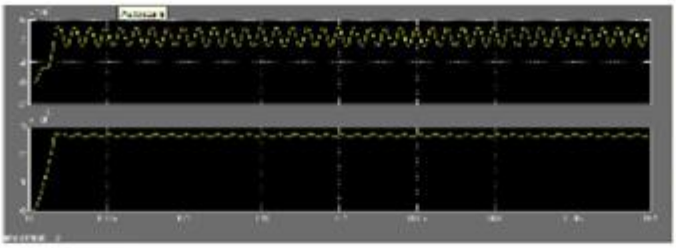
$$P_i = \sum_{k=1}^{N} V_i * V_k \left(G_{ik} * \cos\theta_{ik} + B_{ik} * \sin\theta_{ik}\right) \qquad (1)$$

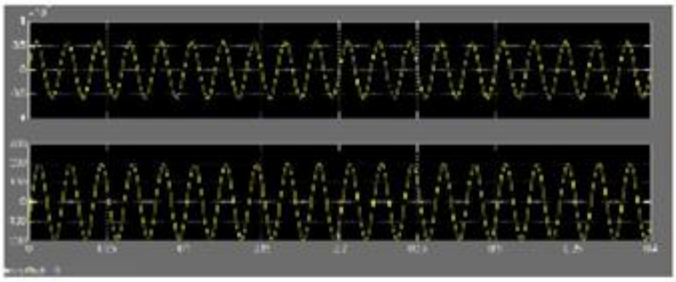
$$Q_i = \sum_{k=1}^{N} V_i * V_k \left(G_{ik} * \sin\theta_{ik} - B_{ik} * \cos\theta_{ik}\right) \qquad (2)$$

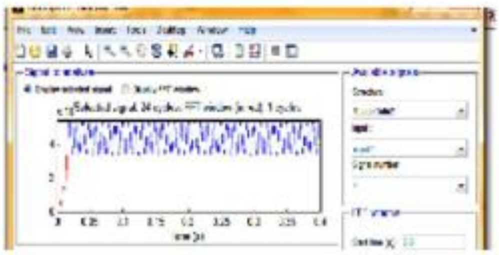
where, $N$ is the total number of buses, $V_i$ & $V_k$ are the voltage at $i$ & $k$ bus respectively, $\theta_{ik}$ is the angle between $i$ & $k$ bus.

In the test system, bus 1 is considered as the slack bus and the base MVA of the system is 100. Bus 2, 13, 22, 23 and 27 are generator bus and all other buses are load bus.

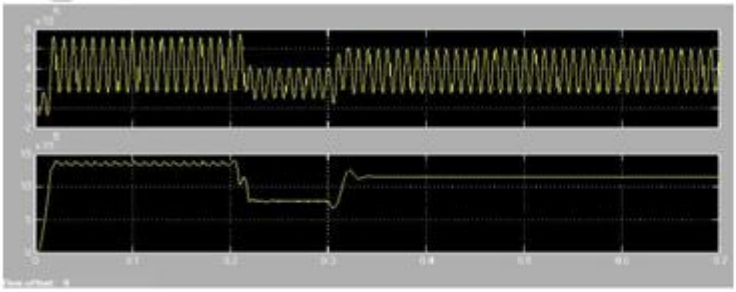
**<u>14 bus system with open loop and SVC :</u>**

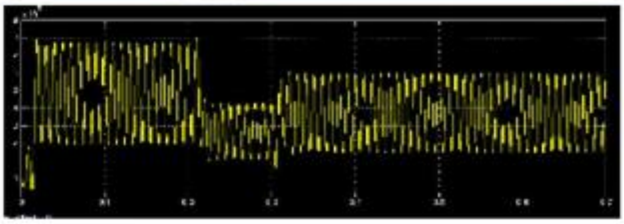




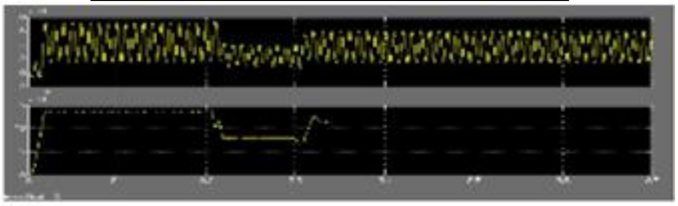


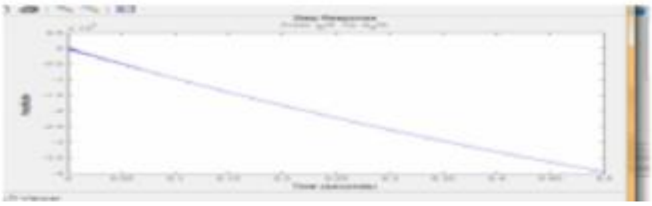
**<u>14 bus system with closed loop SVC</u> :**



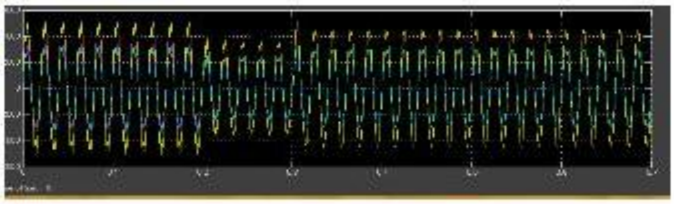


**14 bus system with closed loop and TCVR :**

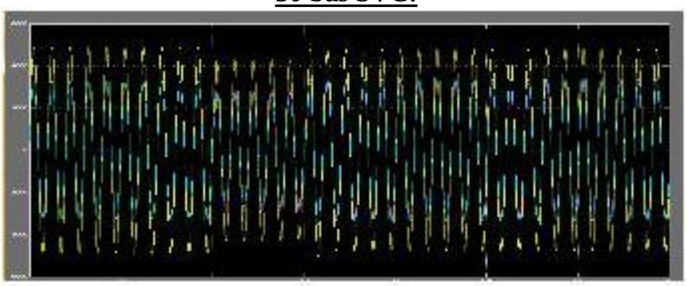




**30 bus closed loop with TCVR :**



**30 bus SVC:**



## IX. Conclusion & Future Scope

In this paper, the proposed method was tested for **IEEE 14 &30 bus system** and FACTS controller used in our method is **SVC and TCVR**. From the above results it is clear that our method has reduced the power losses as well as the total cost in the system.This method to be tested for IEEE 50 bus sytem also in future. Also various FACTS controllers like Static Var Compensator (SVC), Static Synchronous Compensator (STATCOM), Static Synchronous Series Compensator (SSSC) and Unified Power Flow Controller (UPFC) etc., also to be incorporated likely.

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