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Power Quality Improvement of Micro Grid Interfaced Hybrid System Using Dstatcom with Grass Hopper Optimization Algorithm

Abstract: - Microgrids that combine AC and DC have gained popularity in recent years due to the benefits they offer. Due to the MG's dual-grid configuration, AC-DC converters must be interconnected. Non-linear AC loads can adversely affect the quality of the AC bus voltage when an extra harmonic adjustment mechanism is added to the interlinking converters. Typically, active power filters (APFs) are designed to control harmonics, but interconnection converters exchange real and reactive power between DC and AC sub-grids. Switching frequencies should be lower than APFs when the MG has a high capacity. Low switching frequencies may adversely affect harmonic correction or system stability. An integrated PV and wind energy system was incorporated into the hybrid system in this study. The maximum power point tracking (MPPT) method has been proposed to maximize system efficiency. Furthermore, the stability of the hybrid system was improved in this study.Our current work includes the addition of a fact device referred to as DSTATCOM, which is optimized with the grass hopper algorithm (GOA). To reduce power disturbances, reactive power compensation is used along with active power filters. Harmonics as well as sags and swells are also protected by this device. When used as a current controller, it increases current, and when used as a voltage controller, it increases voltage. Due to an issue of unbalanced load in the grid the weak AC supply can be compensated by applying the modified GOA algorithm. Due to the quick response time, modified algorithms are proposed during the occurrence of a power quality issue in the grid. The proposed technique uses solar and wind energy inputs to check the hormonal disturbances in power supply. The control techniques was developed using system parameters and control systems were tested using Mat-lab/ Simulink and the results compared with DPFC.

Keywords: Hybrid systems, Power quality, Optimization, Dstatcom, GOA.

1. INTRODUCTION

PQ difficulties arise when distributed generation (DG) systems are integrated into the current distribution network, including solar photovoltaic (PV), wind turbines (WT), or fuel cells (FC). Microgrids (MGs) are built as suitable and flexible platforms to facilitate the integration of DGs, loads, and energy storage systems for meeting energy demand [5–7]. In order to meet a larger share of the total electricity demand, the microgrid is one of the most promising energy resources. Furthermore, its intermittent nature contributes to significant power supply unpredictability. As a result of climatic conditions, variations in input sun intensity and wind speed will affect PQ, protection, and stability problems in the power sector. Moreover, inverter-based DG will have an impact on traditional power systems' protection strategies when integrated. Under different operating scenarios, therefore, solving the PQ problems in a power system poses a very difficult challenge. Distributed energy resources are widely used in electric power systems[8]. Good performance and less harmonics should be provided by the resources. In the modern power system network, electric resources should be continuous. In a grid system, DSTATCOM consists of a dc voltage source, voltage source converter circuit, coupling transformer, and associated controller. In voltage source converters, the dc input voltage is converted into a set of three phase ac output voltages. A coupling transformer reactance couples these voltages to an ac system. In DSTATCOM, phases and magnitudes of voltage are required to allow effective composition of reactive. Current harmonics and voltage regulation will be eliminated with a voltage source converter[9]. DSTATCOM's control system is used to compensate reactive power in microgrids. IGBT, MOSFET, and Thyristor are used in

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DSTATCOM's three-phase inverter modules. Microgrid reactive power will be generated or observed by DSTATCOM[10]. Inverters such as DSTATCOM are driven by DC capacitor voltage. In order to provide safe operating voltage and low reactance, the voltage source converter is coupled to a transformer[11]. Reduced energy bills, PARs, and consumer discomfort are the main objectives of the energy management system (EMS). To achieve the aforementioned objectives, many algorithms have been developed. Researchers use meta-heuristic techniques to overcome these deficiencies and resolve energy. According to [11,12], genetic algorithms (GA) are used to minimize cost. [13,14] used differential evolution (DE) and ant colony optimization (ACO) to minimize cost and aggregate power consumption. As part of this research work, we implemented GOA in MATLAB simulation to obtain results for sag, swell, and other quality objectives.

2. RELATED WORK

According to recent studies [15,16], power flow was regulated using power and current control loops in grid-connected MG mode. In MG control structures, the proportional integral (PI) controller has been found to be the most widely used regulator due to its robustness, simplicity, and reliability [17]. The performance of PI controllers is purely dependent on appropriate gain tuning to attain suitable values for proportional and integral gains (Kp and Ki) , which limits their use in modern MG control structures. Ziegler–Nichols (Z–N) or trial-and-error methods are generally used to select these two coefficients [18,19]. In addition to the large time consumption and the uncertainty associated with optimal parameter selection, these methods of PI tuning have two major drawbacks. As a result, the studied power system may exhibit a poor dynamic response and may become unstable due to large current and power overshoots. To achieve enhanced transient and steady-state response, the proper tuning of PI parameters is crucial. Recently, soft-computational techniques have been used to enhance the dynamics of the MG system in order to overcome the limitations of the PI controller. Through the use of these soft-computational techniques for choosing parameters for modern MG controls, RES can be injected and disconnected smoothly in existing power systems, with low overshoots, reduced settling times, a better dynamic response during load changes, a smoother power sharing between utilities and MG, improved power quality for consumers, and improved grid-connected MG stability. Additionally, these smart search methods provide an optimal solution for the given problem while providing an improvement over traditional analytical methods [20]. The power flow control of a grid-connected MG has been the focus of research around the world using various soft-computational techniques, such as the General Regression Neural Network (GRNN) algorithm [21], particle swarm optimization (PSO) [23,24], as well as an improved version of PSO [22].It was the fundamental goal of all the research works mentioned above to avoid the time consuming and inefficient conventional PI tuning techniques in order to achieve the optimal power regulation. These studies demonstrated that the PI coefficients selected by the mentioned soft computational optimization methods had a better transient behavior than conventional PI tuning techniques in grid-connected MG systems. However, both GA and PSO have a few key weaknesses as well. It is not suitable for working with dynamic data sets because a GA can be trapped into a local solution. GA has become obsolete in MG controls due to these demerits. PSO, on the other hand, tends to get trapped in local minima when solving high-dimensional optimization problems. A slow convergence rate and uncertainty of parameter selection are also disadvantages [25]. In some benchmark functions, PSO struggles to find an optimum solution despite its good search capability in the initial iterations [16]. Using the intelligence of the Grasshopper Optimization Algorithm (GOA), this research work develops a power flow controller for optimizing the DSTATCOM gains in grid-connected MG mode to achieve the desired MG power-sharing ratio with optimal dynamic response and high power quality. In order to accomplish the stated research objective, the optimization of DSTATCOM parameters is achieved by minimizing an error integrating fitness function (FF) using GOA. The optimized DSTATCOM parameters result in the optimized transient response of the grid-connected MG studied in this study.

3. SYSTEM MODELLING FOR PROPOSED WORK

Present work focused on the two system hybridization solar and wind power for the input to micro-grid as shown in figure1

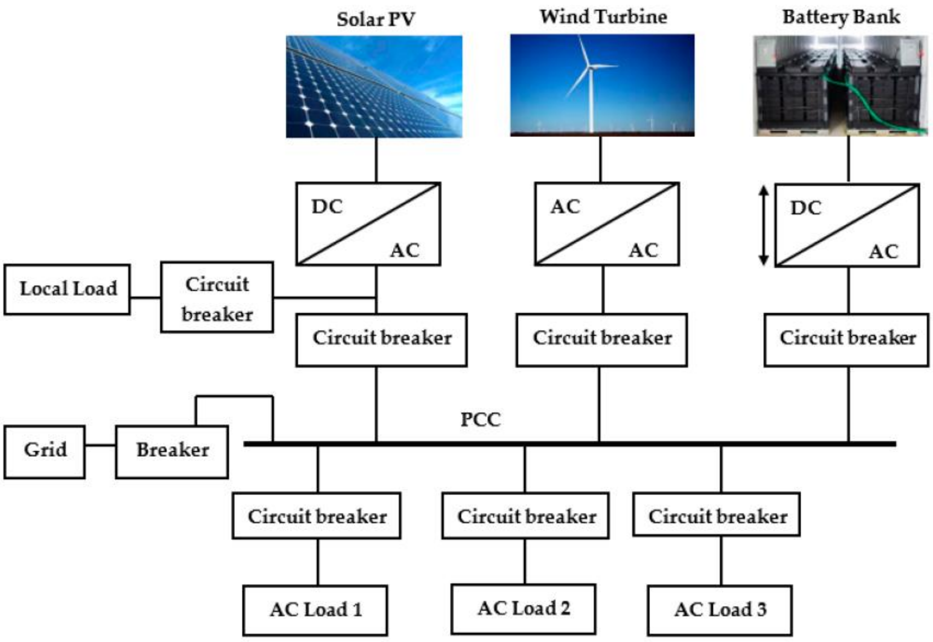


Figure:1 General structure of hybrid power micro grid

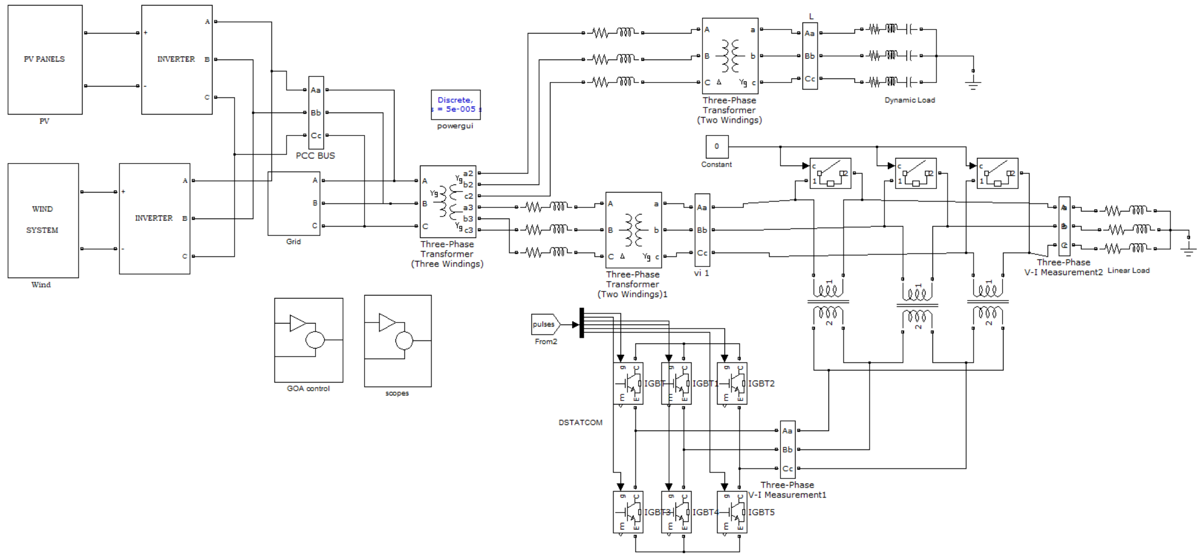


Figure 2: Proposed Matlab circuit

A hybrid system designed as shown in the figure 2 with converter added to the DC power system to check the power flow analysis with the placement of DSTATCOM. The working advantage of DSTACOM over the other compensatory devices the flow disturbances were minimized. The advantage of gross hopper algorithm was the identification of power failures at individual ends by dividing the total grid connectivity by different segments. The optimized algorithm finds the failure in minimal time and immediately activating DSTATCOM to switching the power compensation to keep power harmony in hybrid circuit. The proposed GOA controller shown in figure3.

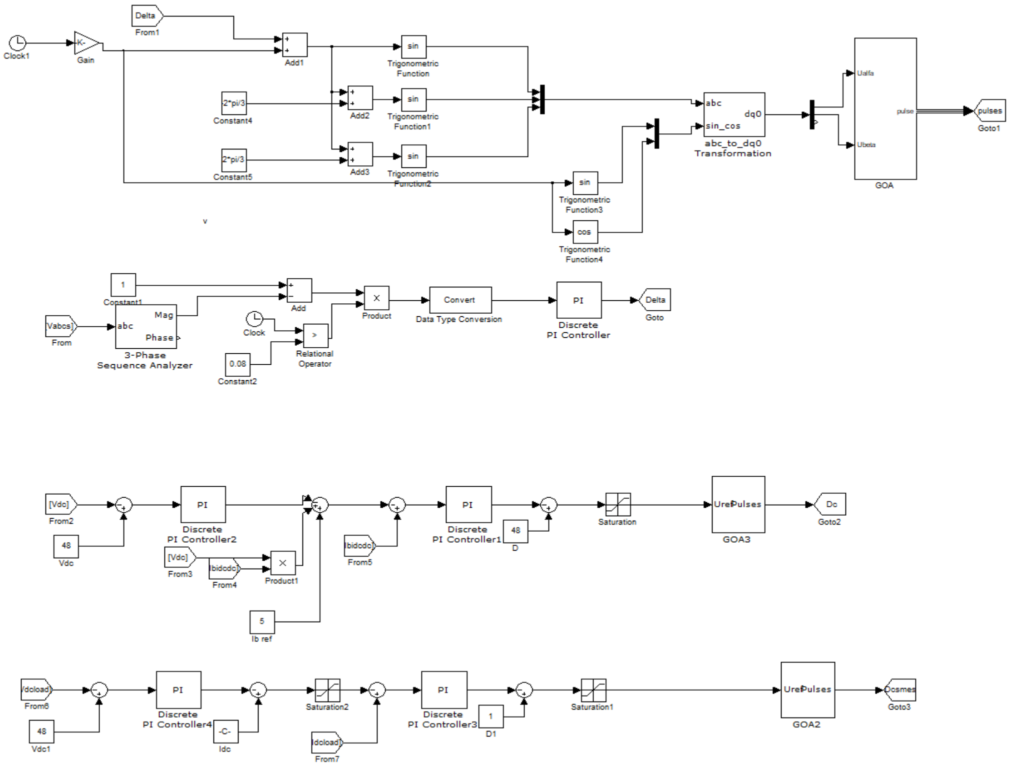


Figure:3 Proposed GOA controller

a. System staratagies

To achieve maximum efficiency and maximum power from solar MPPT techniques were implemented. A boost converter was added to DC-DC for a storage device know as battery system. The system must maintain synchronization with the grid. The solar system was connected to a voltage source inverter to match the frequency levels and system rates, and the control diagram for the inverter was designed using a general PWM technique, and the reference signals were chosen from the grid parameters. The PV and wind models are given below in figure4.

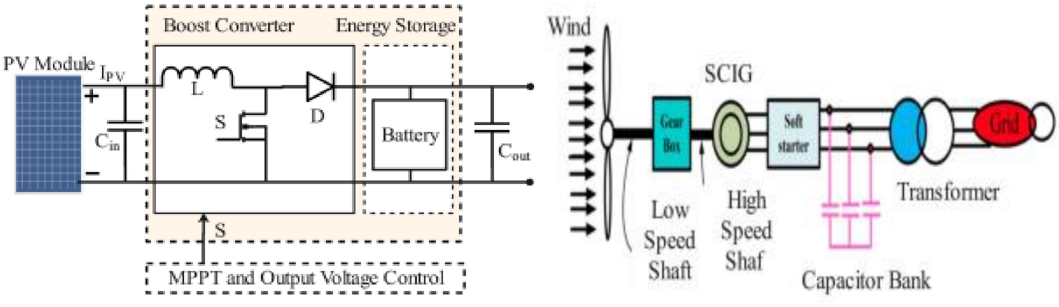


Figure 4: Solar and Wind connectivity as DC

Table: 1 Specifications of DC-DC boost converter

Parameter Variable	Ratings
Input Voltage Range DC (Min)	150V
O/P voltage range DC (Max)	350V
Switching Frequency up to	100KHz
Inductor (L)	5mH
Capacitors (C)	1500μF
IGBT	1200V/100A

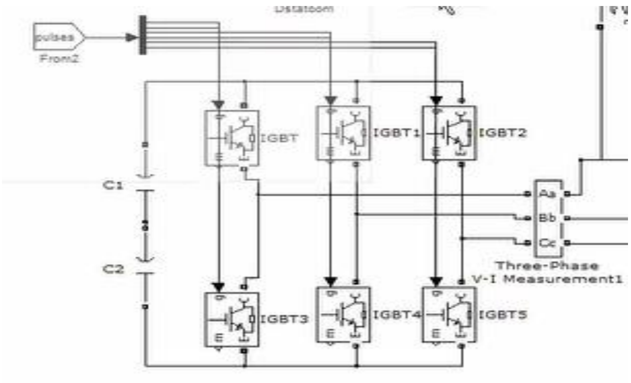


Figure: 5 Proposed DSTATCOM

The continuous power supply should be applied to the load without any interruption like harmonics and power quality issues. DSTATCOM supported by three phase converter to provide the reactive power in a micro grid. Three phase converter is supplied by energy storage element like capacitor bank. By using Gross hopper algorithm the power quality issues can be mitigate with a help of primary and secondary strategy.

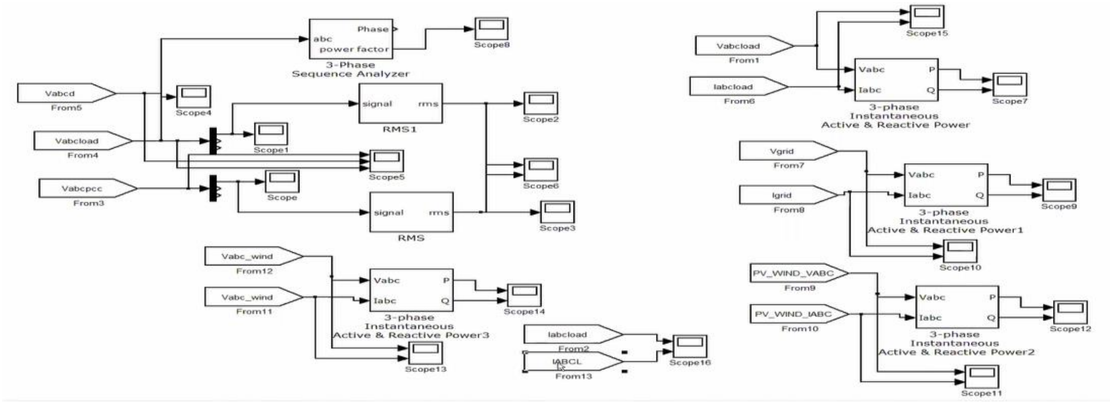


Figure: 6 Load and power input

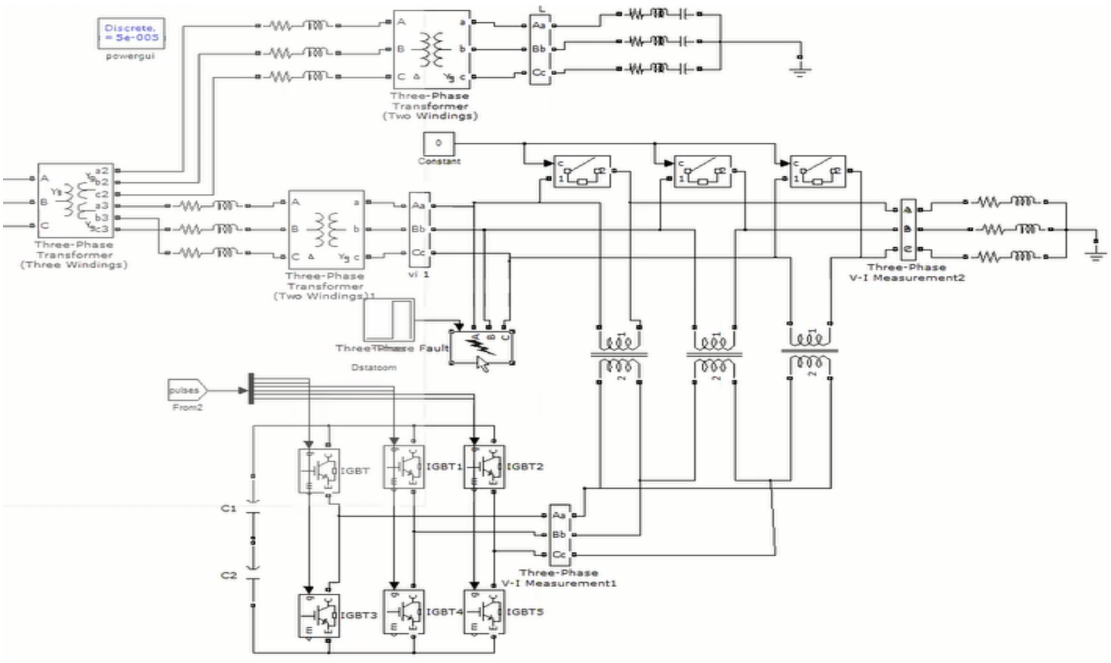


Figure 7: DSTATCOM with GOA

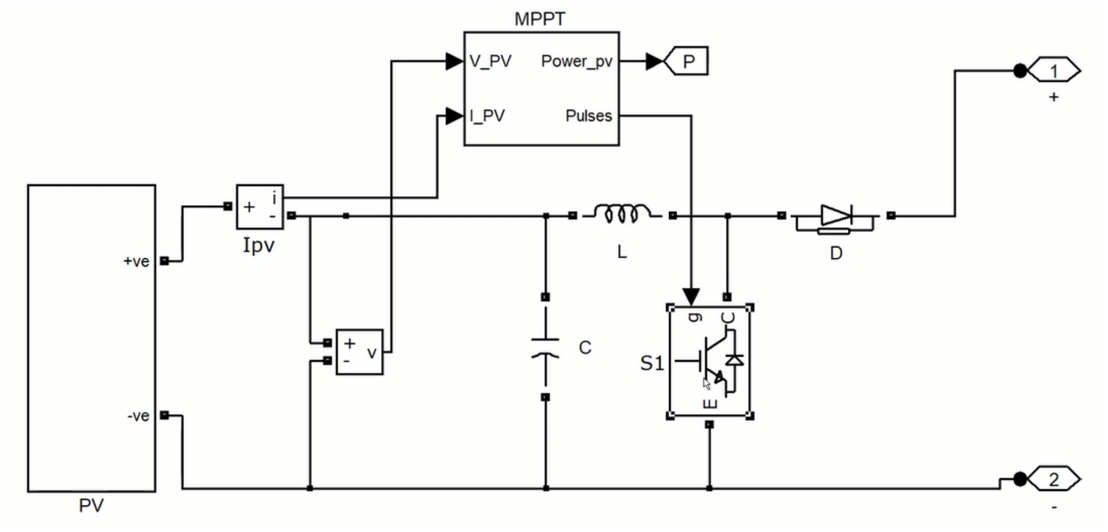


Figure8: MPPT converter

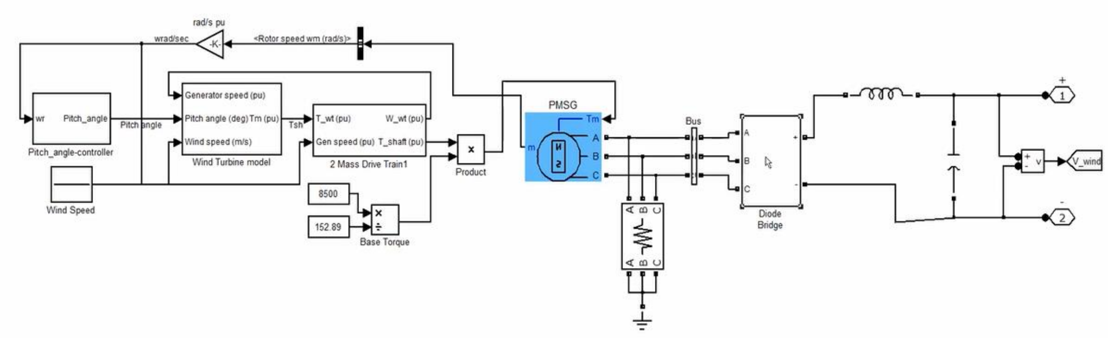


Figure9:Sag generation

3.2 Description of GOA

A key feature of grasshopper's swarm is searching for a food source. During food source searching process, the grasshoppers perform both exploitation (local searching) and exploration (Global searching) during nymph and adulthood, respectively. This exceptional property of grasshoppers makes them an excellent choice for molding their behavior into an optimization algorithm.

For random moving of GOA the equation noted as

$$X_i = C_i + G_i + W_i \text{---------}(1)$$

where Xi is the i-th grasshopper's position, Ci represents social force of interaction for i-th grasshopper, Gi defines the force of gravity on the i-th grasshopper, and Wi denotes the wind convection force. Like all other metaheuristic optimization algorithms, the authors provided the randomness in Equation

$$Xi = r1.Ci + r2.Gi + r3.Wi \text{--------}(2)$$

where r_1, r_2, and r_3 represent the random numbers in the range of [0, 1].

An improved version of the Equation defined as

$$X_i^d(k+1) = b\left[\sum_{\substack{j=1\\ j\neq i}}^{N} b\,\frac{L_u - L_l}{2}\, c\left(\left|X_j(k) - X_i(k)\right|\right)\frac{X_j(k) - X_i(k)}{d_{ij}}\right] + \hat{T}_d \quad \text{......}(3)$$

where L_u denotes the upper limit and L_l represents the lower limit in the D-th dimension, k denotes the magnitude of particles for the current iteration, $k + 1$ is the magnitude of particles for the succeeding iteration, and T_d

represents the magnitude of the D-th dimension in the target which is actually the best possible solution explored till that time. It may be noted here that, in order to make balance between the exploitation and exploration properties of GOA, the coefficient b must be reduced in proportion to the increasing iteration number. This enhance the searching capability of GOA, as with the growing iteration number, the coefficient b decreases the comfort zone proportionately and is found by using

following mathematical expression.

$$b = b_{max} - k\frac{b_{max} - b_{min}}{K_{max}} \qquad \text{.........(4)}$$

where *bmax* denotes the maximum coefficient value, *bmin* represents the minimum value of coefficient *b*, *k* denotes the number of current iteration, and *Kmax* represents the total iterations. A comprehensive flowchart of GOA employment in the designed control architecture is depicted in Figure 8.

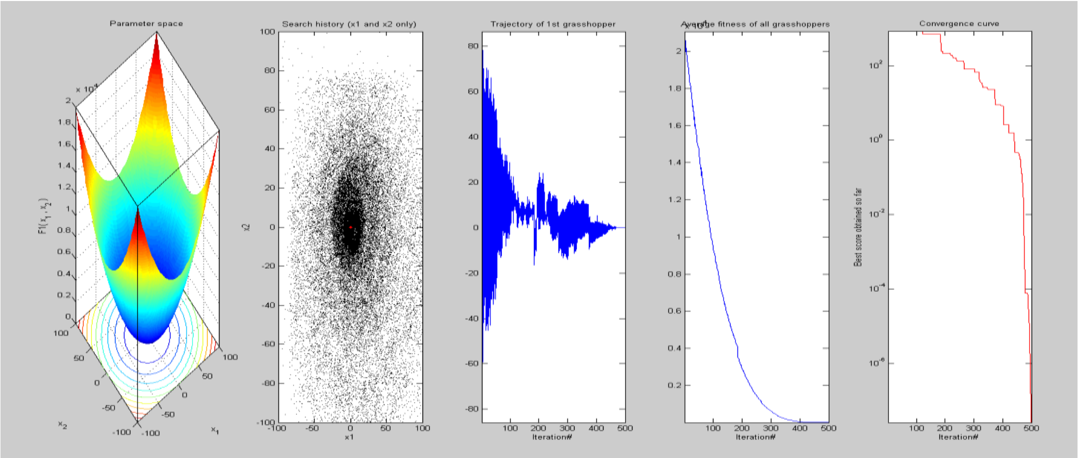


Figure 10: GOA implementation for Power disturbances

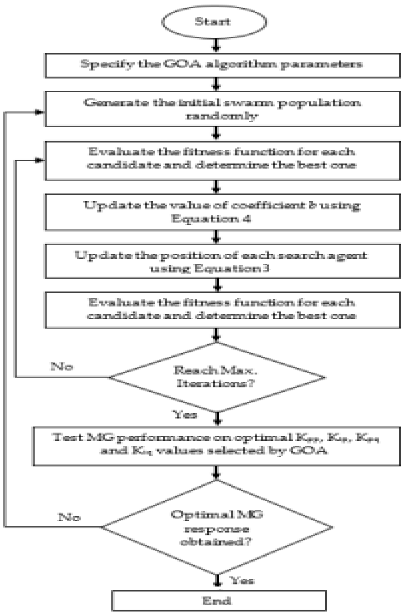
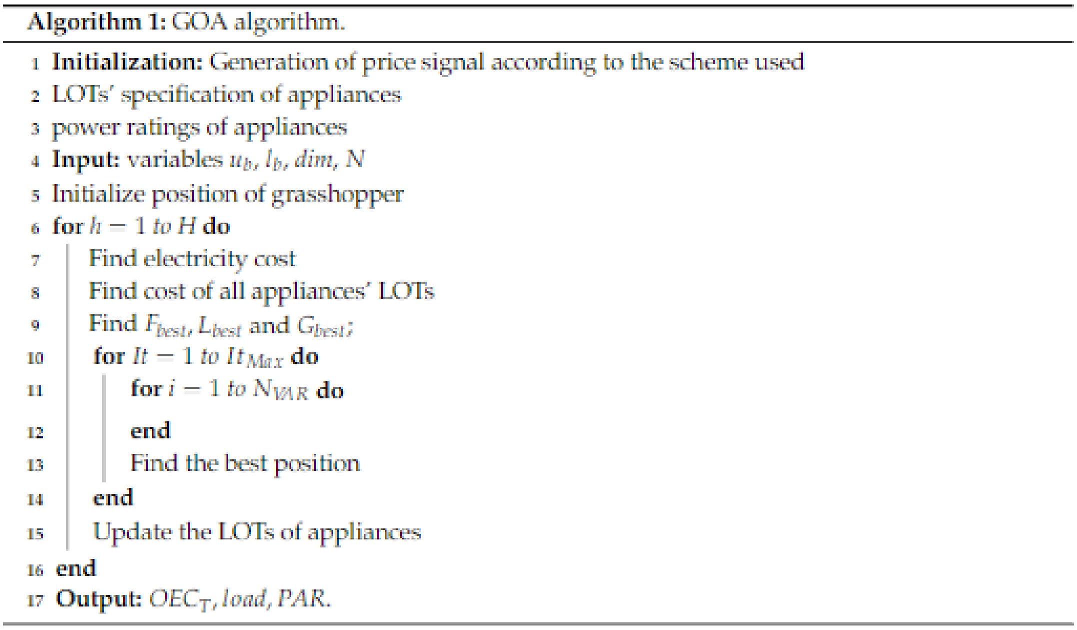


Figure :11 Flow chart for GOA algorithm



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Algorithm 1: GOA algorithm.
Initialization: Generation of price signal according to the scheme used
LOTs' specification of appliances
power ratings of appliances
Input: variables $u_b, l_b, dim, N$
Initialize position of grasshopper
for $h = 1$ to $H$ do
    Find electricity cost
    Find cost of all appliances' LOTs
    Find $F_{best}, L_{best}$ and $G_{best}$;
    for $It = 1$ to $It_{Max}$ do
        for $i = 1$ to $N_{VAR}$ do

        end
        Find the best position
    end
    Update the LOTs of appliances
end
Output: $OEC_T, load, PAR$.
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4.0 RESULTS AND DISCUSSIONS

The input parameters of PV and wind system in above simulink model with DSTATCOM optimized with GOA. The obtained results of swell, sag and total harmonic distortions shown in the results. The input parametrs of both systems given in below tables. In order to evaluate the performance of the developed power flow controller in obtaining the optimal dynamic response with high power quality and power-sharing, the developed model for grid-connected MG is simulated in MATLAB/SIMULINK environment. The power curves for the DG, utility grid, and the load were obtained using optimal power input values selected by GOA. The power quality analysis has also been undertaken to analyze the harmonic content present in the output current waveform.

Table: 2 Solar Input

Parameter variable	Ratings
Maximum power	100W
Voltage at maximum power	18.7V
Current at maximum power	5.35A
Open circuit voltage	22.32V
Short circuit current	5.65A
Number of panels	10
Number of stings	1
Cell in string	10
Type of cell	Poly crystalline silicon

Table:3 Wind paramters input

Parameter variable	Ratings
Rated power output	5000W
Peakpower output	6800W

Rated Voltage	415V
Cut in speed	2m/s
Nominal wind speed	8m/s
Cut off speed	18m/s
Rated rotor speed(RPM)	250
Generator efficiency	0.95
Noise level	<30db
Number of blades	3
Rotor diameter	3600mm
Blade material	Glass fibre
Generator type	SCIG
Cp value at max	0.18

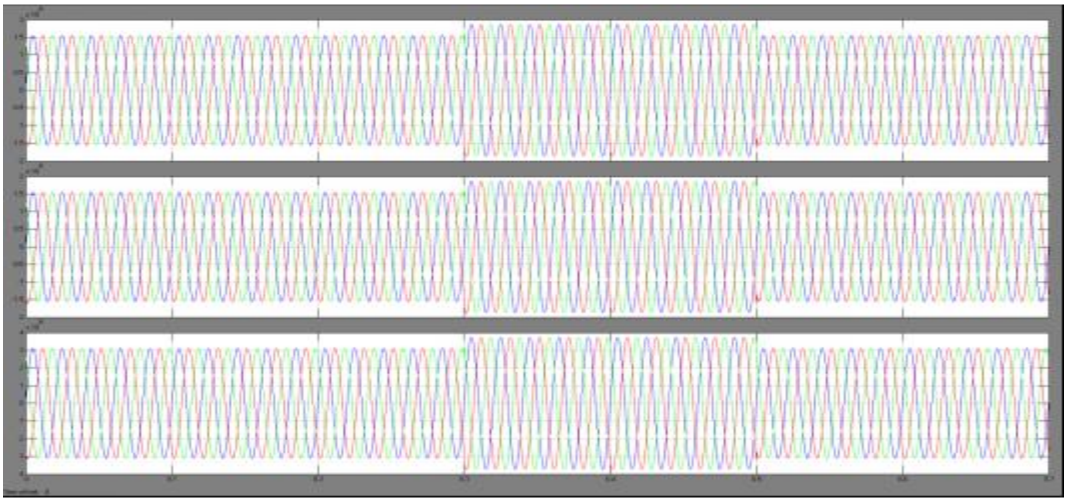


Figure 12: Source & load & PCC voltage swell

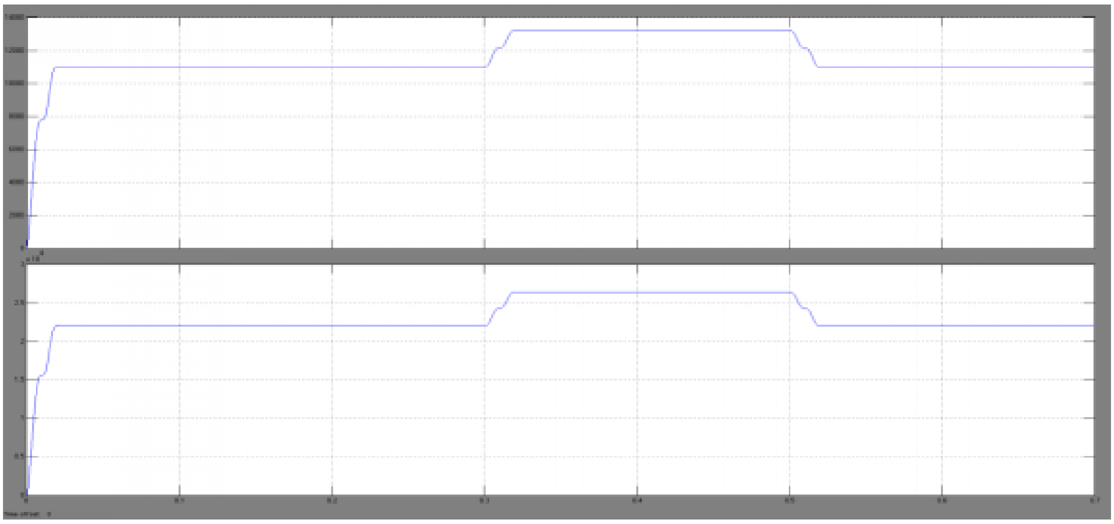


Figure 13:Source & load Vrms

From figure 12 and 13 swell increases with the increase of load condition from both solar and wind inputs. This trend can be attributed to the higher energy demands, which cause the system to adjust accordingly to maintain stability and efficiency.

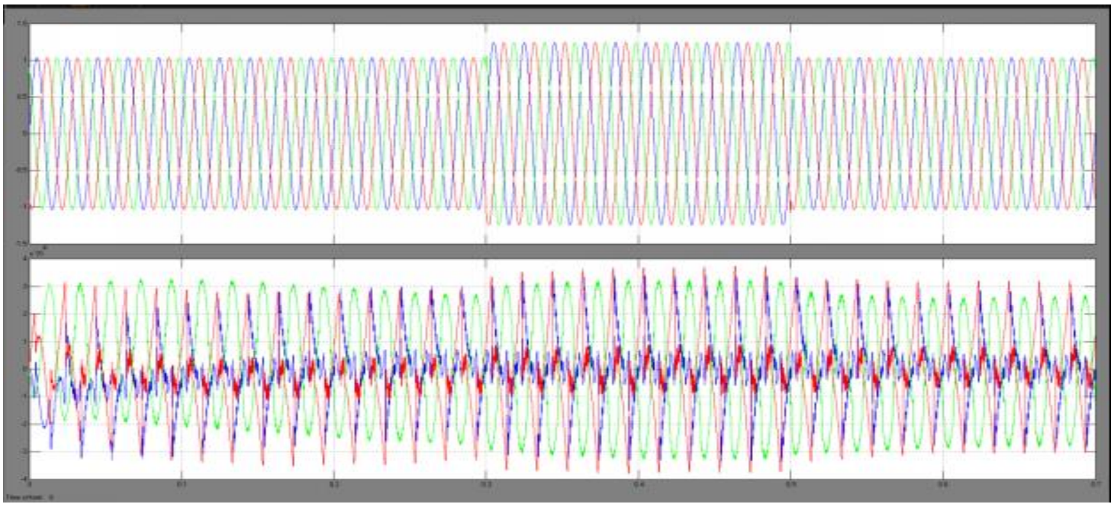


Figure 14: Wind voltage & current

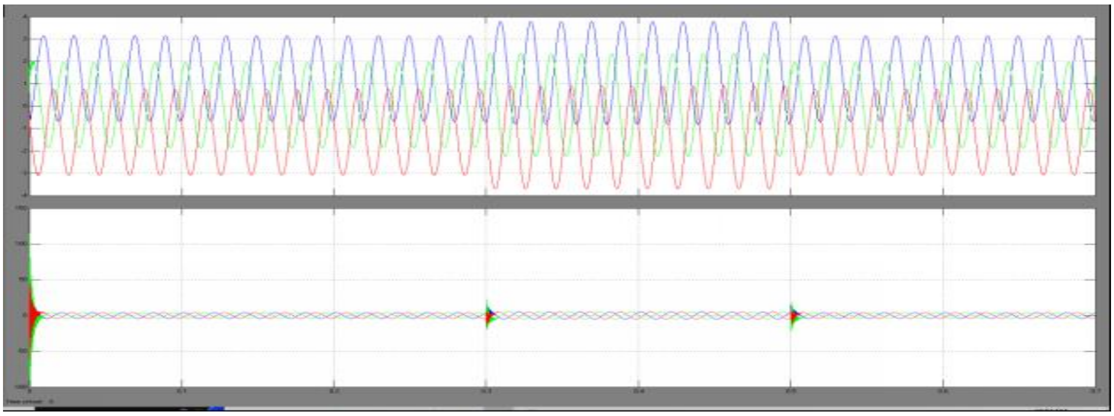
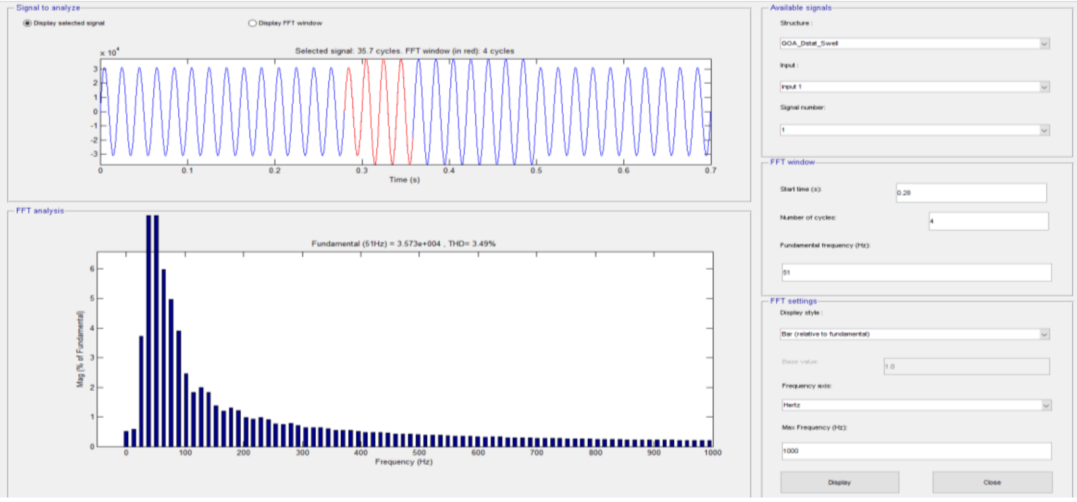


Figure 15: Load & line current



Selected signal: 35.7 cycles. FFT window (in red): 4 cycles

Fundamental (51Hz) = 3.573e+004 , THD= 3.49%

Structure : GOA_Dstat_Swell

Input : input 1

Signal number: 1

Start time (s): 0.28

Number of cycles: 4

Fundamental frequency (Hz): 51

Display style : Bar (relative to fundamental)

Base value: 1.0

Frequency axis: Hertz

Max Frequency (Hz): 1000

Figure 15: Swell THD

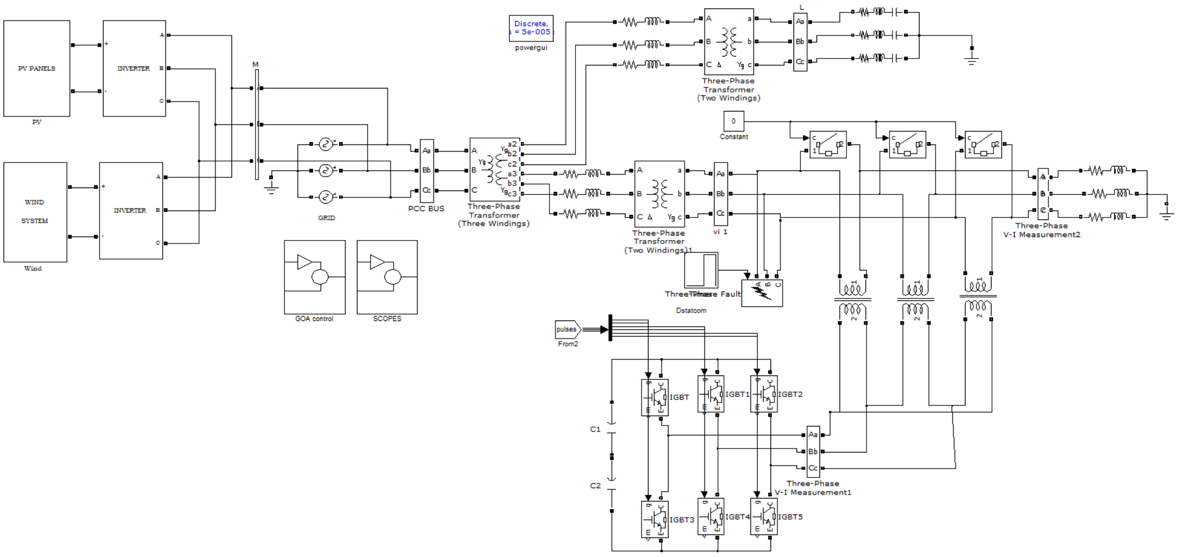


Figure 16: Main circuit testing diagram for Sag

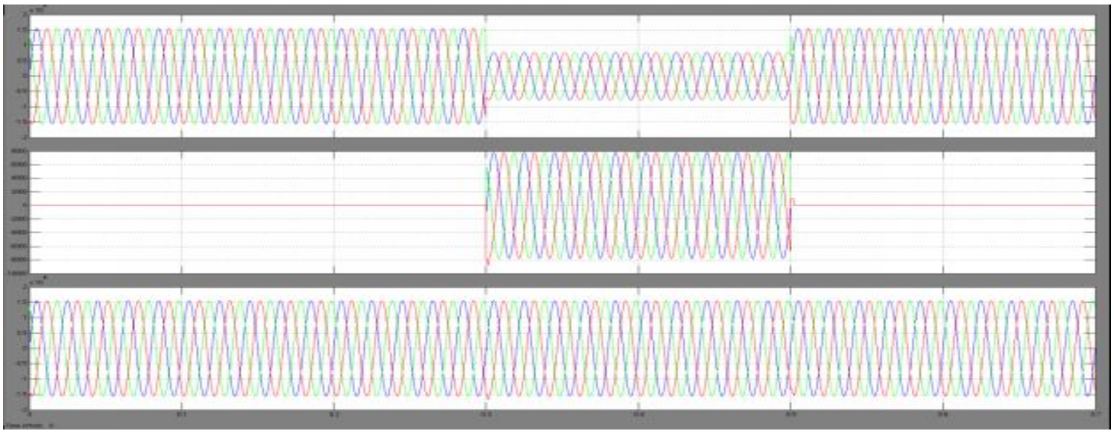


Figure17:Sag voltages

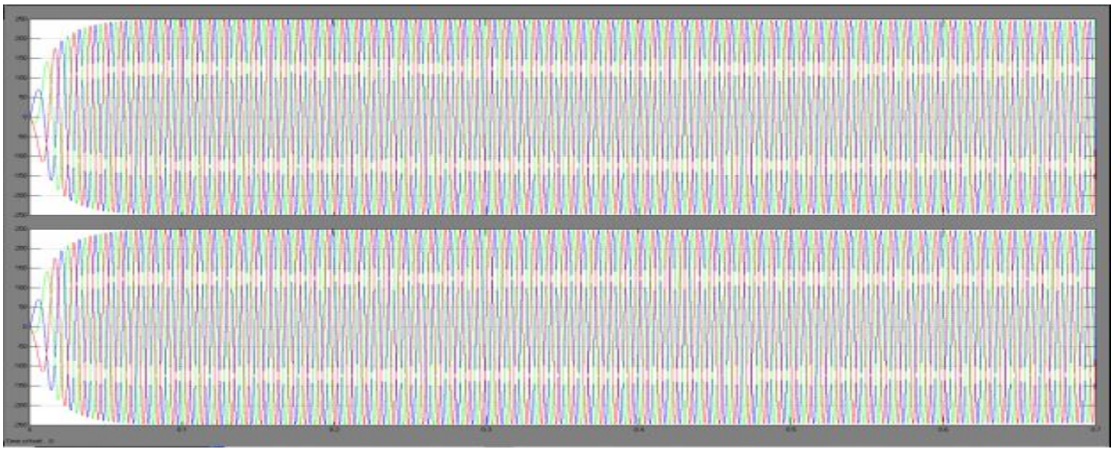


Figure 18: Wind voltage & current

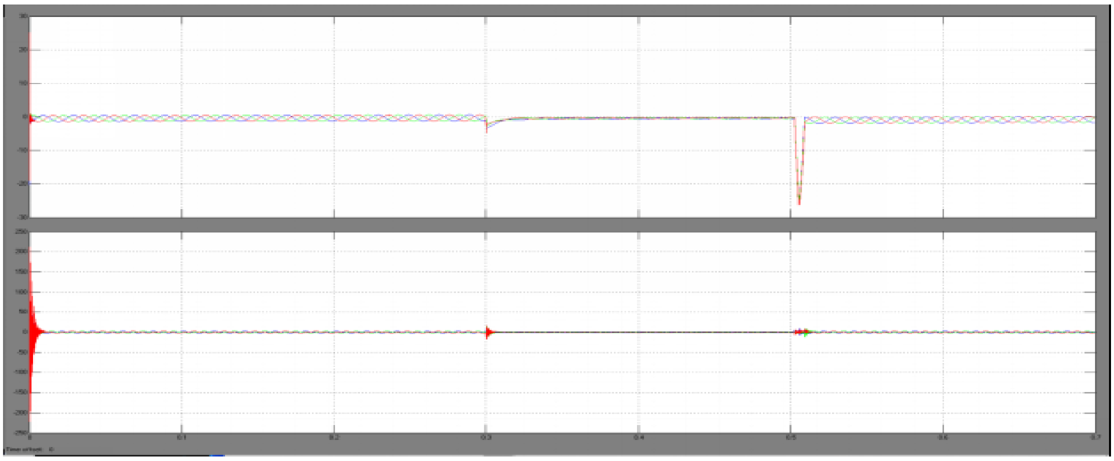


Figure 19:Load & line current

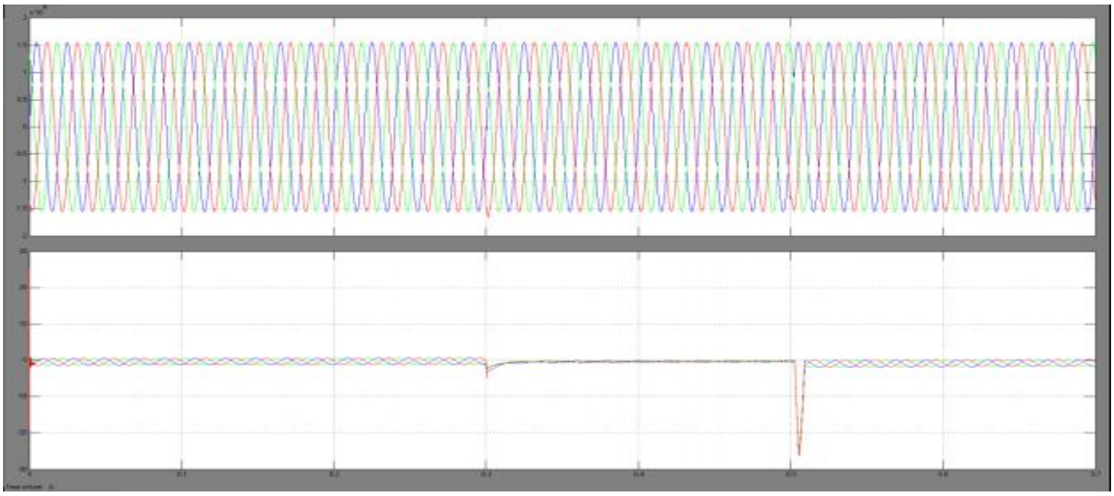


Figure 20: Load voltage & current

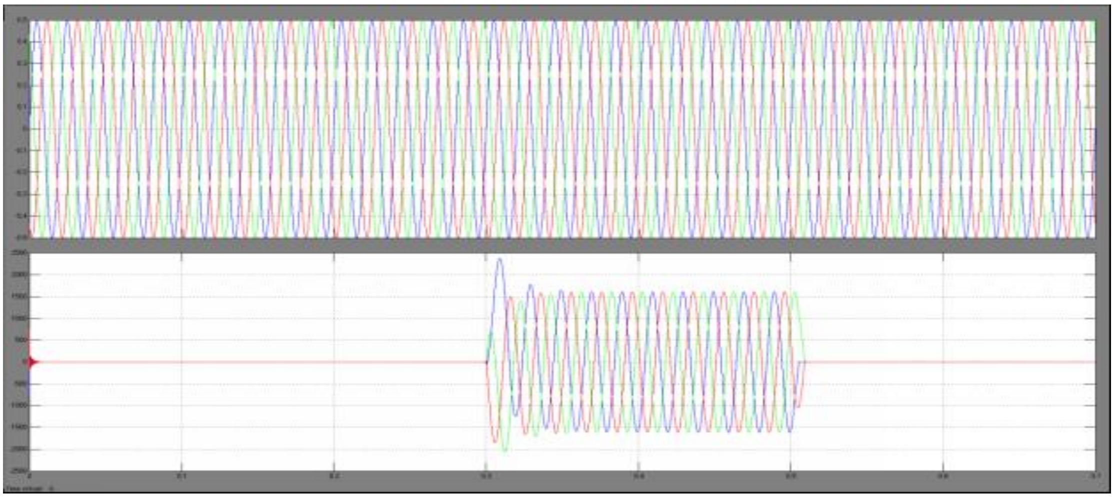


Figure21: Grid voltage & current

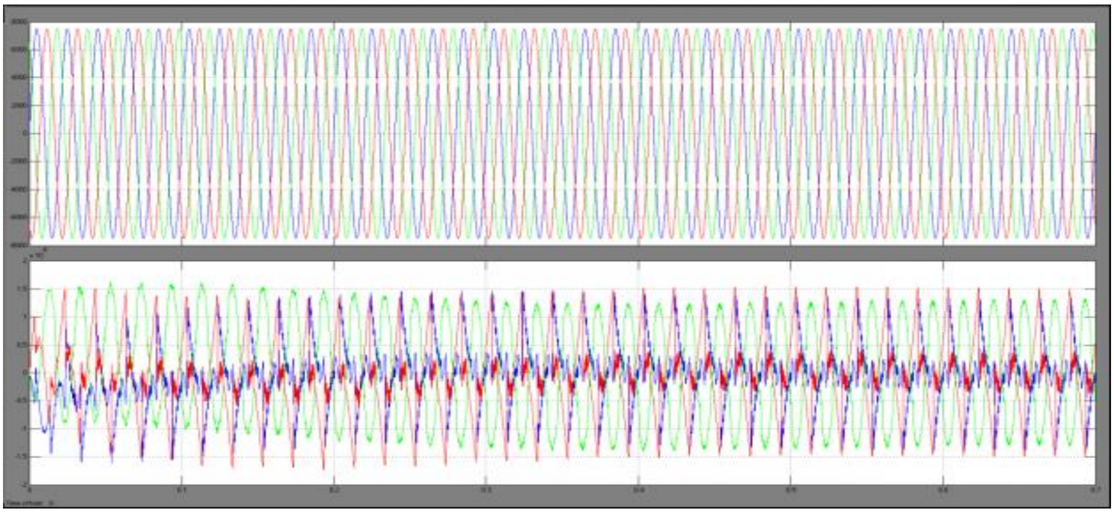
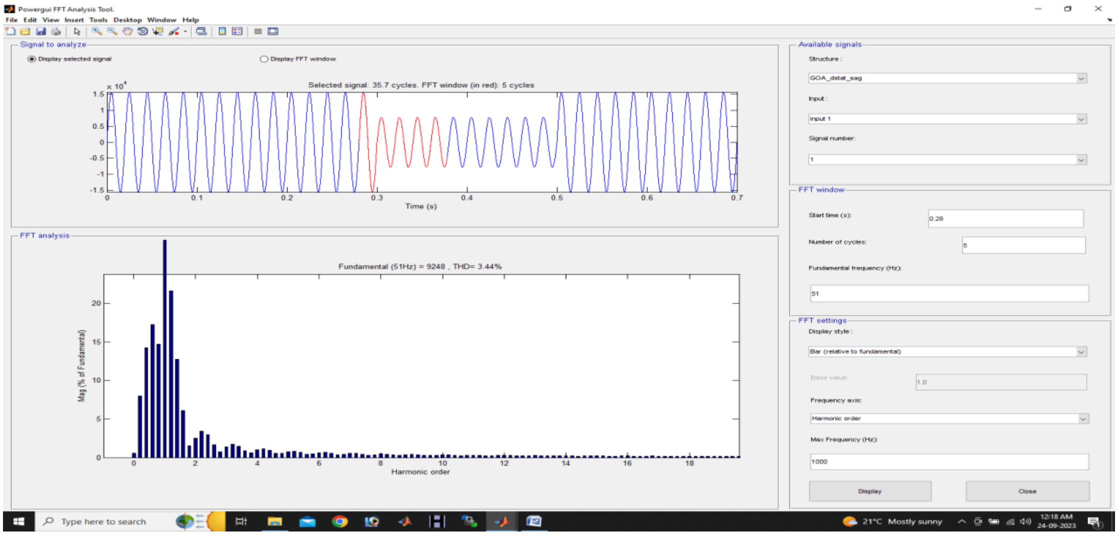


Figure22:PV wind voltage & current



● Display selected signal
○ Display FFT window

Selected signal: 35.7 cycles. FFT window (in red): 5 cycles

Fundamental (51Hz) = 9248 , THD= 3.44%

Structure : GOA_dstat_sag
Input : input 1
Signal number: 1
Start time (s): 0.28
Number of cycles: 5
Fundamental frequency (Hz): 51
Display style : Bar (relative to fundamental)
Base value: 1.0
Frequency axis: Harmonic order
Max Frequency (Hz): 1000

Figure23: Sag THD

Discussions: A convergence rate and the final optimized convergence value of fitness function are the two most important parameters to evaluate the speed and quality of an optimization algorithm. A convergence rate determines the time required to obtain the final optimized value, whereas a minimized or maximized convergence curve determines the quality of the final solution. It is necessary to minimize FF in this case in order to achieve a dynamic response that is as optimal as possible. The smaller the FF's final obtained value, the better the quality of the solution and, consequently, the better the dynamic response. After MG injection and abrupt load changes are simulated, metaheuristic algorithms search for the optimal combination of the parameters. This results in the optimal transient and steady state response of the studied system. As soon as the maximum number of iterations is reached, the search process is terminated. From the present work the harmonic distortion found to be 3.4only. Compared to DPFC it is low, the value of DPFC is 8.34 and with fuzzy controlled DPFC it is 3.96.

5.CONCLUSIONS

This paper presents an intelligent grid-connected MG power flow controller based on GOA. In this study, the main objective was to exchange active and reactive power between MG and utility grid with minimal overshoots, settling times, and a reduced total harmonic distortion at higher DG penetrations (100 kW, 70 kVAR). For the same system configuration and working conditions, the proposed GOA-based DSTATCOM power flow controller has been compared with its dynamic response for active and reactive power regulation with DPFC and DPFC with a fuzzy-based controller.

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