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Optimization of PQ Problem Using Facts Devices

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Abstract—Voltage sags/swells are the most important Power Quality (PQ) problems that many industries and utilities face. It contributes more than 80% of power quality problems that exist in power systems. Voltage sags/swells are not tolerated by sensitive equipment used in modern industrial plants. In this paper a IEEE standard 5 bus system is considered and the power quality problem was mitigated using the FACTS devices – STATCOM of 4 pulse type made of IGBT Switches.

The result for the standard system was obtained by simulating the test system using MATLAB/SIMULINK. The results are provided for the system without fault condition; with fault condition and the result by application of facts devices are provided.

It is proved that by using the STATCOM the power quality problem is mitigated as well the loadablity of the system is improved by twice.

Keywords-Power Quality; Genetic Algorithm; Flexible AC Transmission System ; Static Synchronous Compensator.

I. INTRODUCTION

Recently the requirement for power quality becomes more and more important to keep safety of the electrical devices and consumer satisfaction. Power quality problems mainly include unbalance voltage and current, flicker, harmonics, voltage sag, dip, swell, and power interruption. These power quality problems may cause abnormal operations of facilities or even trip protection devices. Hence, the maintenance and improvement of electric power quality is necessary.

Various flexible ac transmission system (FACTS) devices, such as static synchronous compensators (STATCOM), static synchronous series compensators (SSSC), and unified power-flow controllers (UPFC) are increasingly used in power systems because of their ability to stabilize power transmission systems and to improve power quality in power distribution systems.

STATCOM (Static Synchronous compensator) is one of the most frequently Flexible AC transmission system (FACTS) devices because of its ability to regulate voltages in transmission lines, to improve transient stability and to compensate variable reactive power. The static synchronous compensator (STATCOM) is shunt compensator which consists of voltage source converter where as in the Static Var Compensators (SVC) it uses shunt capacitors and reactors. STATCOM is an active device, which can control voltage magnitude and even the phase angle to a small extent and has the ability to improve the system damping and also the voltage profiles of the system. STATCOM is advantageous for reactive power control applications over the SVC because of its greater reactive current output at depressed voltage, faster response, better control stability, lower harmonics and smaller size, etc.

This paper analyzes the key issues in the Power Quality problems, as one of the prominent power quality problems, the origin, consequences and mitigation techniques of voltage sag/swell problem has been discussed in detail.

The STATCOM is applied to regulate IEEE 5-bus standard system by using the PWM technique for switching of the switches in the STATCOM. The switching time is controlled by the Genetic Algorithm approach for minimizing the switching losses, to allow greater power flow in a voltage limited transmission network, the STATCOM has further potential by giving an inherently faster response and greater output to a system with voltage sag/swell and offers improved quality of supply. The FACTS controllers are shown in Fig.1.The STATCOM exhibits high speed control of reactive power to provide voltage stabilization and other type of system control. The STATCOM protects the utility transmission or distribution system from voltage sag and /or flicker caused by rapidly varying reactive current demand. During the transient conditions the STATCOM provides leading or lagging reactive power to active system stability, power factor correction and load balancing and harmonic compensation of a particular load.

The aim of the developed optimization technique is to provide optimal switching actions on the 4 existing switches of the STATCOM. The GA is to identify the least loss switching timing of the IGBTs of the STATCOM. Since the losses due to switching of the IGBT's is high but the performance of the IGBTs are more advantageous than the GTOs.

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GA in its simplest form is used to find the optimization process.

II. GA APPLIED FOR OPTIMIZATION

Genetic Algorithm is one of the search methods, which was built in comparison with the biological natural selection and survival of the fittest. GA differs from traditional optimization algorithms in the following

1) In GA the search is between population to population and, not between a single point to a single point;

2) GA can search in a discrete solution space instead of continuous values.

Genetic algorithm (GA) is unconventional optimization tool which is more robust, powerful and less data-independent than many other optimization techniques. A solution of problem can be reached by working with a population of possible solutions. Each possible solution is called a "chromosome". The search space is extended by generating new points through GA operations. The GA operators are known as reproduction, crossover and mutation. These operators systematically create fitter off springs through successive generations. Then the new generations quickly drive the search towards optimal solution

A conventional GA process can be described as Fig1

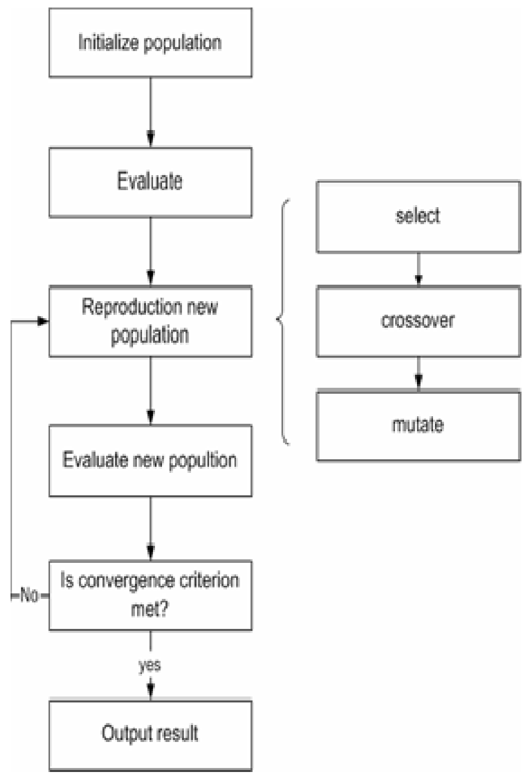

Fig 1: A conventional GA Process

A. Basic Operetors in GA

The basic operators mainly used by Genetic Algorithm are:

a. Reproduction

b. Crossover

c. Mutation

a) Reproduction

Reproduction is the first operator which is applied on the generated population. Individuals are created according to their corresponding fitness values. These created individuals are the parents to cross over and produce off springs. For example:

Chromosome (string) A": 111 111 11

Chromosome (string) B": 000 000 00

b) Crossover

It is a type of recombination operator, where members of the newly reproduced strings in the mating pool are mated at random. An inter position is randomly

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selected along the string length and the values between the position are swapped between two strings following the selected position. For example if the random selection of a position is two, and then the new strings following cross over would be:

Offspring A': 00'111111

Offspring B': 11'000000

c) Mutation

This operator receives the strings after cross over. Mutation involves flipping a bit in the string and changing 0 to 1 and vice versa. New genetic structures can be introduced in the population by randomly changing some of the off spring's bits. For example, if mutation occurs at 5th position of obtained strings the new off springs become:

Offspring A': 00110'111

Offspring B': 11001'000

III. SWITCHING TIME DETERMINATION USING GA APPROCH

The aim of the developed optimization technique is to provide optimal switching actions on the 4 existing switches of the STATCOM. The GA is to identify the least loss switching timing of the IGBTs of the STATCOM. Since the losses due to switching of the IGBT's is high but the performance of the IGBTs are more advantageous than the GTOs.

GA in its simplest form is used to find the optimization process. However, the requirement of achieving minimal computational time was not relaxed. The following constraints/attributes of the switches were considered to reduce computational time.

The nature of the switching action permits a binary-state coding scheme implementation to represent the open and close positions of the switches. Hence, there is no need to provide any enhanced coding techniques to reduce the number of variables.

The two-point crossover method has been identified as being superior to single- point crossover

Each topology used in further analysis must first be deemed valid or invalid depending on the outcome of load-flow analysis which determines if any of the constraints have been violated.

The core functionality of GA must possess the ability to reinsert the best solutions from present generations into future generations.

The GA should be equipped with the functionality to create a list of infeasible topologies. Such a data structure prevents the infeasible topologies from being revisited and re-evaluated, thus improving the efficiency.

Optimization processes stagnation (i.e., no change in an optimal solution thus far) is characteristic of extensive computational times. The application of a stopping criterion, which determines whether stagnation has occurred and the optimal solution is found, curtails the extensive computational times appropriately.

IV. TEST SYSTEM USED

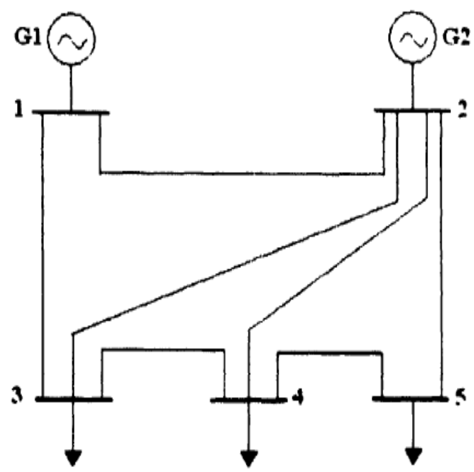

Fig 2: Line Diagram of IEEE Standard 5 BUS System

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V. SIMULATION AND RESULTS

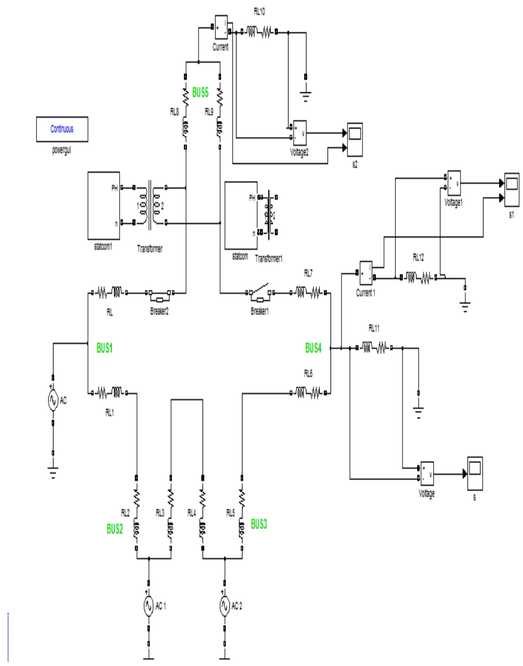

Fig 3: Simulation Block Diagram

The circuit is simulated in MATLAB/SIMULINK the description of the simulation diagram is given in the table below

Table 1: Parameters Used in the Simulation

	Values
Supply voltage per source(v)	440
Load resistance of bus 4(Ω)	200
Load inductance of bus 4(mH)	6
Load resistance of bus 5(Ω)	100
Load inductance of bus 5(mH)	3
Transformer resistance(Ω)	0.05
Transformer leakage inductance(μH)	0.05

STATCOM

Pulse Generated using GA approach used in STATCOM:

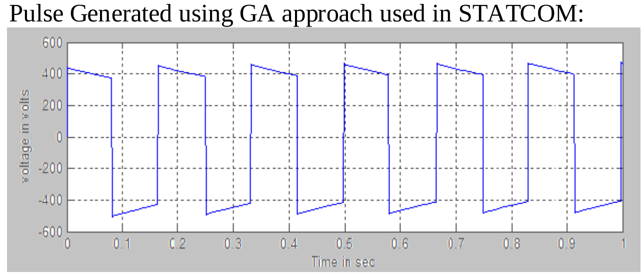

Fig 4 : Pulse Generated using GA approach - operation of STATCOM

ANALYSIS IN BUS 4

BUS 4 Line Voltage without Fault:

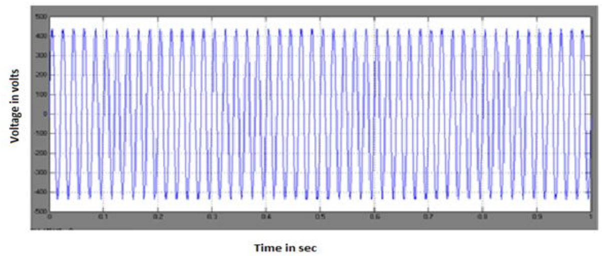

Fig 5: BUS 4 Line Voltage without Fault

BUS 4 Fault Voltage:

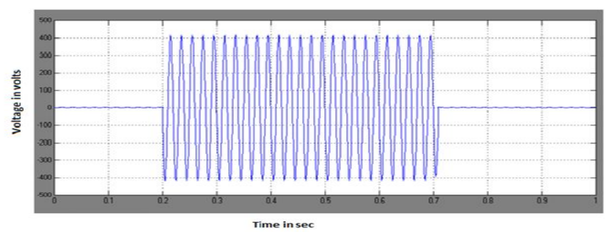

Fig 6: BUS 4 Fault Voltage

BUS 4 Line Voltage with Fault:

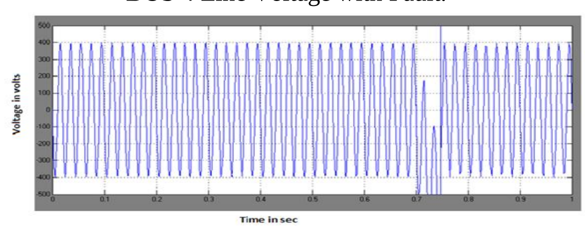

Fig 7: BUS 4 Line Voltage with Fault

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BUS 4 Line Voltage with STATCOM After Fault Occurrence

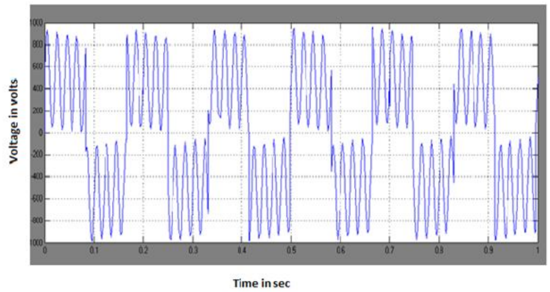

Fig 8: BUS 4 voltage with STATCOM After Fault Occurrence

ANALYSIS IN BUS 5

BUS 5 Line Voltage without Fault:

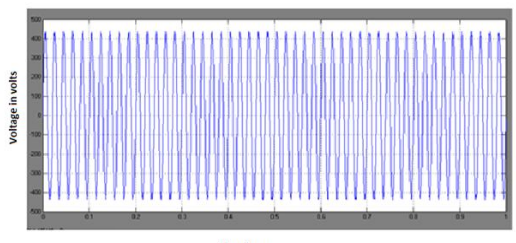

Fig 9: BUS 5 Line Voltage without Fault

BUS 5 FAULT Voltage

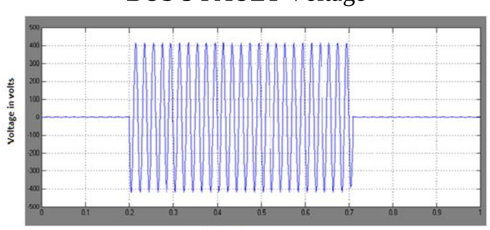

Fig 10: BUS 5 Fault Voltage

BUS 5 Line Voltage with Fault:

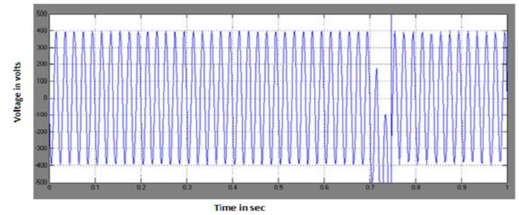

Fig 11: BUS 5 Line Voltage with Fault

Analysis of Voltage in BUS 5 and BUS 4

Table 2 Analysis of BUSES 4 and 5

	Without STATCOM	With STATCOM
Bus 4	440v	880v
Bus 5	300v	600v

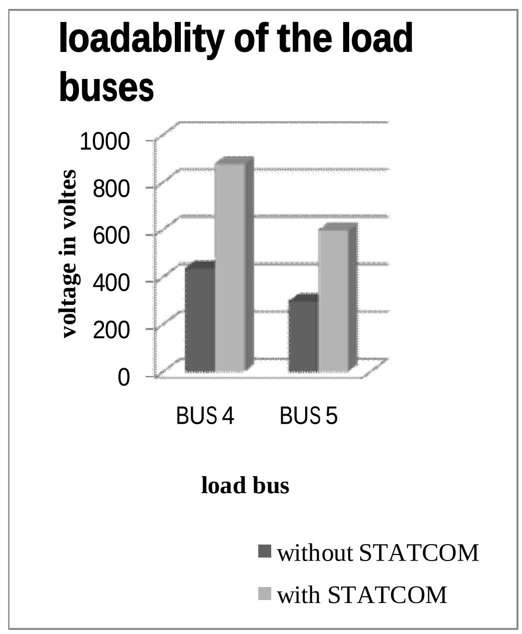

Fig 12: Loadablity of load BUSES

VI. CONCLUSION

This paper the application of a PWM switching technique by means of genetic algorithms for improvement of the performance of the STATCOM in order to mitigate the voltage sags/swell indices in electrical systems has been presented. The optimization methodology leads to finding the optimal switching timing for the designed STATCOM topology in which the voltage sags/swell indices at the load buses are under reference values fixed according to statistical data of the electrical system.

The efficiency of the proposed methodology has been proven in the 5-BUS IEEE test systems. This method successfully finds the best alternative to the switching and the to minimize voltage sags/swell indices in electrical systems.

Another outstanding feature of the proposed reconfiguration method is the significant reduction of voltage sags/swell and the best timing for STATCOM switching were obtained.

In the simulation study, MATLAB/SIMULINK environment is used to simulate the model of STATCOM connected to a 5-BUS IEEE test systems in single phase system. This project presents the control and performance of the STATCOM used for power quality improvement. Voltage compensation using STATCOM is studied. The voltage compensation using STATCOM system is also studied for 5 bus IEEE test system. Simulation results show the effectiveness of STATCOM to control the real and reactive powers by which the voltage sag/swell it is found that there is an improvement in the real and reactive powers through the transmission line when STATCOM is introduced. The STATCOM system has the advantages by which the switching efficiency is improved by using the GA approach. GENETIC ALGORITHM MATLAB TOOLBOX was used for this purpose. STATCOM is capable of improving the power quality by injecting the voltage. The simulation results are presented for reference.

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