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Optimization of FLC Using PSO – FF Hybrid Algorithm Using DSTATCOM for Power Quality Improvement

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ABSTRACT

Electrical power is the most established form of power and the people is greatly dependant on the electric power supply. A life cannot be imagined with no supply of electricity. Most of the industrial and domestic loads require uninterrupted and high standard continuous power supply. The electric power suppliers and consumers are getting more concerned about the quality of electric power that is provided to them and which is consumed by the users. Therefore, retaining the qualitative power is of most important [1].

In this research paper our main aim is to optimize and Analysed the performance of PSO – FF hybrid algorithms [2] for the control of DSTATCOM in power quality improvement [3] and the results are analysed with the help of MATLAB software.

KEYWORDS: *DSTATCOM, Fuzzy Logic Controller(FLC) base rule, optimized membership function , PSO – FF hybrid algorithm, flowcharts, matlab simulation*

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INTRODUCTION

The Power Quality is defined as the degree to which the power supply access the ideal case of stable, balance, uninterrupted, zero distortion and disturbance free power supply[1]. Upgrade power quality is the progressive force for today's developed engineering areas. Most of the industrial and domestic loads require uninterrupted and high standard continuous power supply. Manufacturer and consumers needs faster, stable and more proficient machinery. Power quality (PQ) is very vast subject and has many factors that affect it. These factors includes voltage changes, sag, transients, noise, harmonics, voltage unbalance, etc[4]

Optimization Techniques [5] – optimization is the method of searching for the best output values based on some given conditions. Optimization, in a universal sense has the objective of obtaining the most excellent achievable result given in a variety of choices. Thus optimizing a known function is to look for the parameters which guide to the biggest, or smallest, achievable result. The selection process of an objective function is not inconsequential, because the optimal selection with respect to a criterion will not be appropriate for a new criterion. The choice of the objective function is the most significant decision in the entire optimization procedure. The aim of a optimization problem will be to maximize or to numerical value.

A. Hybrid Optimization Algorithm[2]

Hybrid optimization algorithm which put together both PSO and a part of FF algorithm. The hybrid algorithm is bringing in to improve the search capacity of PSO. The division of FF algorithm which is the Cartesian distance among two swarm fireflies is used in the PSO algorithm to speed up the convergence speed.

Hybrid algorithm can overcome the disadvantages of both the PSO and FF algorithms and has a practical meaning. The high speed computation property of PSO algorithm is combined with FF algorithm so as to improve the global search capability.

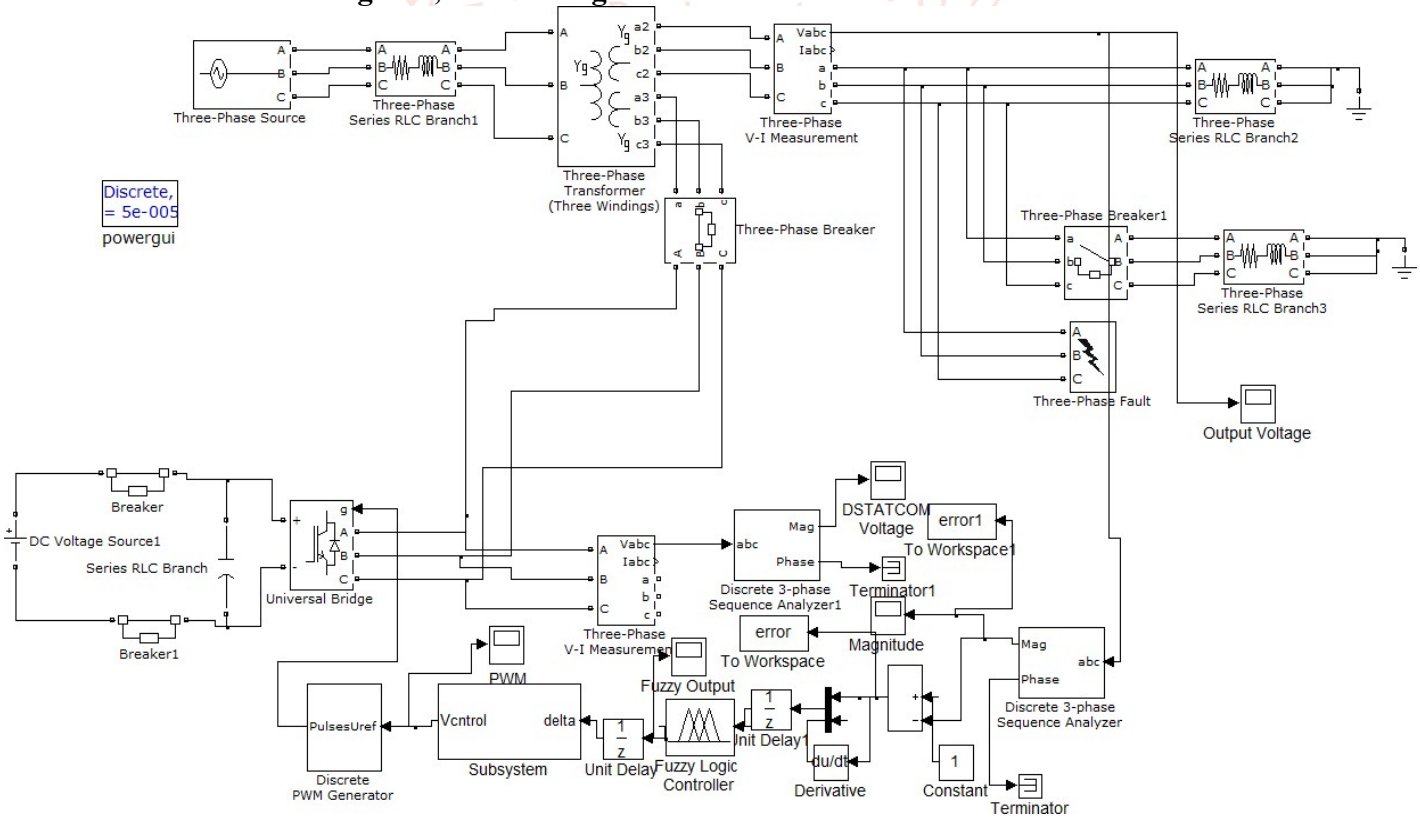
Literature Survey

- Power Quality Improvement has been fast growing and interesting area in modern society. There are a lots of various causes for the vast increase in the attention in power quality. These causes are voltage unbalance, distortion, voltage sag, noise, transients etc[4].
- A lot of loads at the power supply lines like industry equipments, variable speed drives, domestic utilities etc. have suffered from the problems of voltage variations, harmonic distortion, transients and disturbances. Above all power quality mainly connected with issues[4] like retaining a stable voltage on the common connecting point without considering the any voltage variations. There are a lot of techniques[6] to overcome the voltage sag effect and among them the best method is to attach a FACT device at the common coupling point. FACTS devices play a important role in voltage sag mitigation[7]. DSTATCOM is one of the FACTS devices that can be used for the compensation of power quality issues[8].

DSTATCOM can advance the progressive performance of the power quality of the power system[3]. The FF algorithm is a population based algorithm to locate the global optimal solution based on swarm intelligence, examining the foraging behaviour of fireflies[9]. The major function of the firefly's flash is to function as indication system to draw the attention of other fireflies .

PSO algorithm is an inhabitants based stochastic optimization method. A basic alternative of the PSO algorithm performs by possessing a inhabitants (called a swarm) of aspirant solution (called particles). The above particles are stimulated in the region of search-area based upon a small number of uncomplicated formulae. Compared to other optimization techniques the PSO algorithm is simple to realize, there are a small number of parameters to adjust and displays stable convergence[5]. By the application of the hybrid optimization algorithm the performance of a power network can be enhanced to a greater extend.

DSTATCOM: It is a FACTS device which is attached in parallel to the system. It has become an effective device for power quality enhancement. DSTATCOM is one of the useful method for controlling the voltage[10]. The consequence of voltage sag can be regulated by using DSTATCOM. The inertia effect due to mechanical elements is not present in it. The basic structure of the DSTATCOM is three phase in nature, connected in shunt to the system and to the connected load[11].



Modelling of the Test System in MATLAB for Three Phase Fault with Fuzzy Logic Controlled DSTATCOM

In this paper there are two inputs for the fuzzy logic controller. They are error (E) and change in error (CE). The error output come from the error detector and change in that error are given as the inputs to the fuzzy logic controlle[12]r. For the given two inputs and one output there are seven linguistic terms each. Here input 1 is E (error), input 2 is CE (change in error) and the output is control signal. From the rule base table it is evident that there are 49 rules in total. The seven linguistic terms[12] are named as NB, NM, NS, ZE, PS, PM and PB.

- The above linguistic terms can be expanded as follows
- NB - Negative Big
- NM - Negative Medium
- NS - Negative Small
- ZE - Zero
- PS - Positive Small
- PM - Positive Medium Table : Fuzzy Logic Control(FLC) Rule Base[12]
- PB – Positive Big
- For understanding a few base rules of FLC can be expanded as[12] :
- 1st Rule : if E (error) is NB (Negative Big) and CE (change in error) is NB then the control signal is NB.
- 2nd Rule : if E is NM and CE is NB then the control signal is NB.
- 49th Rule : if the E is PB and CE is PB then the control signal is PB.

E \ CE	NB	NM	NS	ZE	PS	PM	PB
NB	NB	NB	NB	NB	NM	NS	ZE
NM	NB	NB	NB	NM	NS	ZE	PS
NS	NB	NB	NM	NS	ZE	PS	PM
ZE	NB	NM	NS	ZE	PS	PM	PS
PS	NM	NS	ZE	PS	PM	PB	PB
PM	NS	ZE	PS	PM	PB	PB	PB
PB	ZE	PS	PM	PB	PB	PB	PB

Table : Fuzzy Logic Control(FLC) Rule

Properties of Input and Output Terms in the FLC

VariableName	Variable Type	Range
Error	Input 1	**[-5 5]**
Change inError	Input 2	**[-5 5]**
ControlSignal	**Output**	**[-10 10]**

Optimization Of Fuzzy Logic Controller Using HybridOptimization Technique[2]

Hybrid optimization technique is an optimization algorithm which is a combination of PSO algorithm andFF algorithm. Hybrid algorithm is almost similar to the PSO algorithm. But during the velocity and position updating process, it makes use of the FF algorithm. At that time the distanceof the particle from pbest and gbest are calculated and is applied in the equation for updating the values. The steps involved in the hybrid optimization algorithm are given below

Step 1: Define the initial particle population and randomly take initial position and speed of the particle

Step 2: Initialise pbest with a copy of initial position value Step 3: Find out the fitness value for each particle

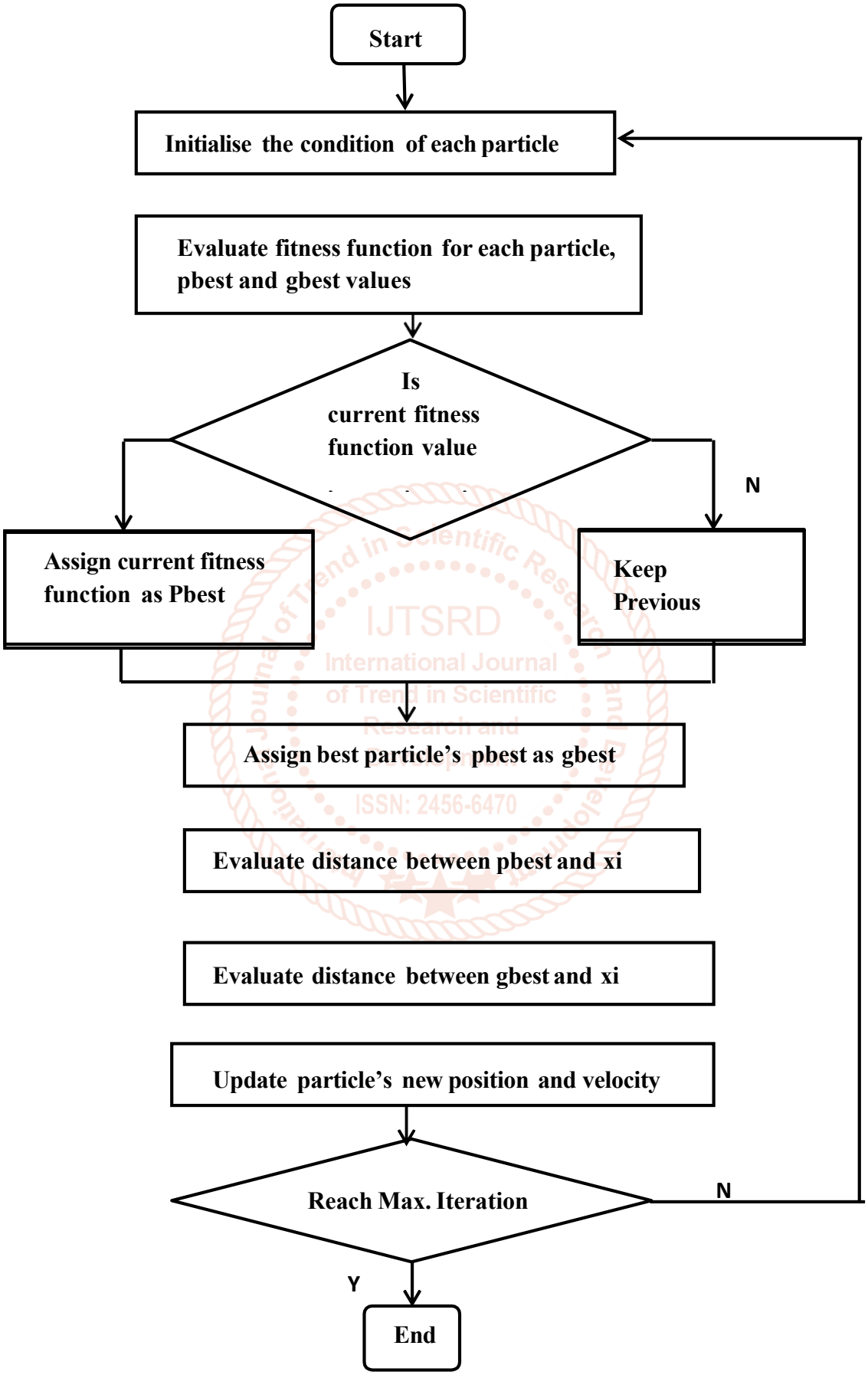
Step 4: Check whether the fitness value is better to the best fitness value so far. If thatvalue is superior then set present value as the recent pbest.

Step 5: Choose the particle with the most excellent fitness value of the entire particlesas the gbest

Step 6: Find the distance of each particle from pbest and gbest Step 6: Find particle velocity and renew particle position

Step7 : if highest iteration number is not reached go to step 3 or else stop the process.

FLOW CHART OF HYBRID OPTIMIZATION ALGORITHM[2]



In the firefly algorithm the distance between two fireflies increases as the brightness between them decreases. In hybrid optimization algorithm the distance between pbest, (parameter in the PSO algorithm) and the position x_i can be evaluated in the Cartesian framework by the following equation

$$r_{pxi} = \sqrt{\sum_{n=1}^{d} (pbest_{i,n} - x_{i,n})^2}$$

where r_{pxi} is the distance between $gbest_i$ and x_i which are considered as two swarm fireflies and d is the dimension of the search space.

The equation between $gbest_i$ and the position x_i is

$$r_{gxi} = \sqrt{\sum_{n=1}^{d} (gbest_{i,n} - x_{i,n})^2}$$

where r_{gxi} is the distance between $gbest_i$ and x_i

The new velocity and position of each particle is assessed by the equations given below.

$$V_i^{n+1} = w * v_i^n + r_1 * e^{-r2}{}_{pxi} * (pbest_i - x_i^k) + r * e^{-r2}{}_{gxi} * (gbest_i - x_i^n) + \alpha(gbest_i - 0.5)$$

$$x_i^{n+1} = x_i^n + v_i^{n+1}$$

where, w – inertia weight factor; c_1 & c_2 – acceleration constants

r_1 & r_2 – random numbers b/w 0 and 1

$v_i^{(t)}$ – velocity of the particle I in n_{th} iteration

$x_i^{(t)}$ – position of particle I in n_{th} iteration

selection of w gives equilibrium b/w global and local explorations and it is set according to the equation given below

$$w = w_{max}((w_{max} - w_{min}) * {}^{t}/_{T})$$

w_{max} – maximum value of inertia weight

w_{min} – minimum value of inertia weight

t – current iteration number

T – maximum number of iteration

The values of different parameters taken in the hybrid optimization algorithm are same as PSO algorithm and Firefly algorithm. The gbest value found after the completion of the iteration process in the hybrid optimization algorithm is the optimized value of the output variable of the fuzzy logic inference system.

FLC RULE BASE AFTER USING HYBRID OPTIMIZATION ALGORITHM

CE / E	NB	NM	NS	ZE	PS	PM	PB
NB	NB	NB	NB	NS	NM	NS	ZE
NM	NB	NB	NS	NM	NS	ZE	PS
NS	NB	NS	NM	NS	ZE	PS	PM
ZE	NS	NM	NS	ZE	PS	PM	PM
PS	NM	NS	ZE	PS	PM	PM	PB
PM	NS	ZE	PS	PM	PM	PB	PB
PB	ZE	PS	PM	PM	PB	PB	PB

RESULTS :

CASE 1 : SIMULATION WITH FUZZY LOGIC CONTROLLED DSTATCOM : the fault is applied for a time period of 0.6s to 0.7s. the fault resistance is taken as 0.66 ohm. The simulation time is taken as 1s. this given data is applied for all faults like three phase fault, double line to ground fault, and single line to ground fault.

The fuzzy logic control DSTATCOM acted effectively during faults and reduces the voltage sag.

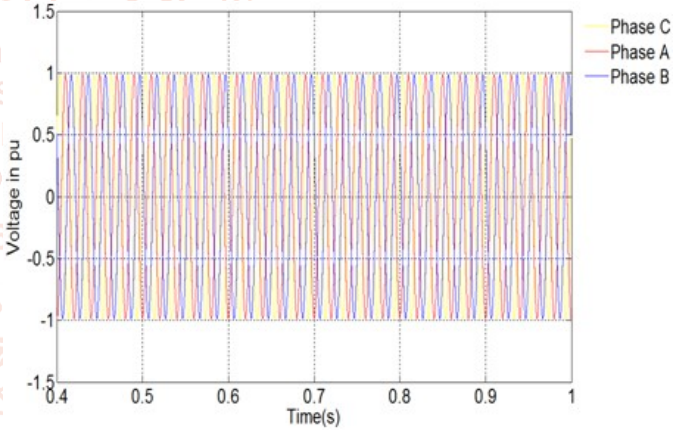


Fig : Test system output without any fault applied

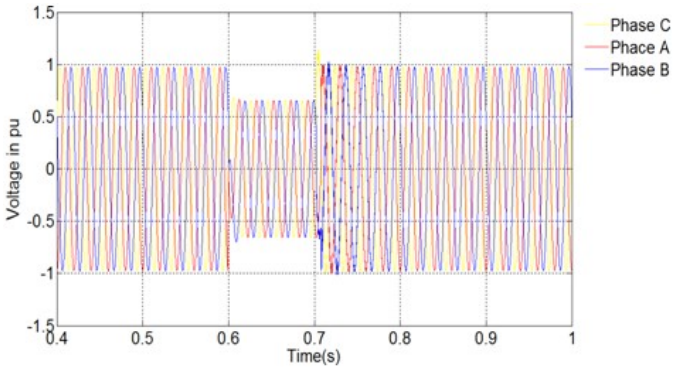


Fig : Test System Output without Connecting DSTATCOM during Fault

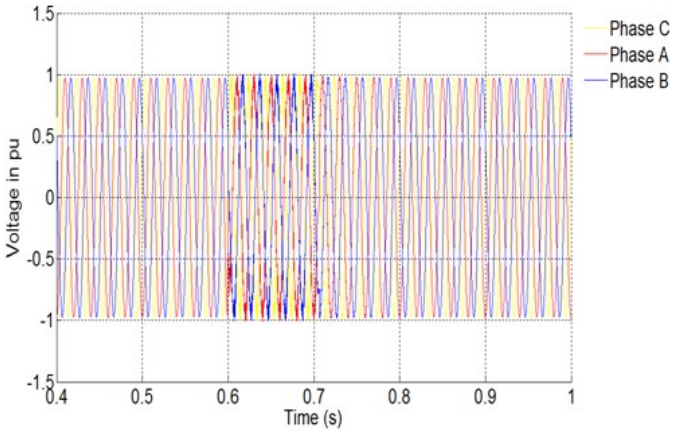


Fig : Test system output with DSTATCOM during fault.

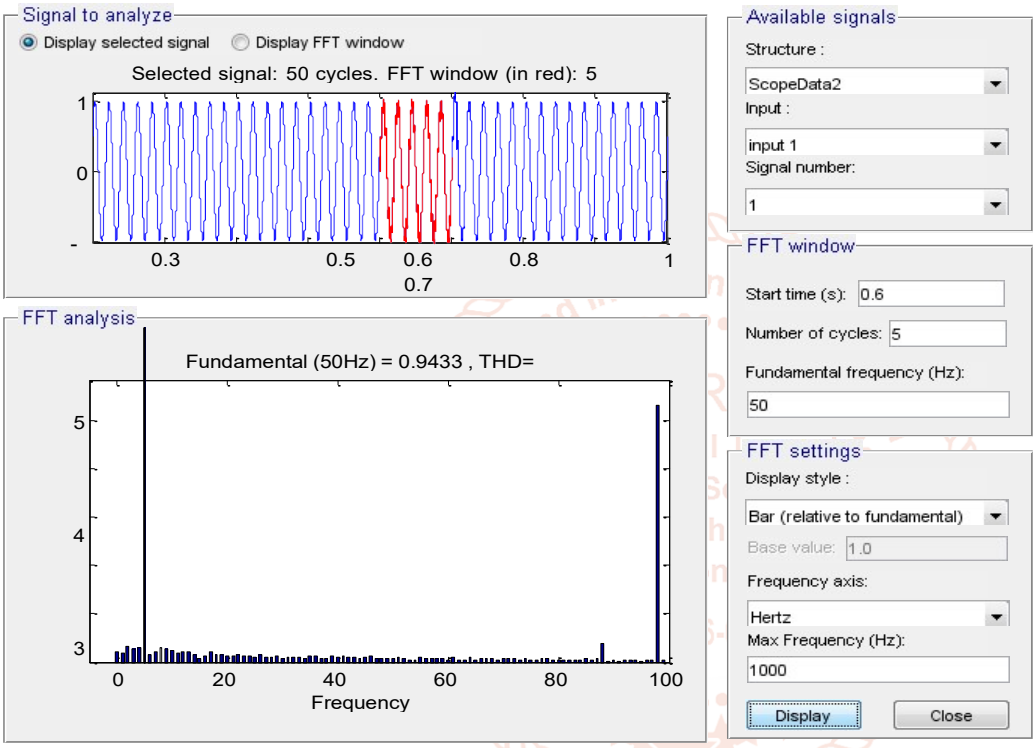


Fig: Fuzzy Logic Controlled DSTATCOM during Three phase fault- phase A

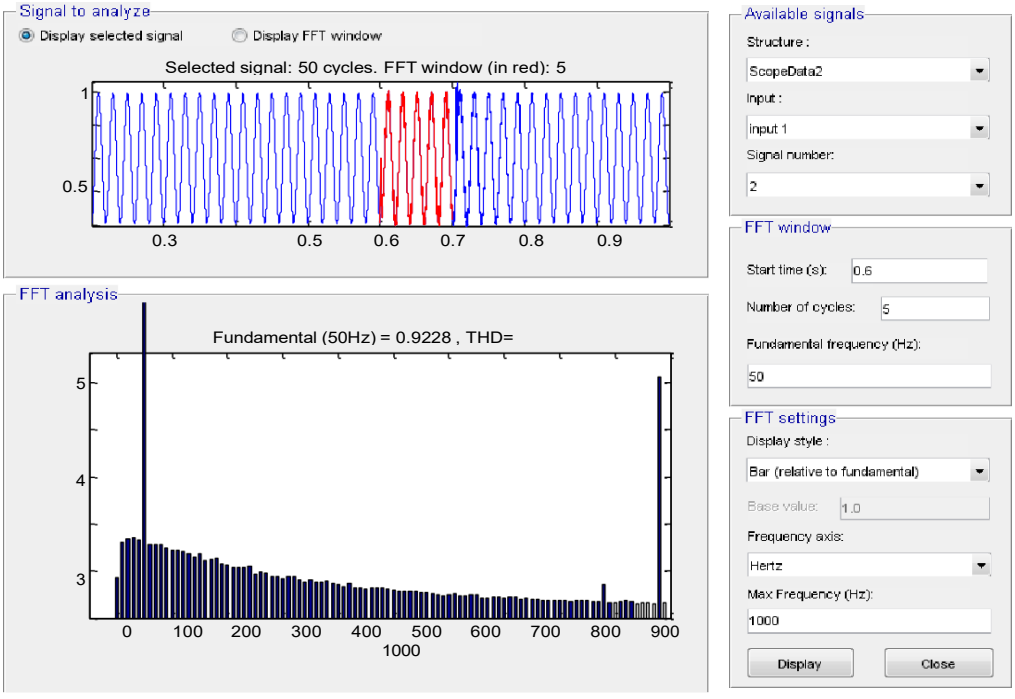


Fig : FLC DSTATCOM during double line to ground fault phase B

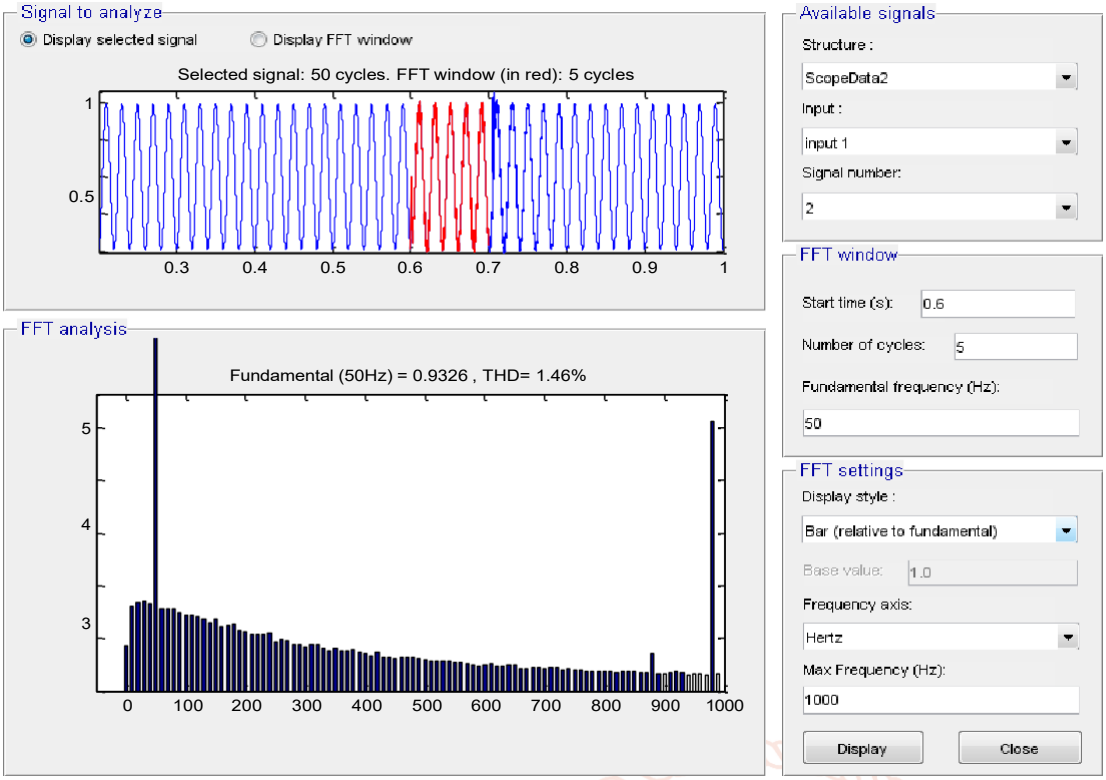


Fig: Fuzzy Logic Controlled DSTATCOM during three phase fault phase C

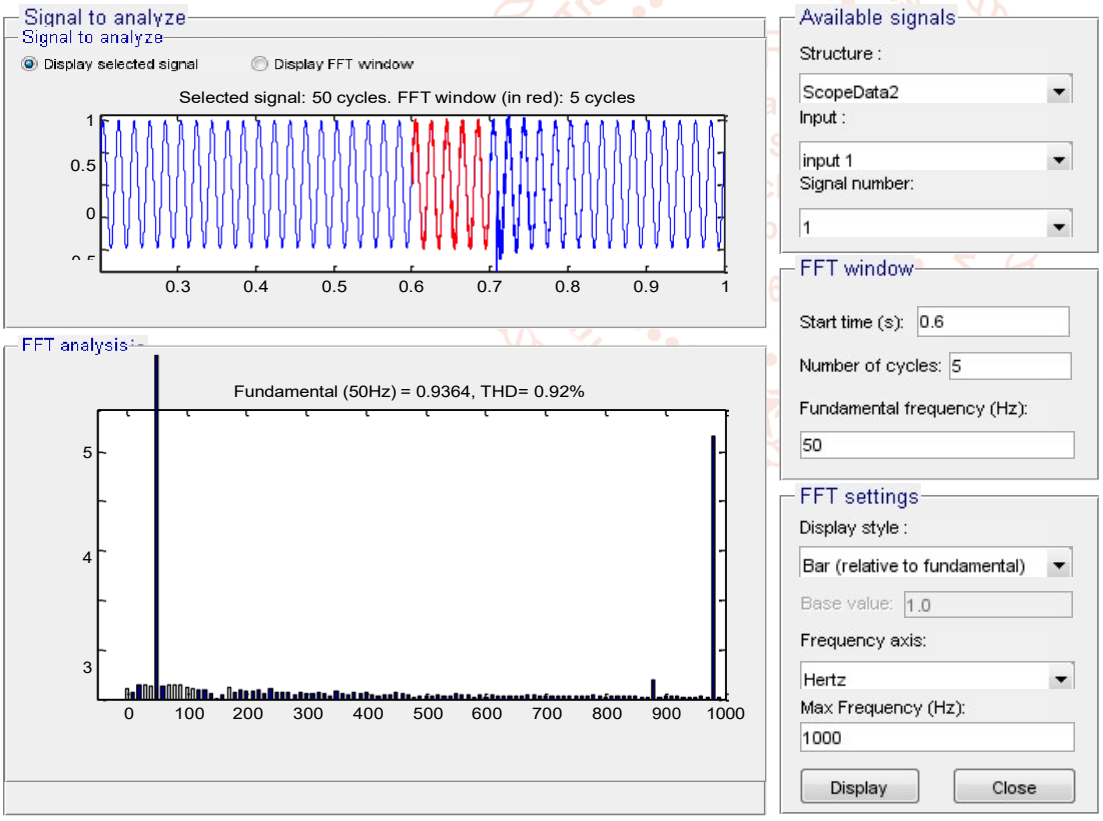


Fig : FLC DSTATCOM during double line to ground fault phase A

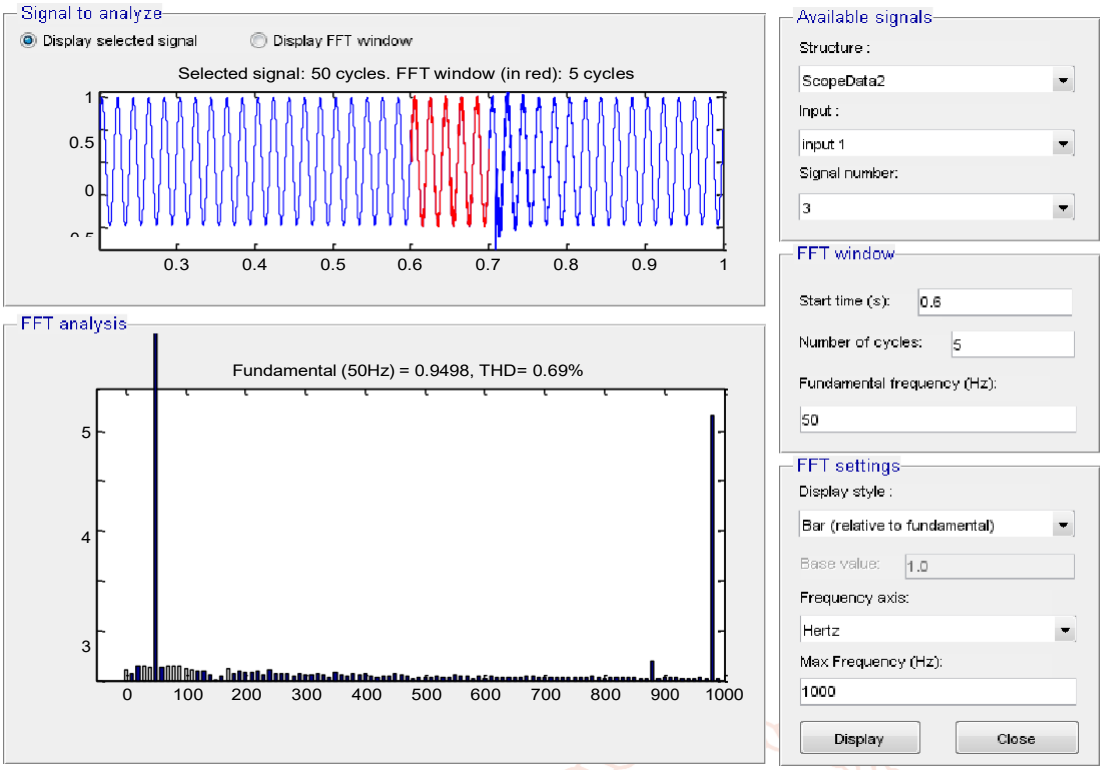


Fig : FLC DSTATCOM during double line to ground fault phase C

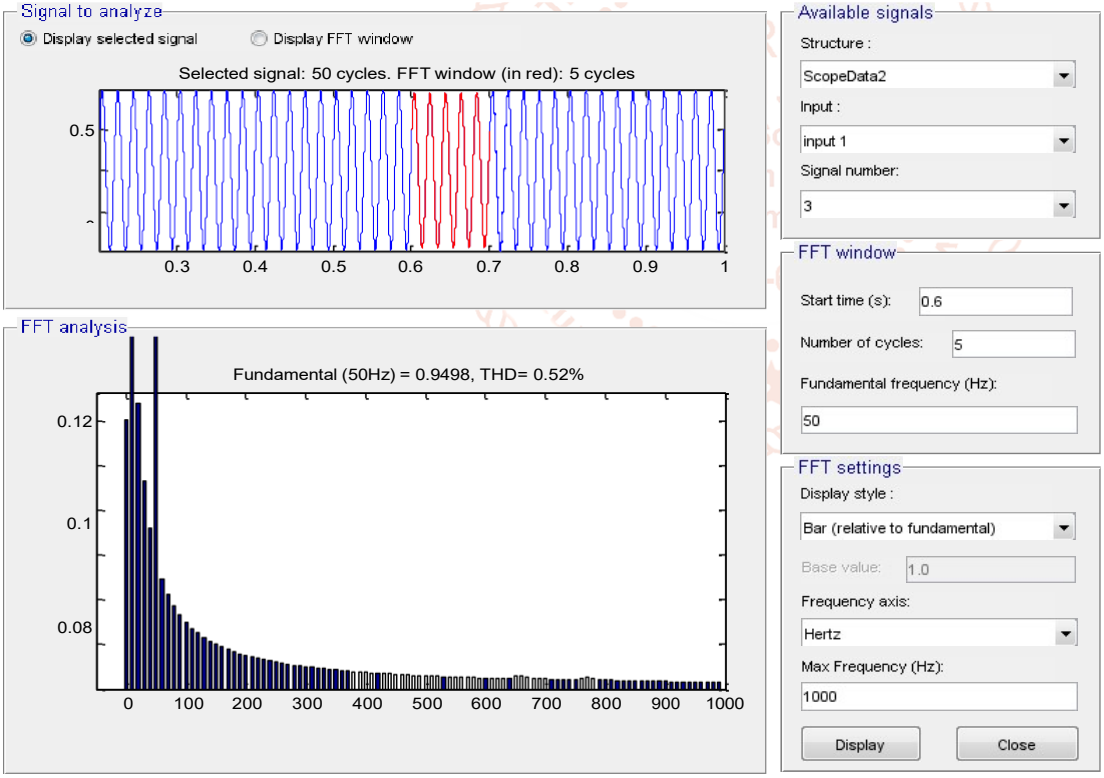


Fig : FLC DSTATCOM during single line to ground fault phase A

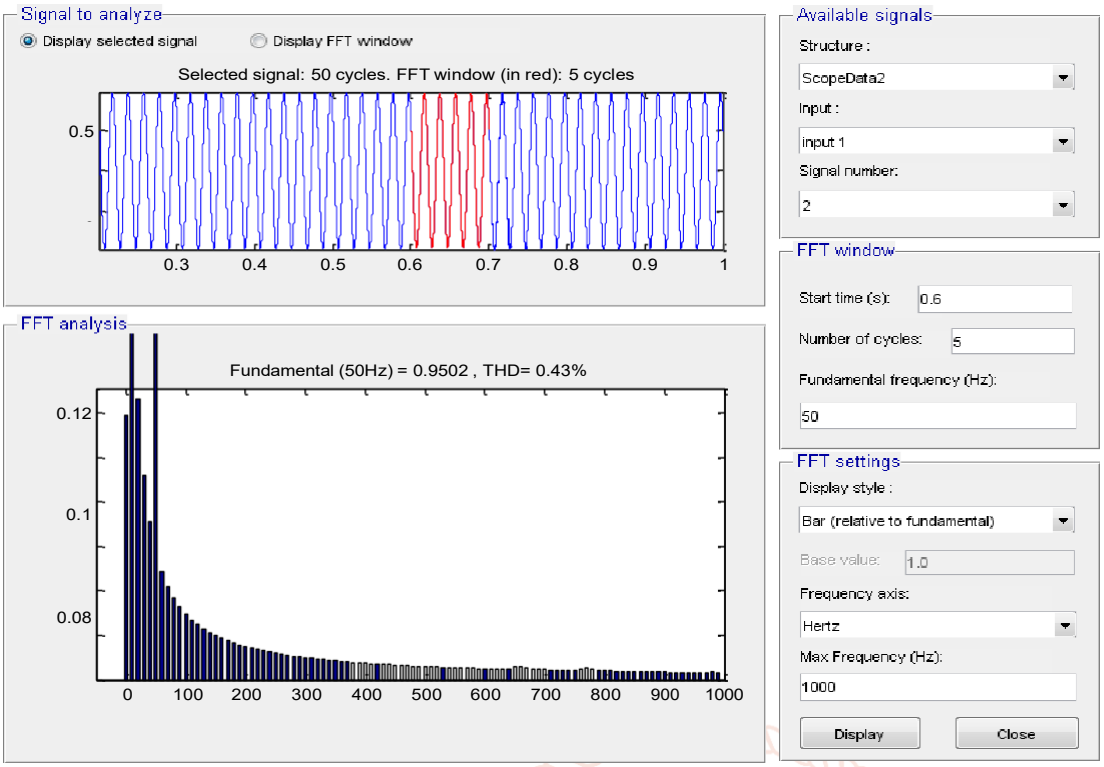


Fig : FLC DSTATCOM during single line to ground fault phase B

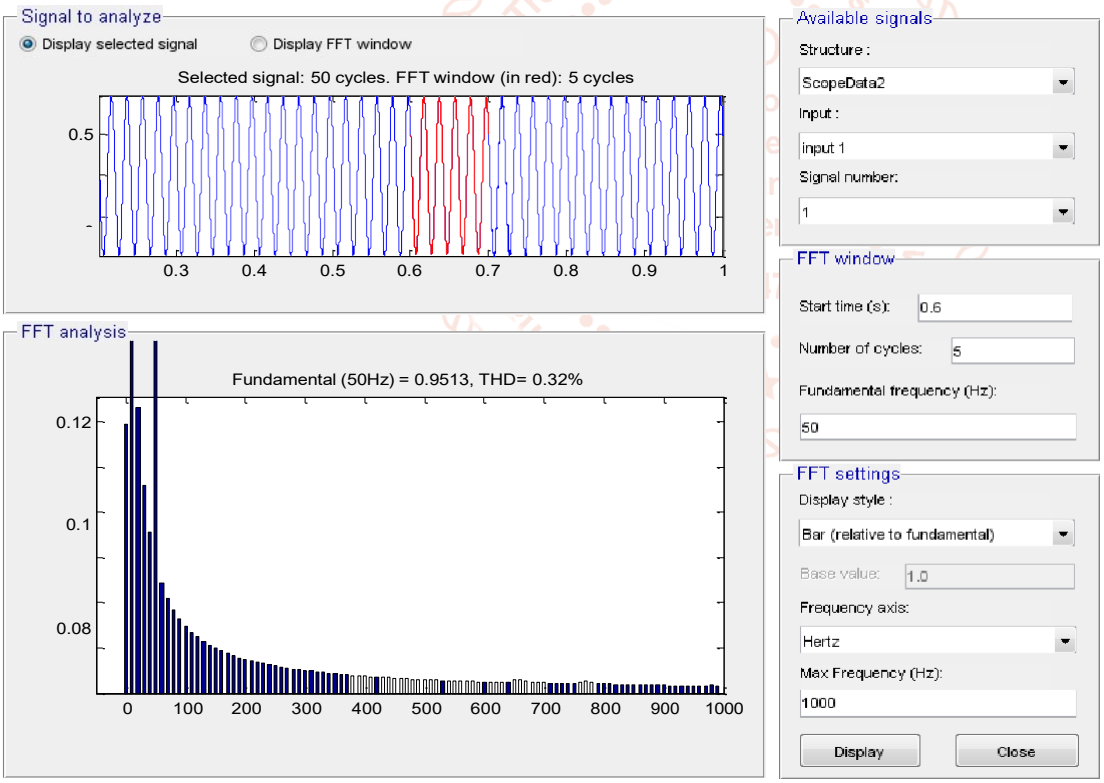


Fig : FLC DSTATCOM during single line to ground fault phase C

In the above case the performance of DSTATCOM with FLC is given in the graph. The THD analysis of the system during fault is also given. It is evident from the results that the DSTATCOM with FLC can reduce the effect of voltage sag.

CASE 2 : SIMULATION OF HYBRID – FLC DSTATCOM.

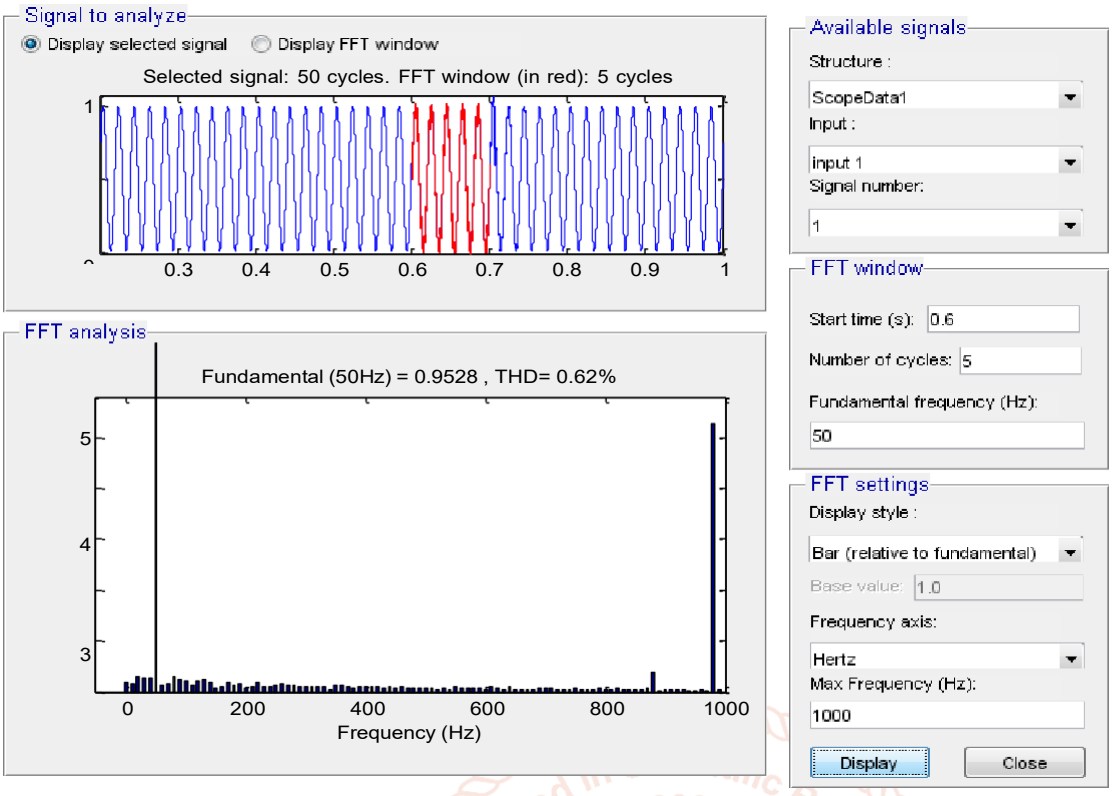


Fig : Hybrid PSO –FF algorithm optimized Fuzzy controlled DSTATCOM during three phase fault phase A

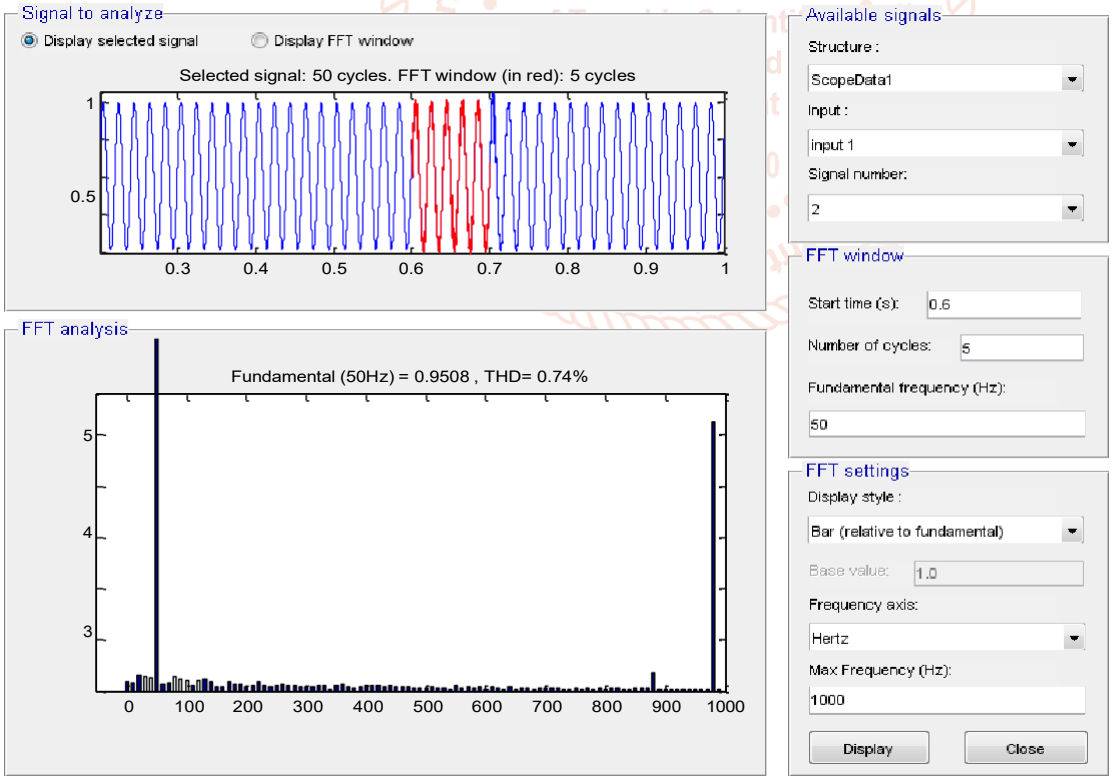


Fig : Hybrid PSO – FF algorithm optimized fuzzy controlled DSTATCOM during three phase fault phase B

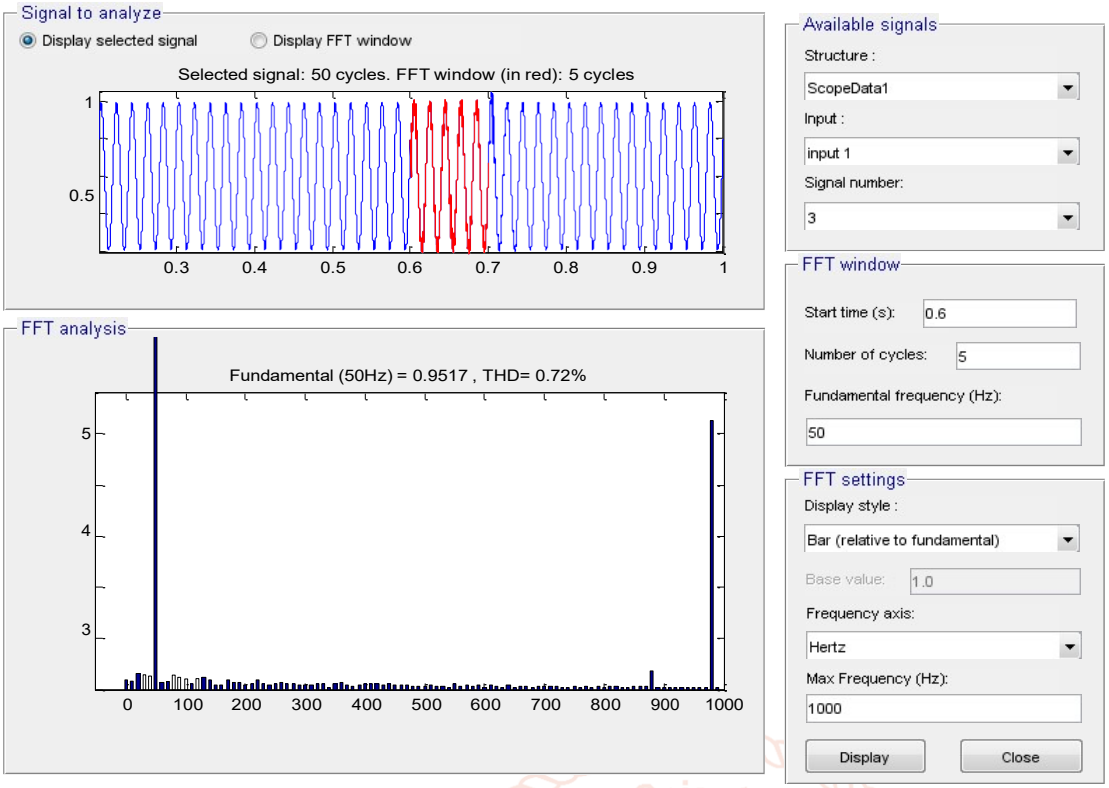


Fig: Hybrid PSO–FF Algorithm optimized fuzzy logic controlled DSTATCOM three phase fault phase C

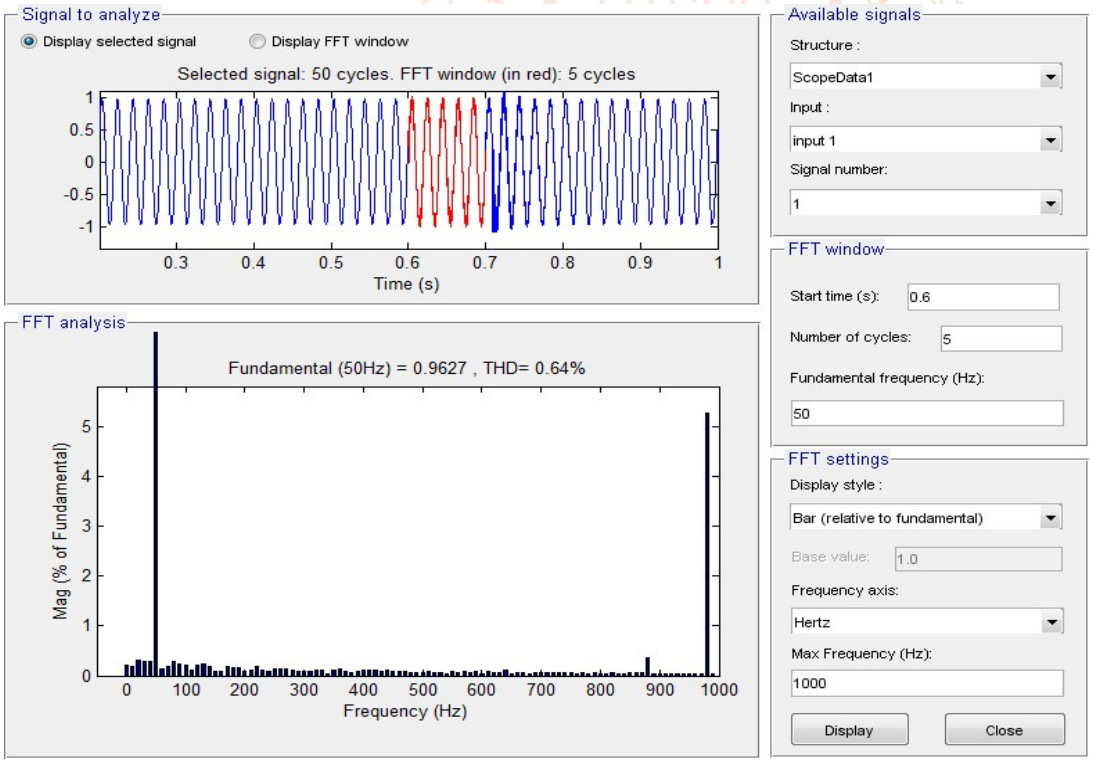


Fig : Hybrid PSO – FF algorithm optimized fuzzy controlled DSTATCOM during double line to ground fault phase A

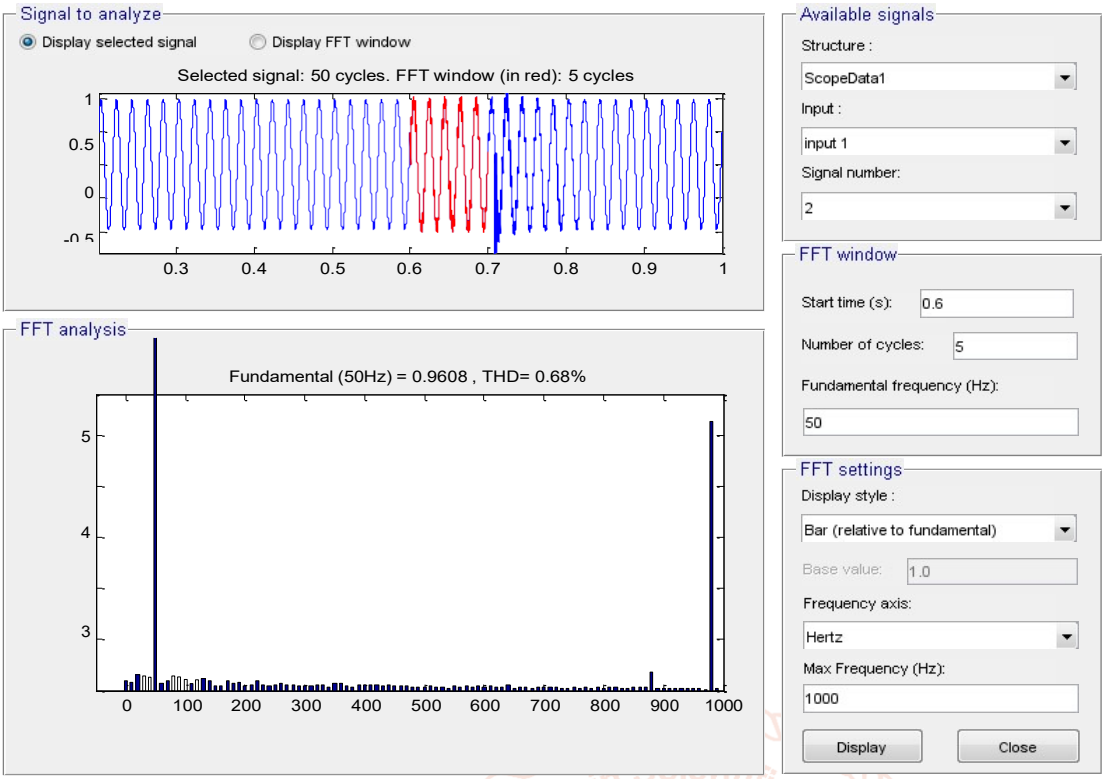


Fig: Hybrid PSO–FF Algorithm optimized fuzzy logic controlled DSTATCOM double line to ground fault phase B

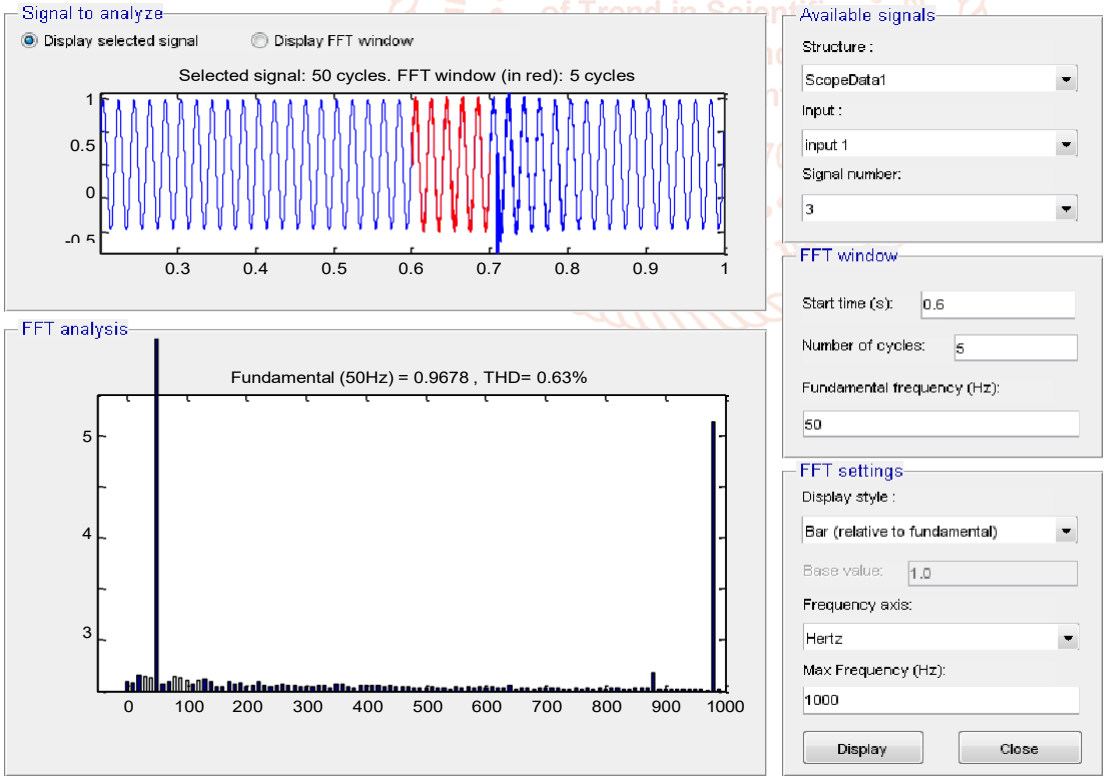


Fig: Hybrid PSO–FF Algorithm optimized fuzzy logic controlled DSTATCOM double line to ground fault phase c

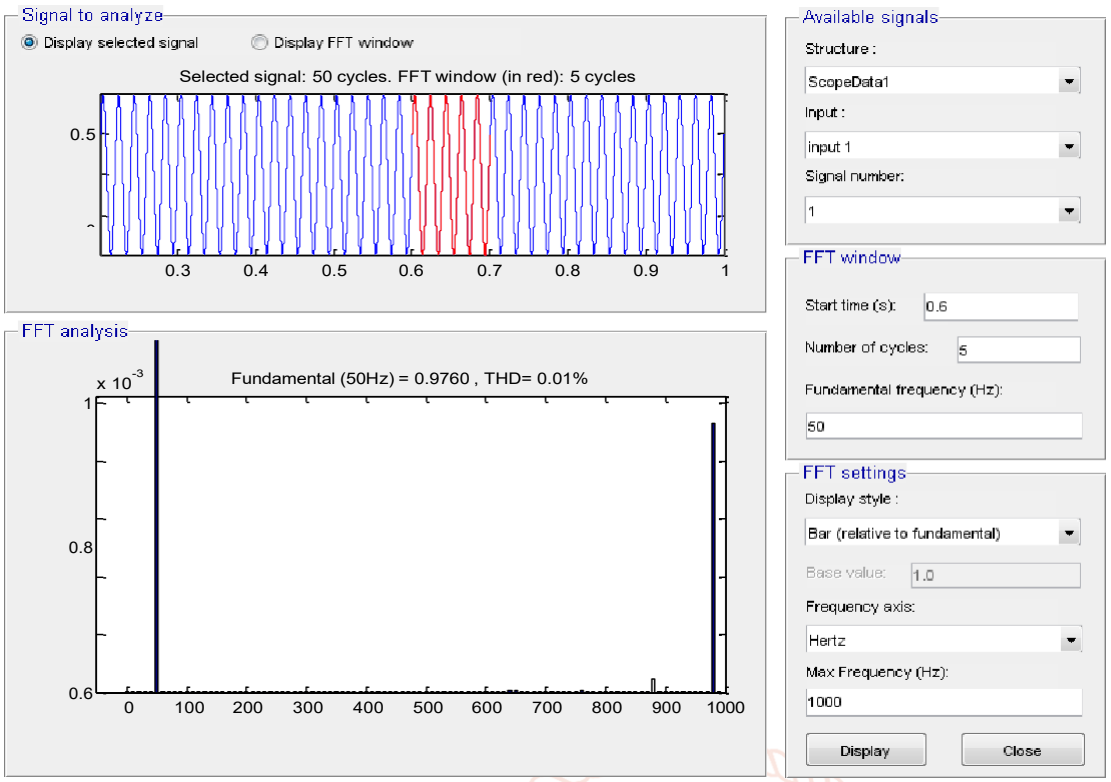


Fig: : Hybrid PSO–FF Algorithm optimized fuzzy logic controlled DSTATCOM single line to ground fault phase A.

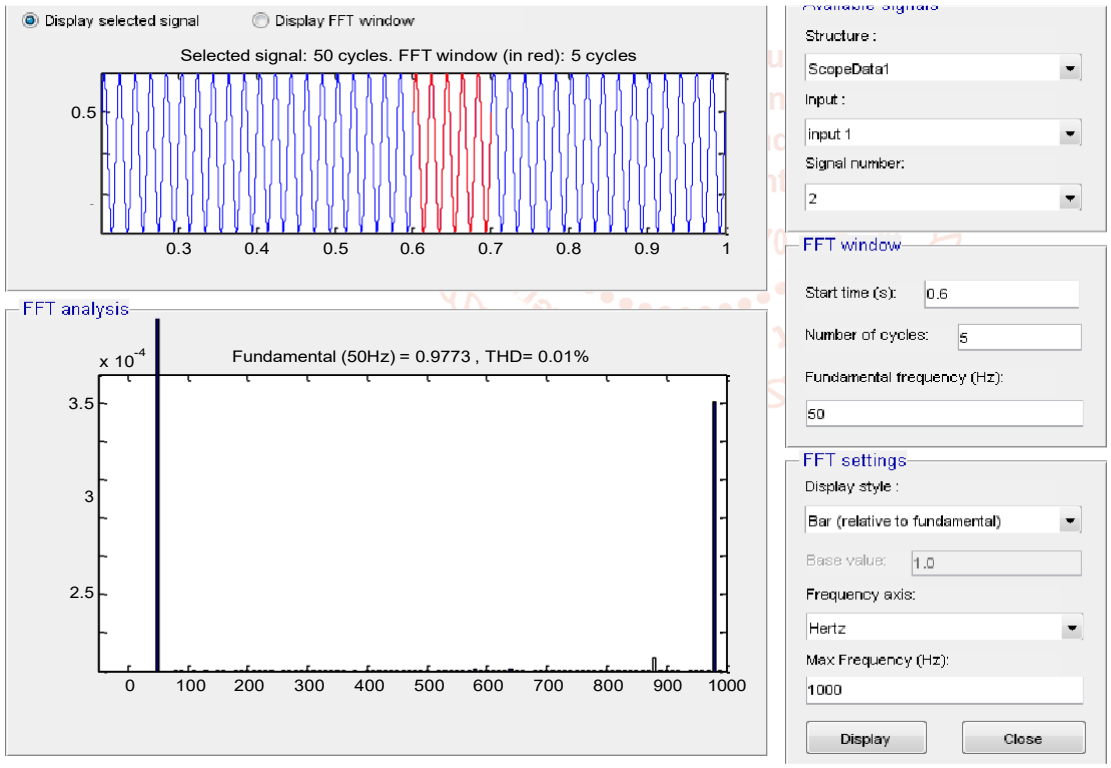


Fig : Hybrid PSO – FF algorithm optimized fuzzy controlled DSTATCOM during single line to ground fault phase B

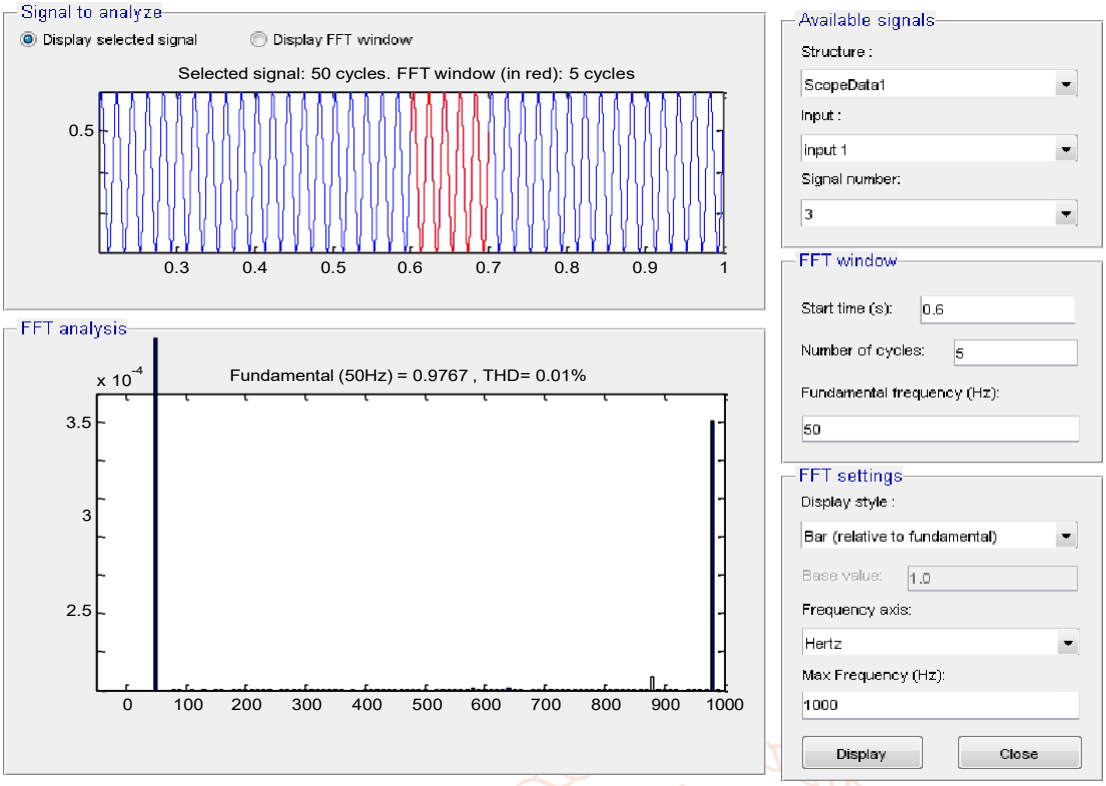


Fig : Hybrid PSO–FF Algorithm optimized fuzzy logic controlled DSTATCOM single line to ground phase c

In the above case the performance of hybrid optimization algorithm optimized DSTATCOM provided an improved result in voltage sag mitigation. The performance of hybrid algorithm optimized DSTATCOM is given in the figures above. The THD analysis during various faults is also given. It is evident from the test results that the hybrid algorithm optimized DSTATCOM can effectively mitigate the voltage sag problems. The THD can also be controlled efficiently using hybrid algorithm optimization. The performance of hybrid algorithm optimized DSTATCOM in voltage sag reduction is much better[2]

Table : Comparison of FLC and Hybrid – FLC using DSTATCOM during Three Phase Fault

	Phase A		Phase B		Phase C	
	Voltage in pu	THD%	Voltage in pu	THD%	Voltage in pu	THD%
FLC DSTATCOM	0.9433	0.65	0.9228	1.79	0.9326	1.46
Hybrid -FLCDSTATCOM	0.9528	0.62	0.9508	0.74	0.9517	0.72

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Table : Comparison of FLC and Hybrid – FLC using DSTATCOM during Double Line to Ground Fault.

	Phase A		Phase B		Phase C	
	Voltage in pu	THD%	Voltage in pu	THD%	Voltagein pu	THD%
FLC DSTATCOM	0.9444	0.70	0.9364	0.92	0.9498	0.69
Hybrid -FLC DSTATCOM	**0.9627**	**0.64**	**0.9608**	**0.68**	**0.9678**	**0.63**

Table : Comparison of FLC and Hybrid – FLC DSTATCOM during Single Line to Ground Fault

	Phase A		Phase B		Phase C	
	Voltage in pu	THD%	Voltage in pu	THD%	Voltagein pu	THD%
FLC DSTATCOM	0.9498	0.52	0.9502	0.47	0.9513	0.32
Hybrid -FLCDSTATCOM	**0.9760**	**0.01**	**0.9733**	**0.01**	**0.9767**	**0.01**

CONCLUSION : It is identified that one of the ways to mitigate the voltage sag is by means of DSTATCOM[10]. In order to verify or examine whether voltage sags can mitigate by means of DSTATCOM or not, MATLAB Simulink was selected in order to perform simulation for the distribution scheme and mitigate the voltage sag. Based on the results and simulations that have been prepared, it can be illustrated and shown that DSTATCOM device is able to overcome the voltage sag issue.

During the time of fault in the system voltage sag occurs in the system and there is no control over the system without DSTATCOM. In this case the voltage sag cannot be regulated. Fuzzy controlled DSTATCOM offers much more enhancement in voltage sag mitigation[13]. At the time of voltage sag, the magnitude of voltage output of the system with Fuzzy controlled DSTATCOM is superior than that of the system with PI controlled DSTATCOM and it is much more increased by the application of hybrid optimization technique . From the test results it can be seen that the performance of hybrid optimization algorithm is much better than other optimization techniques.

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