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POWER SYSTEM FUNCTIONING ENHANCEMENT BY COMPOUND FACTS APPORTIONMENT

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KEYWORDS: ANN, NSGA-II, P&O algorithm, Severity index, flexible AC transmission system, enhance system security.

ABSTRACT
The energy system performance could be enhanced by using the Flexible AC transmission System (FACTS) devices such as, Interline Power Flow controller (IPFC) and Static Series Synchronous Compensator (SSSC). Because of its considerable cost, it is very important to limit the amount of these controllers and locate them optimally in the ability system to be able to achieve an improved utilization of FACTS devices. Firstly, we've applied optimization techniques, namely, Artificial Neural Network (ANN), Elitist Nondominated Sorting Genetic Algorithm(NSGA-II) and Perturb and Observe Method Algorithm (P&O) to learn the perfect amount of multi-devices of Interline Power Flow Controller and Static Series Synchronous Compensator to be able to improve the device loadability and to ensure the steady state security of the network. Secondly, we performed a contingency analysis procedure based on severity index (SI) to spot and classify the absolute most severe line contingencies. Then, we determined the perfect placement and parameter setting of FACTS devices in power system by using the above optimization approach to ease the line overloads. To guarantee the robustness and effectiveness of the proposed method, the optimization problem presented in this paper aims at reducing FACTS installation cost and decreasing total real and reactive power losses.

INTRODUCTION
Power quality issues are a problem that is becoming increasingly crucial that you electricity consumers at all levels of usage. Power quality related issues are of most distress because of the extensive utilization of electronic equipment. In arrears to the, various power quality dilemmas arises like voltage sag or dip, very small and long distractions, voltage spike, voltage grows, harmonic distortion, voltage fluctuation, sound, voltage unbalance and altered our power system. Power quality problems have now been attracting the attention of researches for decade. The clear presence of voltage disturbances at the point of common coupling (PCC) results in malfunction of sensitive industrial instrumentality, that come out grid part failures, such as for example transformers, and economical losses. FACTS devices would be the possible response to shield sensitive loads against probably the most significant voltage disturbances, voltage harmonics, imbalance and sags. Definition of power quality can vary from individual to individual because we cannot define what power quality we only define what good is or bad power quality is really as we can observe that two identical devices or bits of equipment might react differently to exactly the same power quality parameters as a result of differences in their manufacturing or component tolerance. In accordance with institute of Electrical and Electronic Engineers Standard power quality is defined as a, “the thought of powering and grounding sensitive electronic equipment in a way suited to the equipment & . The focus of the survey is on the usage of FACTS devices in mitigation of Power quality problems.

In this, we address most of these issues and propose a larger version of NSGA, which we call NSGA-II. Maximum energy place checking represents a vital role in photovoltaic programs because it increase the energy production from the PV system for established number of conditions, and therefore maximize the array efficiency and minimize the entire system cost. Since the maximum power point (MPP) varies, on the basis of the irradiation and cell temperature, appropriate algorithms must be used to track the MPP and maintain the operation of the machine in it. Matlab/Simulink can be used to establish a style of photovoltaic system with (MPPT) function.

PROPOSED SYSTEM

The key aim comprising of price, line loadings and load voltage deviations is planned to tap maximum benefits out of the installation and the loads given for them decide the irrelative importance. The impact of installing Static Series Synchronous Compensator and Interline Power Flow Controller in minimizing the formulated objective has been analysed in enhancing security, under increased system loading conditions. The optimization techniques just the Artificial Neural Network, Elitist Nondominated Sorting Genetic Algorithm and Perturb and Observe Method Algorithm is applied to discover the perfect quantity of multi-devices of Interline Power Flow Controller and Static Series Synchronous Compensator to manage to improve the machine loadability and to ensure the steady state security of the network. A contingency analysis procedure are performed to spot and classify the most severe line contingencies. Finally the perfect placement and parameter setting of FACTS devices in power system are determined utilising the above optimization approach to help relieve the line overloads. To guarantee the robustness and effectiveness of the proposed method, the optimization problem presented in this paper aims at reducing FACTS installation cost and decreasing total real and reactive power losses.

MODELLING OF FACTS DEVICES AND BUS SYSTEMS

FACTS devices play a vital role in improving the static alongside dynamic performance of the capability systems. This items are very efficient in improving the voltage profile, reducing the line loadings and line losses, providing reactive power support over wide selection of operating voltages and enhancing the stability of the system. However the type, location and rating of the important point's devices play a significant role in deciding the extent to which the goal of improving the machine performance is achieved in an amount effective manner. There are many FACTS devices can be found using this the static series synchronous compensator and interline power flow controller are used to enhance system security, under increased system loading condition.

Static Series Synchronous Compensator

Static synchronous series compensator is a modern power quality FACTS device that employs a voltage source converter connected in series to a transmission line by way of a transformer. The SSSC operates such as for instance for example a controllable series capacitor and series inductor. The primary difference is that its injected voltage is not connected to the product range intensity and may be handled independently. This feature allows the SSSC to work satisfactorily with high loads alongside lower loads.

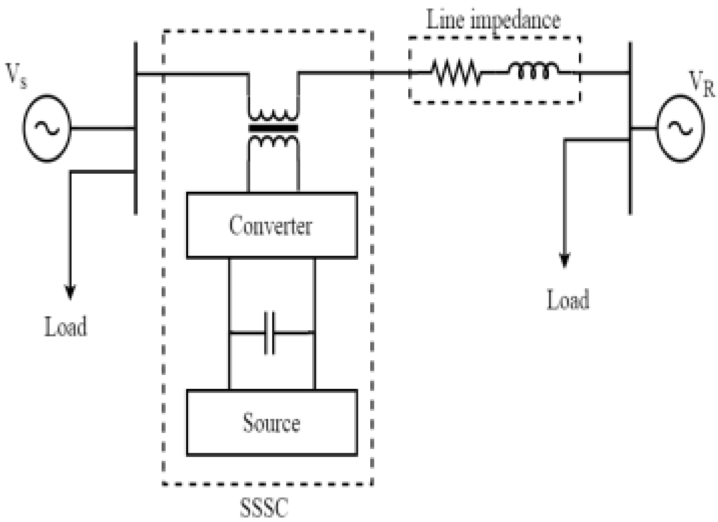

Figure 1 Static Series Synchronous Compensator

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Mathematical modelling of SSSC

SSSC is just a series compensator using Gate Turn fully off (GTO) based voltage source inverter. It's capable of providing active and reactive power support. In reactive power support mode, it could regulate reactive voltage drop in line and can control power flow to ease congestion.

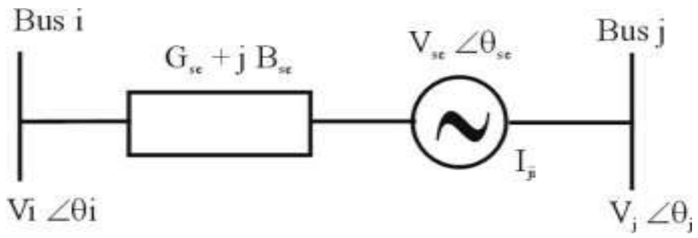

Figure 2 Static Model of SSSC

At bus i

- $P_i = V^2_i\, G_{ii} – V_i\, V_j\,(G_{ij} \cos\theta_{ij} + B_{ij} \sin \theta_{ij}) – V_i\, V_{se} \quad (G_{ij} \cos \theta_{ise} + B_{ij}\, \mathrm{Sin}\, \theta_{ise})$ (1)
- $Q_i = V^2_i\, B_{ii} – V_i\, V_j\, (G_{ij} \sin \theta_{ij} - B_{ij} \cos \theta_{ij}) – V_i\, V_{se}\, (G_{ij} \sin \theta_{ise} - B_{ij} \cos \theta_{ise})$ (2)

At bus j

- $P_j = V^2_j\, G_{jj} – V_i\, V_j\, (G_{ij} \cos \theta_{ji} + B_{ij} \sin \theta_{ji}) + V_j\, V_{se}\, (G_{ij} \cos \theta_{jse} + B_{ij}\, \mathrm{Sin}\theta_{jse})$ (3)
- $Q_j = V^2_j\, B_{jj} – V_i\, V_j\, (G_{ij} \sin\theta_{ji} - B_{ij} \cos\theta_{ji}) + V_j\, V_{se}\, (G_{ij} \sin \theta_{jse} - B_{ij} \cos \theta_{jse})$ (4)

Where,

- $\theta_{ij} = \theta_i - \theta_j$, $\theta_{ji} = \theta_j - \theta_i$
- $\theta_{ise} = \theta_i - \theta_{se}$, $\theta_{jse} = \theta_j - \theta_{se}$
- G_{ii} & B_{ii} = Conductance and susceptance of bus i
- G_{jj} & B_{jj} = Conductance and susceptance of bus j.
- G_{ij} & B_{ij} = Conductance and susceptance of line i - j.

The SSSC is effective at internally generating a controllable compensating voltage over any capacitive or inductive range independent of the magnitude of the line current. The SSSC has the capacity to be interfaced with an external dc power supply. The external dc power supply is used to offer compensation for the line resistance. The SSSC with energy storage may raise the potency of the power oscillation damping by modulating the sum total amount of series settlement to be able to raise or decrease the transmitted power. The SSSC can control the ability flow in transmission line. Additionally it may inject fast changing voltage in series with the line regardless of the magnitude and phase of the line current.

Interline Power Flow Controller

The IPFC addresses the issue of compensating several transmission lines at confirmed substation. Conventionally series capacitors are used to improve the actual power transfer in confirmed line. However, it cannot control the reactive flow in the line, thus leading to improper compensation. This issue occurs once the ratio of reactance to resistance of transmission line (X/R) is relatively low. By using capacitive combination, the reactance of the line decreases which in turn reduces the (X/R) ratio of the line, leading to improper compensation and improper load balancing in indication lines. Series reactive payment reduces just the effective reactive impedance X and, therefore, notably reduces the effective X/R rate and therefore advances the reactive power movement and failures in the line. The IPFC scheme, along with independently controllable reactive series compensation of each individual line enables the transfer of real power involving the compensated lines. IPFC can be employed to transfer power between multiple lines in a substation, where as one other available FACTS devices can control the power flow through single line only. The energy flow through a line can be regulated by controlling both

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magnitudes and angles of the series voltage injections. The converters have the capacity of independently generating or absorbing the reactive power.

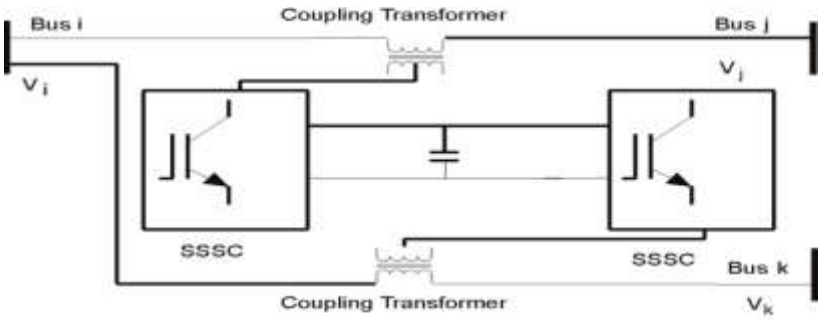

Figure 3 Interline Power Flow Controller

Mathematical modelling of SSSC

Mathematical model for IPFC that will be known as power injection model is useful in understanding the impact of the IPFC on the power system in the steady state. Additionally, this IPFC design can certainly be integrated in energy movement analysis. Usually, in the steady state analysis of power system, the Voltage Source Converters (VSC) may be represented as a synchronous voltage source injecting an almost sinusoidal voltage with controllable magnitude and angle.

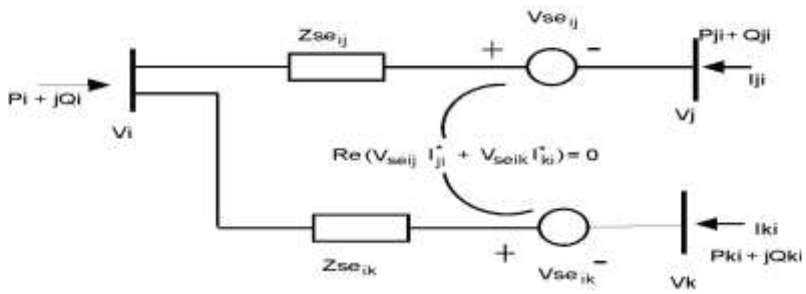

Figure 4 Mathematical Model of IPFC

Vi, *Vj* and *Vk* will be the complex bus voltages at the buses i, j and k respectively, *Vsein* may be the complex controllable series injected voltage source, and Zsein (*n = j, k*) may be the series coupling transformer impedance. The complex power injected by series converter connected between bus i and bus j.

- $P_i = V_i^2 g_{ii} - \Sigma^n_{j=1} V_i V_j (g_{ij} \cos\theta_{ij} - b_{ij} \sin\theta_{ij}) -$
  - $+ \Sigma^n_{j=1} V_i V_{seij} (g_{ij} \cos(\theta_{ij}-\theta_{seij}) - b_{ij} \sin(\theta_{ij}-\theta_{seij}))$ (5)
- $Q_i = V_i^2 g_{ii} - \Sigma^n_{j=1} V_i V_j (g_{ij} \sin\theta_{ij} - b_{ij} \cos\theta_{ij}) -$
  - $+ \Sigma^n_{j=1} V_i V_{seij} (g_{ij} \sin(\theta_{ij}-\theta_{seij}) - b_{ij} \cos(\theta_{ij}-\theta_{seij}))$ (6)
- $P_{ji} = V_j^2 g_{ii} - \Sigma^n_{j=1} V_i V_j (g_{ij} \cos(\theta_j-\theta_i)_{ij} - b_{ij} \sin(\theta_j-\theta_i)) -$
  - $+ \Sigma^n_{j=1} V_i V_{seij} (g_{ij} \cos(\theta_{ij}-\theta_{seij}) - b_{ij} \sin(\theta_{ij}-\theta_{seij}))$ (7)
- $Q_{ji} = V_j^2 g_{ii} - \Sigma^n_{j=1} V_i V_j (g_{ij} \sin(\theta_j-\theta_i)_{ij} - b_{ij} \cos(\theta_j-\theta_i)) -$
  - $+ \Sigma^n_{j=1} V_i V_{seij} (g_{ij} \sin(\theta_{ij}-\theta_{seij}) - b_{ij} \cos(\theta_{ij}-\theta_{seij}))$ (8)

Where

- $g_{ij} = -g_{ij} = Re(1/Zse_{tj})$ (9)
- $b_{ij} = -b_{ij} = Im(1/Zse_{ij})$ (10)

The active power exchange between series connected inverters via the most popular dc link is

- $P_{mn} = \Sigma^n_{j=1} Re(Vse_{ij} * I_{ij}^*)$ (11)

Problem Formulation

As the expense of the FACTS devices is high, to be able to achieve probably the most benefit, the devices could be installed at the optimal locations. The target purpose has three terms; the first expression represents the instalment price of the devices, the second and third terms addressing force bus voltage deviations and range loadings respectively. The minimization of the proposed objective function needs to result in a price effective security oriented device placement. The objective function is formulated as

- $MinF = W1 [(CFACTS*S)] + W2 [LVD] + W3 [LL]$ (12)

where

F is the objective function.
C_{FACTS} is the cost of FACTS device.
S is the operating range of the FACTS device
LVD is the Load voltage deviation
LL is the Line loading
W1, W2&W3are the weight factors

1) Cost

The initial term of the objective function CFACTS, presents the installation cost of FACTS devices considered and are shown by these equations.

- $C_{IPFC} = 0.0015s2 - 0.7130s + 153.75$ (13)
- $C_{SSSC} = 0.0003s2 - 0.3051s + 127.38$ (14)

where

C_{IPFC} is the cost of IPFC device in US $/kvar.
C_{SSSC} is the cost of SSSC device in US $/kvar.

2) Load Voltage Deviation

Excessive high or low voltages may cause an undesirable support quality and may cause voltage instability problems. FACTS devices connected at appropriate locations play a respected role in improving voltage profile thereby avoiding voltage collapse in the ability system. The 2nd term considered represents force voltage deviations to be able to steer clear of the under or over voltages at network buses.

- $LVD = \sum_{m=1}^{nb} ((V_{mref} - V_m) / V_{mref})^n$ (15)

where

Vm is the voltage magnitude at bus m, Vmref is the nominal voltage at bus m & is considered as 1.0 pu, m refers to the load buses, Vm is less than Vmref.

3) Line Loading

FACTS devices are observed to be able to take away the overloads and to distribute the strain flows uniformly. To make this happen, line loading is known as as another term in the objective function.

- $LL = \sum_{l=1}^{nl} (Sl / Sl\ max)^n$ (16)

where

Sl is the apparent power in the line l.
Slmax is the apparent power rating of line.

CONTROL ALGORITHM

Algorithm is often a procedure or formula for solving a challenge, centred on conducting a routine of specified actions. Algorithms are trusted throughout all areas of information technology. Well you may find various types of algorithm nevertheless the absolute most fundamental kinds of algorithm are recursive algorithms, dynamic programming algorithm, backtracking algorithm, divide and conquer algorithm, greedy algorithm, brute force algorithm and randomized algorithm. In this paper, the artificial neural network algorithm are accustomed to learn the right quantity of multi-devices of FACTS in order to improve the equipment loadability and to guarantee the steady state security of the network.

Artificial Neural Network

Artificial Neural Network (ANN) or connectionist applications are control applications vaguely prompted by the natural neural web sites that constitute puppy brains. An ANN is based on an accumulation of connected items or nodes named synthetic neurons, which loosely product the neurons in a organic brain. Each connection, like the synapses in a biological brain, can transmit a sign to other neurons. A synthetic neuron that receives a sign then processes it and can signal neurons linked to it. The first goal of the ANN approach was to fix problems in the same way that a human brain would. But with time, attention moved to performing specific tasks, ultimately causing deviations from biology.

Flow chart of Artificial Neural Networks

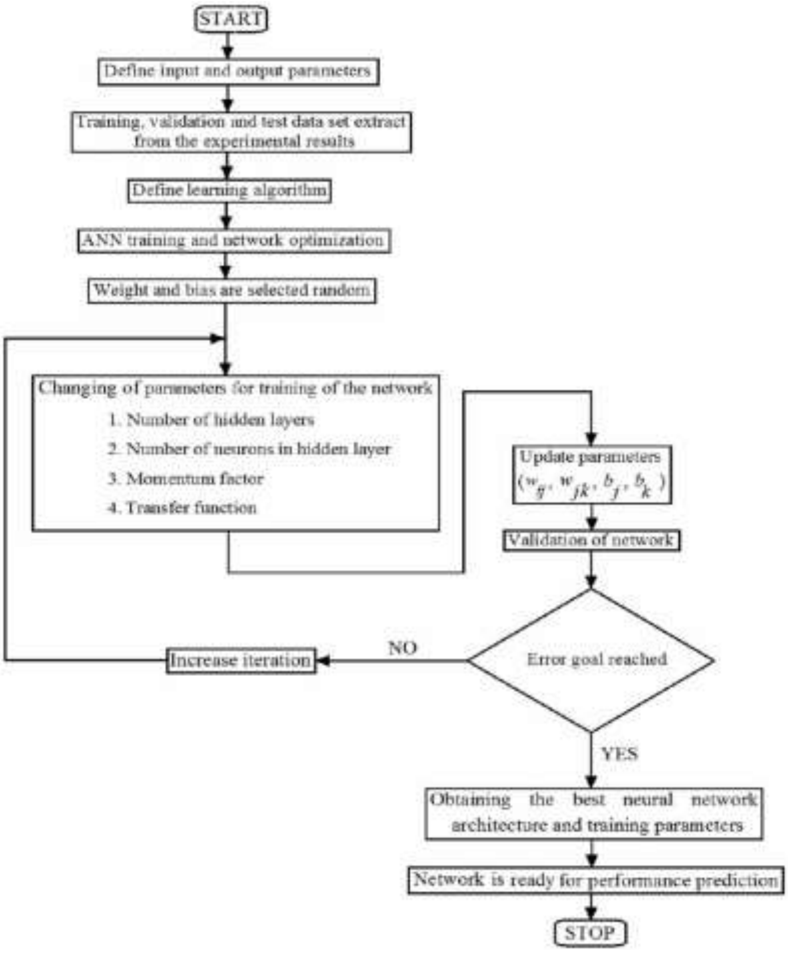

Figure 5 Flow chart of Artificial Neural Networks

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B) Elitist Non-Dominated Sorting Genetic Algorithm -II

Multi-objective optimization is really a host to numerous requirements decision creating that is anxious with mathematical optimization issues concerning a whole lot more than one aim function to be enhanced simultaneously. Multi-objective optimization has been applied in plenty of areas of research, including executive, economics and logistics wherever maximum choices should be used in the clear presence of trade-offs between several contradictory objectives. Reducing price while maximizing ease while investing in a vehicle, and maximizing performance though reducing gas consumption and emission of pollutants of an vehicle are forms of multi-objective optimization issues concerning two and three objectives, respectively. In practical problems, there may be a lot more than three objectives.

The **NSGA-II** is a marked improvement of a previous algorithm produced by the exact same authors called NSGA. NSGA, and other multi-objective evolutionary algorithms following the exact same principles, received three mayor criticisms:

- The non-dominated sorting of the populace includes a high complexity of O(MN3), being M the amount of objectives and N the amount of individuals in the population.
- These algorithms don't consider the use of elitism strategies, which prevent the increased loss of good solutions, and can hence be considered a key factor in speeding up the search.
- Additional parameters must certainly be set for ensuring diversity, mostly with the aid of a sharing parameter.

Flow Chart of NSGA-II

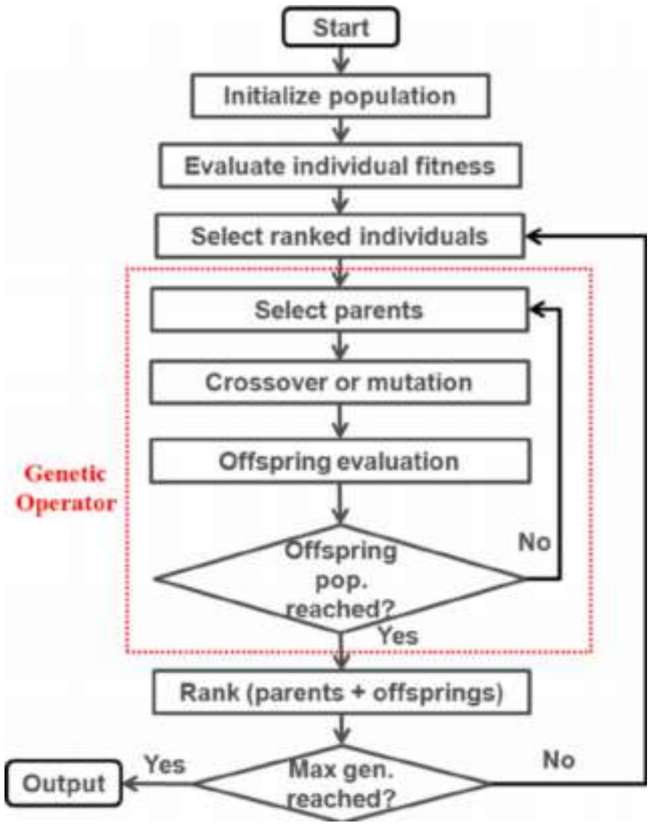

Figure 6 Flow Chart of NSGA-II

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Crowding distance:
The crowding distance value of a solution offers an estimate of the density of solutions surrounding that solution. The crowding distance value of a particular solution may be the average distance of its two neighbouring solutions.

Pareto Optimal Solution:
The Pareto Optimal Solution refers to a solution, around which there is no means of improving any objective without degrading at least one other objective.

Nondominated Solution
A nondominated solution is the one which provides the right compromise between all objectives without degrading any of them. Indeed, the concept of Pareto dominance consists of comparing each solution x with every other solution in the people until it is dominated by one of them.

c) Perturb and Observe Method Algorithm
In this process, the controllers set a little bit of voltage from the array and calculate the power. From then on, this voltage is increased by a touch and the energy is calculated again. Thus the energy is compared. If the energy increases, further increments of voltages are done because direction before the increment of power stops. This is called the Perturb and Observe (P&O) method. It is referred as a mountain climbing method as this will depend on the rise of the curve of power against voltage below the most power point, and the fall of the curve above that point.

Flow Chart of Perturb and Observe Method Algorithm

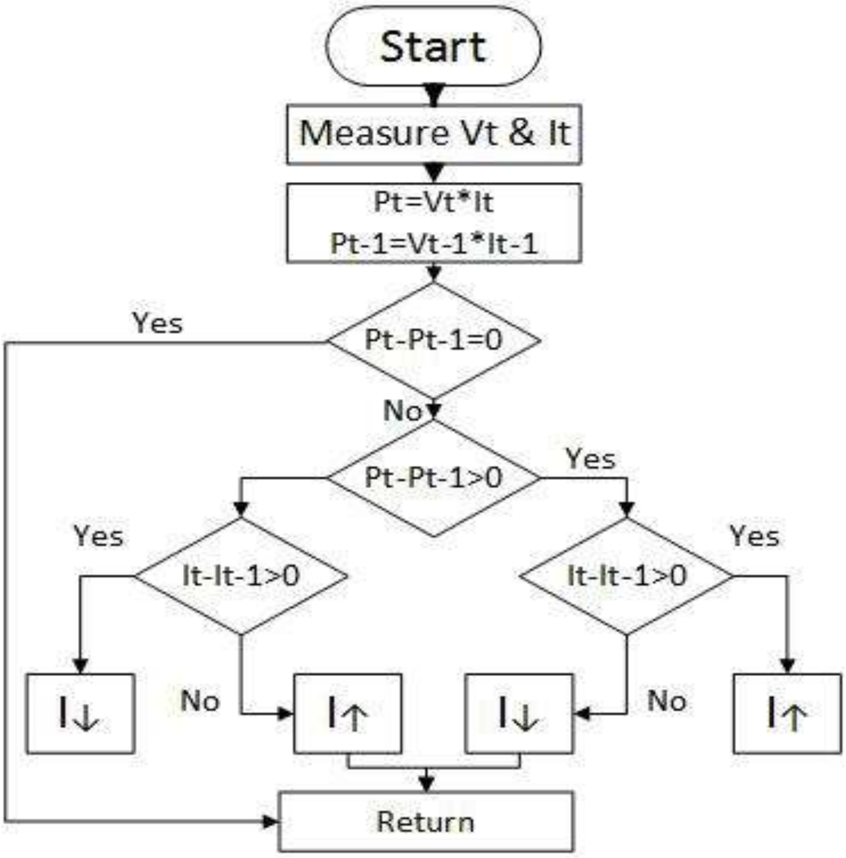

Figure 7 Flow Chart of Perturb and Observe Method Algorithm

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The algorithm reads the worth of current and voltage from the solar PV module. Power is calculated from the measured voltage and current. The worth of voltage and power at kth instant are stored. Then next prices at (k +1)th instant are calculated again and energy is determined from the calculated values. The ability and voltage at (k+1)th instant are subtracted with the values from kth instant. When we observe the ability voltage curve of the solar pv module we observe that in the proper hand side curve where in fact the voltage is almost constant the slope of power voltage is negative (dP/dV<0) where as in the left hand side the slope is positive.(dP/dV>0). The proper side curve is for the low duty cycle (nearer to zero) where because the left side curve is for the higher duty cycle (nearer to unity). With respect to the sign of dP (P(k+1) - P(k)) and dV (V(k+1) -V(k)) after subtraction the algorithm decides whether to increase the work cycle or to lessen it.

SIMULATION WORK

To validate the proposed technique, the answers are simulated using MATLAB codings for standard IEEE 14 and 30 bus systems. The result are simulated for just two different cases namely, with SSSC connected and with IPFC mounted on the system. To examine the effectation of the installing FACTS devices under overload conditions, the loads on the unit were increased in an in depth manner. The real and reactive power loads related at numerous fill buses were increased maintaining force power component constant.

Simulation Model: Fourteen Bus System

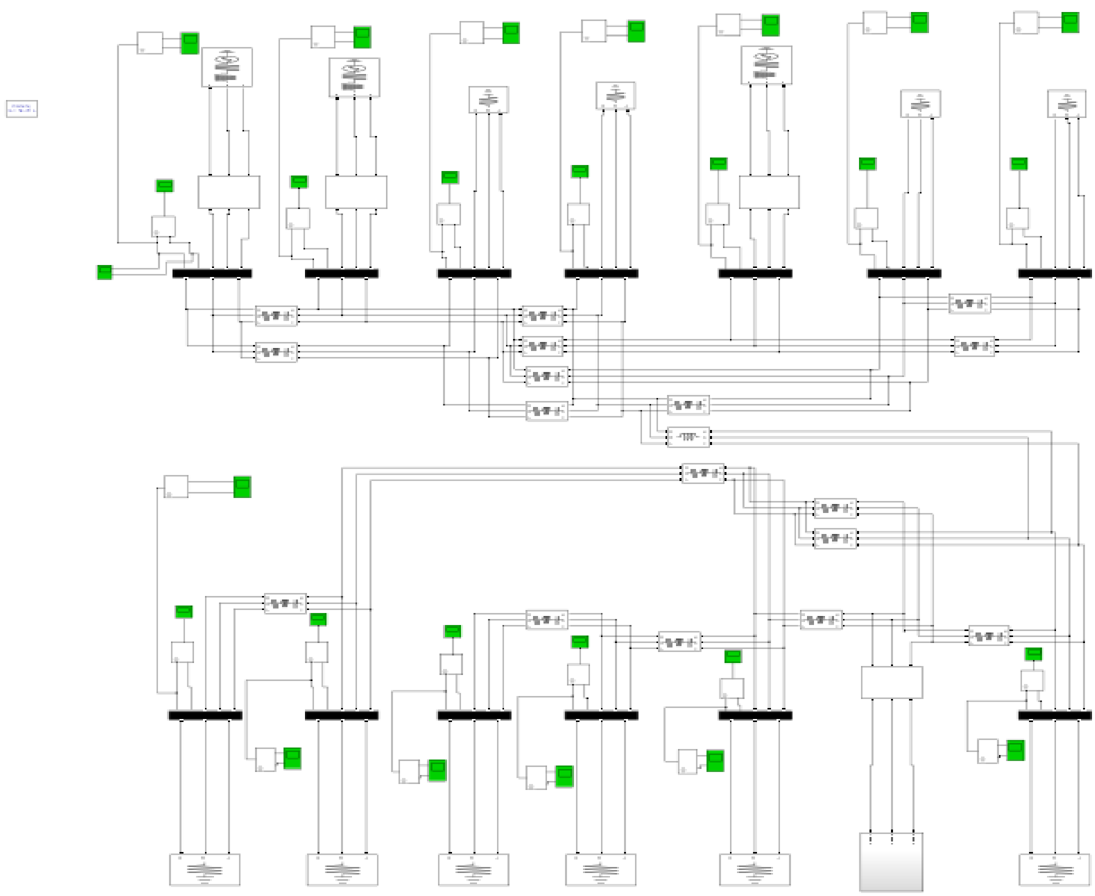

Figure 8 Fourteen bus system

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Thirty Bus System

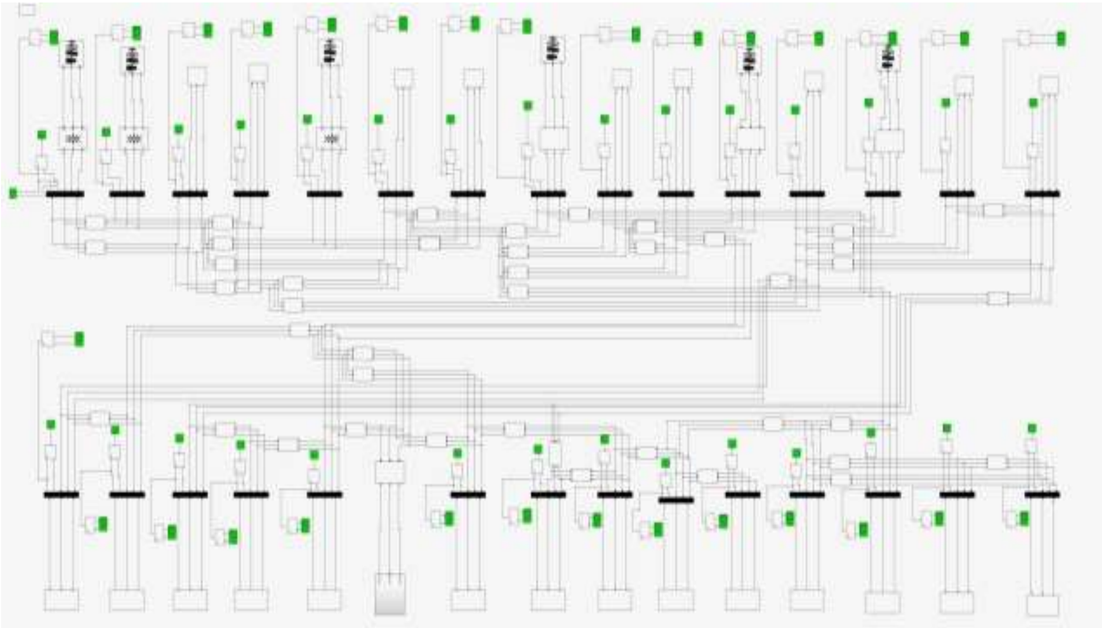
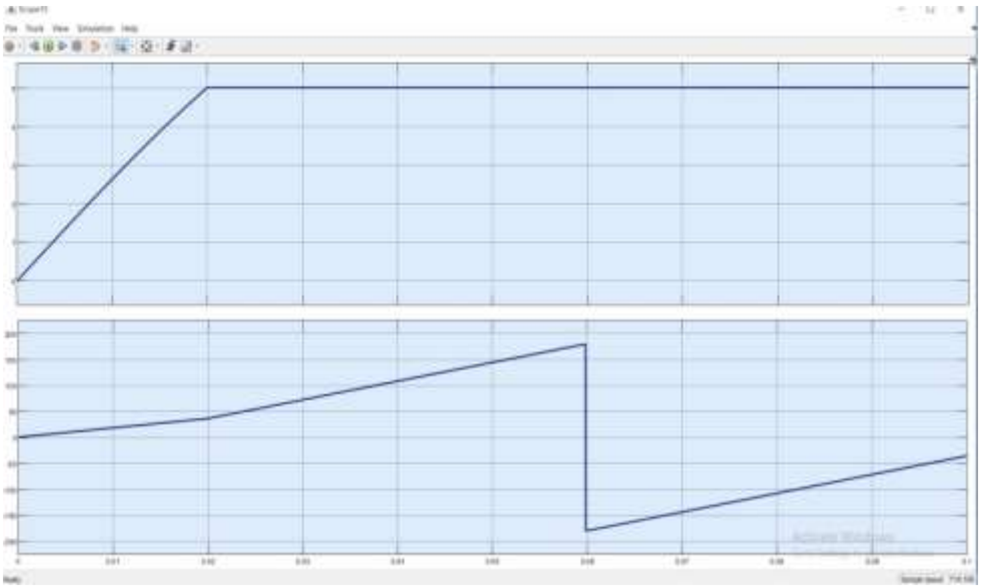


Figure 9 Thirty bus system

Simulation Result

Y-axis : Magnitude and Phase

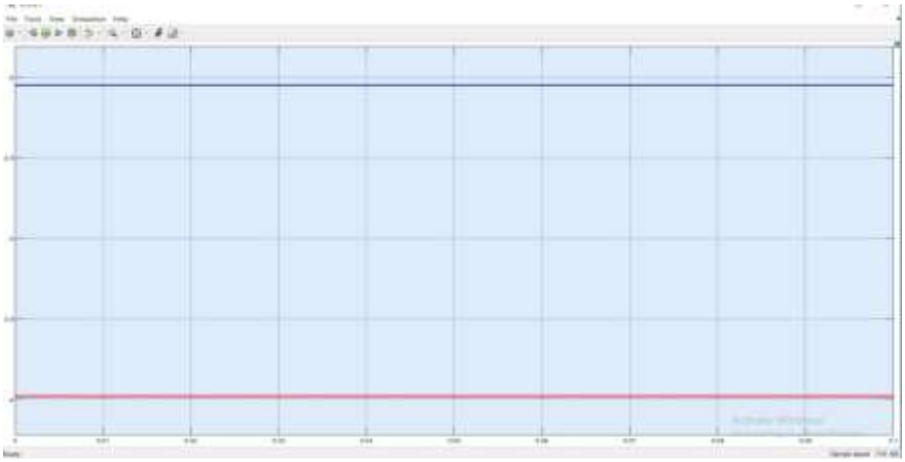


Time

Figure 10 Output of magnitude and phase of the bus systems

The above diagram is the curve of magnitude and phase for the IEEE Standard 14 and 30 bus sytems.

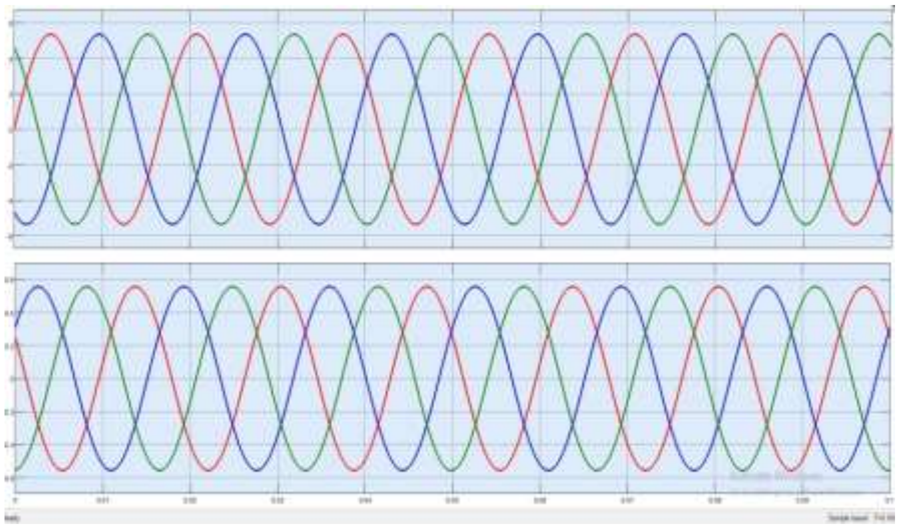
Y-axis : Real and Reactive Power



Time

Figure 11 Output of real and reactive of 14 bus system
The above curve shows the real and ractive power waveform of IEEE standard 14 and 30 bus systems.

Y-axis : Voltage and Current



Time

Figure 12 Output of voltage and current of 30 bus system

This waveform reveals the voltage and current curve for both the bus systems.

CONCLUSION

The analysis of FACTS device placement is inevitable, because the most ease of power systems could be exploited by way of installing FACTS devices. Though FACTS devices could be placed at any feasible location in the ability system, their location and rating need to be fixed optimally to attain the most benefit. Here the problem of FACTS devices placement; with comprehensive objective function consisting of cost of the FACTS devices, load voltage deviations and line loadings are analysed using Artificial Neural Network algorithm algorithms.

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This work investigates and proposes new solution processes for the suitable keeping of FACTS devices, for the enhancement of system security under varying system load. The potency of the suitable installing of SSSC and IPFC in upgrading the security of power systems, when it comes to minimizing the line loading and load voltage deviations are examined. The developed algorithms for the suitable keeping varied FACTS devices is validated by conducting case studies on standard IEEE test systems. The analysis shows following the suitable FACTS device placement, both force bus voltage deviations and line loadings are minimized hence enhancing the machine security. Henceforth the proposed technique devoted to ANN optimization, yields an efficient solution which considerably reduces load voltage deviations and relieves the lines off their over loads under various loading conditions.

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