Simulation of grid connected PV system with PI, fuzzy-GA based controllers for power flow control

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Article Info

Article history:

Received Jan 4, 2023
Revised Feb 23, 2023
Accepted Mar 6, 2023

Keywords:

Controllers
Fuzzy-GA
Grid-connected PV system
MATLAB/Simulink
PI-GA
STATCOM

ABSTRACT

Nowadays, renewable energy sources turned into a choice to fulfill the expanding load need since they are ecological inviting and furthermore accessible bountiful in nature. Due to the easy availability of solar-powered vitality, the photovoltaic (PV) system is gaining popularity as a renewable energy option. Most of the energy from a PV array may be dissipated by using the maximum power point tracking (MPPT) method. The force quality problems, the real and responsive force stream problems, are a major concern when transferring a mass measure of intensity from a PV array to the power grid. This research proposes a unique control technique for regulating the power flow and resolving power quality concerns brought on by the integration of PV arrays into an existing power infrastructure. For effective management of real and receptive force stream in matrix related photovoltaic framework, it includes a PI-GA, fuzzy-GA based flowed regulator dealt with adaptable AC transmission framework gadget, specifically static synchronous compensator (STATCOM). As a result, the fuzzy rationale regulator creates a control vector, which is in this way tweaked utilizing a standard calculation.

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1. INTRODUCTION

Over the previous five years, photovoltaic (PV) vitality has expanded and is rapidly turning into a significant piece of the essentialness blend in unambiguous locales and power systems. This extension has moreover prompted the development of highly efficient PV power converters, which have progressed from simple, one-stage network-attached inverters into more experimental territory to maximize power conversion efficiency, power harvesting from modules, and product consistency without raising prices. There has been a tremendous increase in solar photovoltaic (PV) energy transformation frameworks, from a total absolute force of around 1.2 GW in 1992 to 136 GW in 2013 [1]–[7]. Over ninety-nine percent of the photovoltaic (PV) limit is introduced by frameworks that relate to a matrix, as opposed to independently developed frameworks. Since the PV plant's output is sent directly to the matrix for distribution and use, there is no need for storage batteries in a matrix-associated photovoltaic architecture. The PV power generated reduces the need for additional network supporting energy sources like hydro or petroleum products, whose investment funds go about as energy stockpiling in the framework, giving force guiding and reinforcing capabilities comparable to those of a battery in a standalone system. An overwhelming amount of power mixing of different sustainable sources like renewable with current electrical grid is greatly aided by electronic technology. The rapid development of power hardware over the last several years may be attributed to two main factors. The creation of rapid semiconductor switches that can withstand high power without being damaged is one such advancement. The second development is the availability of real-time PC regulators with the ability to do complex control calculations.

The power electronic points of interaction expected to change the energy source's result into framework prepared voltages are a regular feature of modern energy conversion systems. Distributed Generation systems that rely on renewable energy or micro sources [8], [9]. PV electricity that is fed into the utility grid is gaining popularity because of rising global power demands. It has been shown that solid-state inverters are the enabling technology for interconnecting PV installations with the grid [10]. Distribution and centralization are the two main types of PV systems that link to the grid.

2. METHOD

2.1. PI controller design

It relies on the relative, indispensable, and ancillary terms of the proportional integral (PI) regulator. By changing the parameter of the model, settling time, the regulator hopes to minimize the rate of error. In PI controller design as shown in Figure 1, the tuning of gain parameters is done in grid side of inverter of Proportional plus Integral controller in a view to obtain performance w.r.t input variations and disturbances in terms of discrete as (1). The proportional plus Integral controller state equations are mentioned in (1).

$$X(k+1) = G_I X(k) + H_{1I} iref(k) + H_{2I} u2(k),$$
$$Y(k) = C_{1I} X(k), C_{1I} = [0\ 0\ 1\ 0],$$
$$G_I = \begin{bmatrix} G-(Kp+KI)H1C3 & H1 \\ -KIC3 & 1 \end{bmatrix}, X(k) = \begin{bmatrix} iL(k) \\ uc(k) \\ ig(k) \\ eI(k) \end{bmatrix}$$
$$H_{1I} = \begin{bmatrix} (kp+kI)H1 \\ KI \end{bmatrix}, H_{2I} = \begin{bmatrix} H2 \\ 0 \end{bmatrix} \quad (1)$$

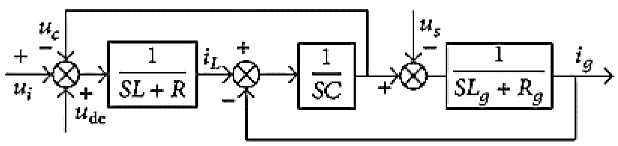

Figure 1. PI controller block diagram

2.2. Design of FLC controller

Mamdani and Sugano's fluffy derivation framework is suggested as the justification for the planned coordination of DG by the regulator as shown in Figure 2. The measuring of the DG is assessed utilizing fluffy rationale regulator. The pattern of Induction measure for Mamdani type warm thinking regulator has technique for MIN-MAX total and defuzzification measure with the reference of self-organizing map method. Defuzzification strategies for Mamdani-type deductions are also proposed, with the alternative setting being a Sugeno-type setting for fluffy rationale regulators [10]–[12].

Both the error itself, denoted as E(t) and increase in rate of error, DE(t), these values selection is based on potential data points. Alterations to the current and voltage are selected as the yield factors. The error function, E(t), is characterized as the distinction in terms of yield R(t), and cycle yield, Y. (t) as shown in (2) and (3).

$$E(t) = R(t) - Y(t) \quad (2)$$

$$DE(t) = E(t) - E(t-1) \quad (3)$$

Membership functions are used to introduce uncertainty into the input variables. The controller improves the system's transient responsiveness and dampens the error signal by utilizing three-sided and trapezoidal enrolment capabilities, separately. Using a system to convert power is standard engineering practice in the world of electricity. Devices like rectifiers, inverters, FACTS units, etc. These power conversion devices cannot effectively act without a suitable controller. It is difficult to design the settings for a cascaded PI with fuzzy controller because of the controller's nonlinear characteristics.

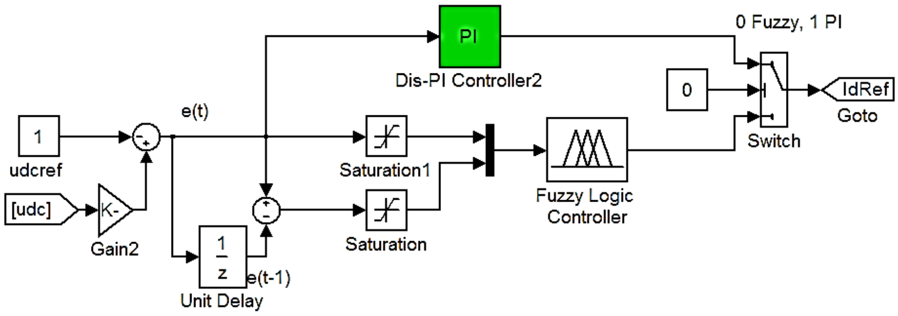

Figure 2. Fuzzy logic control strategy

2.3. Genetic algorithm

Presently Genetic algorithms and its applications are increased. The basic search techniques are adopted since they depend upon the basic evolution principles. There is a broad range of applications of Genetic Algorithms in terms of their extensive properties. Some of the commonly used evolutionary algorithms are Neural Networks, optimization methods and Machine learning. Genetic algorithms include with and without boundary conditions and constraints [6]. The genetic algorithm adopted in this work is mentioned below:

- Step 1: For Initial population, Individual solutions are randomly obtained
- Step 2: The degree of conformity is calculated for each individual within a fixed set. Rules are varied.
- Step 3: To obtain Crossover, the parents necessary are selected.
- Step 4: Selection of random mutation.
- Step 5: Stop and terminate once the condition is satisfied.

Basic genetic algorithm m-file:

t = 0;
// P(t) is initialized
// P(t) structures are evaluated
repeat
t= t+1
select- reproduction C(t) from: P(t-1)
merge and mutate structures in C(t) forming C'(t);
obtain structures in C'(t)
select-replace P(t) with C '(t) and P(t+ 1);
Until (stop and terminate if condition satisfied)

Within a loop structure are evaluated and C(t) - selection buffer is initialized by considering all the values of P(t - l), "select-reproduction procedure". The fitness C(t) is obtained from all the structures in the loop and necessary replacements are done as shown in Figure 3.

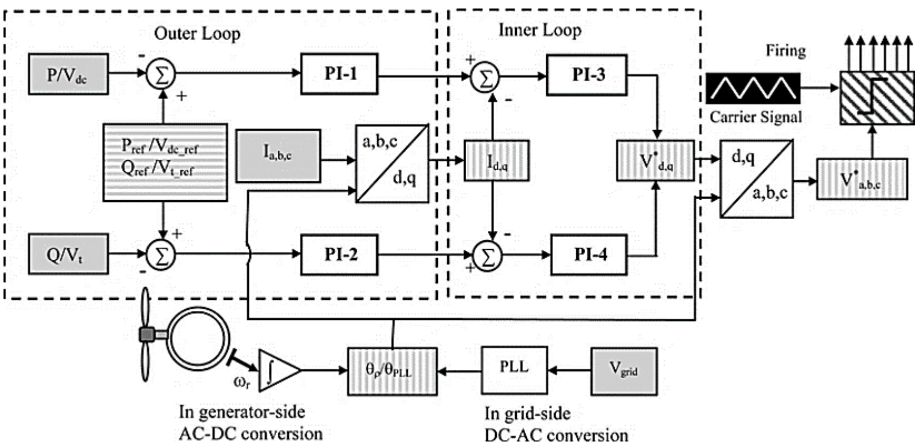

Figure 3. Cascaded PI, FLC-GA controller sub-block diagram

The amounts P, Q, V_{grid} and I_{abc} are spoken to the deliberate or real qualities. The change point 'q', I_{dq}, V_{dq}, V_{abc} speaks to determined qualities. The P_{ref}, Q_{ref} speaks to reference esteems or set focuses. Tuning of four fluffy regulators is an awkward cycle and tedious. This issue can be settled by ideal plan of fell regulator boundaries utilized in the force transformation framework [13], [14].

3. RESULTS AND DISCUSSION

3.1. PV cell modelling

The solar-powered component of the module is made up of many PV cells are series connected in modules, which forms a chain. Figure 4 depicts a simplified model of a photovoltaic cell, a single diode, with a current source, I_{ph}, which tells the current measured in the cell as a result of incident photons from the sun by (4) and (5) [15].

$$I_{ph} = [I_{sc} + K_1 - 298]] \frac{G}{100} \tag{4}$$

$$I = I_{ph} - I_d - \frac{V+Rs\,I}{Rsh} \tag{5}$$

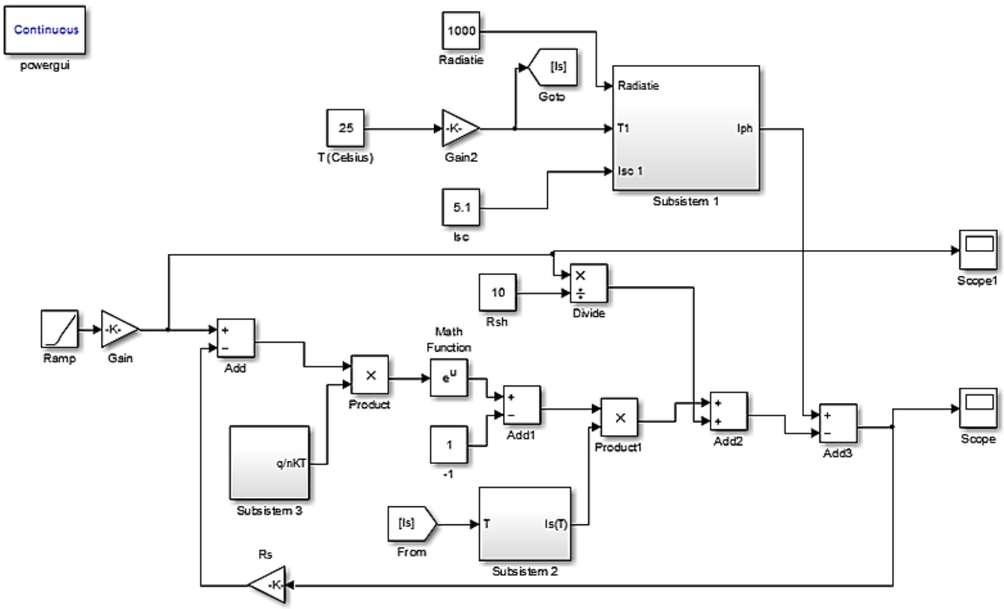

Figure 4. Basic PV cell model

The ohmic deterrent between conductor and metal contact to by utilized by an opposition, R_s. The PV power modules biggest flaw is its wildly fluctuating yield voltage. It is feasible to embed a DC converter between the PV framework and the inverter to help in measuring voltage and maximum power point following (MPPT) are obtained as shown in Figures 5 and 6 [16].

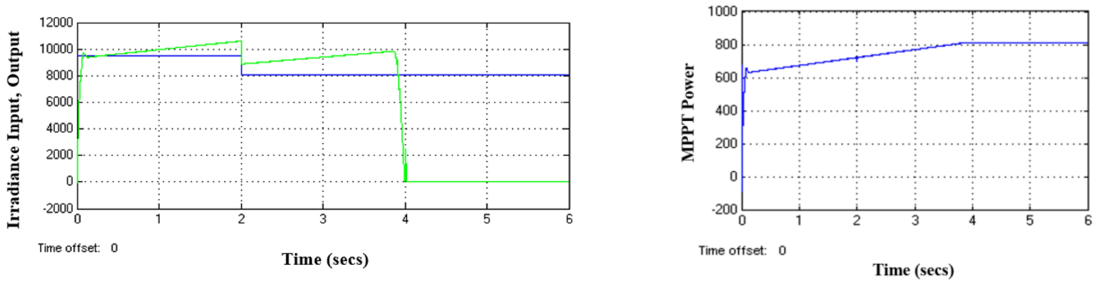

Figure 5. Irradiance input, output variation and MPPT power versus time (secs)

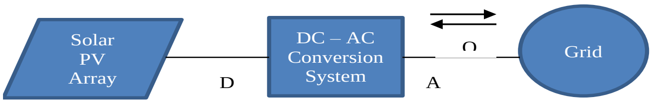

Figure 6. Grid-connected photovoltaic system

MATLAB, which stands for "Matrix Laboratory," is a PC application optimized for certain tasks, such as design and logical counting. A flowed fluffy rationale regulator utilizes two circles, an internal circle, and an external circle, with two fluffy regulators in each loop to propagate error signals with FACTS Controllers for Grid-connected photovoltaic system [17], [18] as shown in Figures 7 to 9. PWM signal is used to switch the switches in the converter generated by the controller, which serves as a reference voltage for the three-phase power system. Fuzzy logic rationale regulators work on the capacity to oversee power electronic switches by sending a controlled vector, which is then calibrated utilizing a hereditary calculation [19], [20].

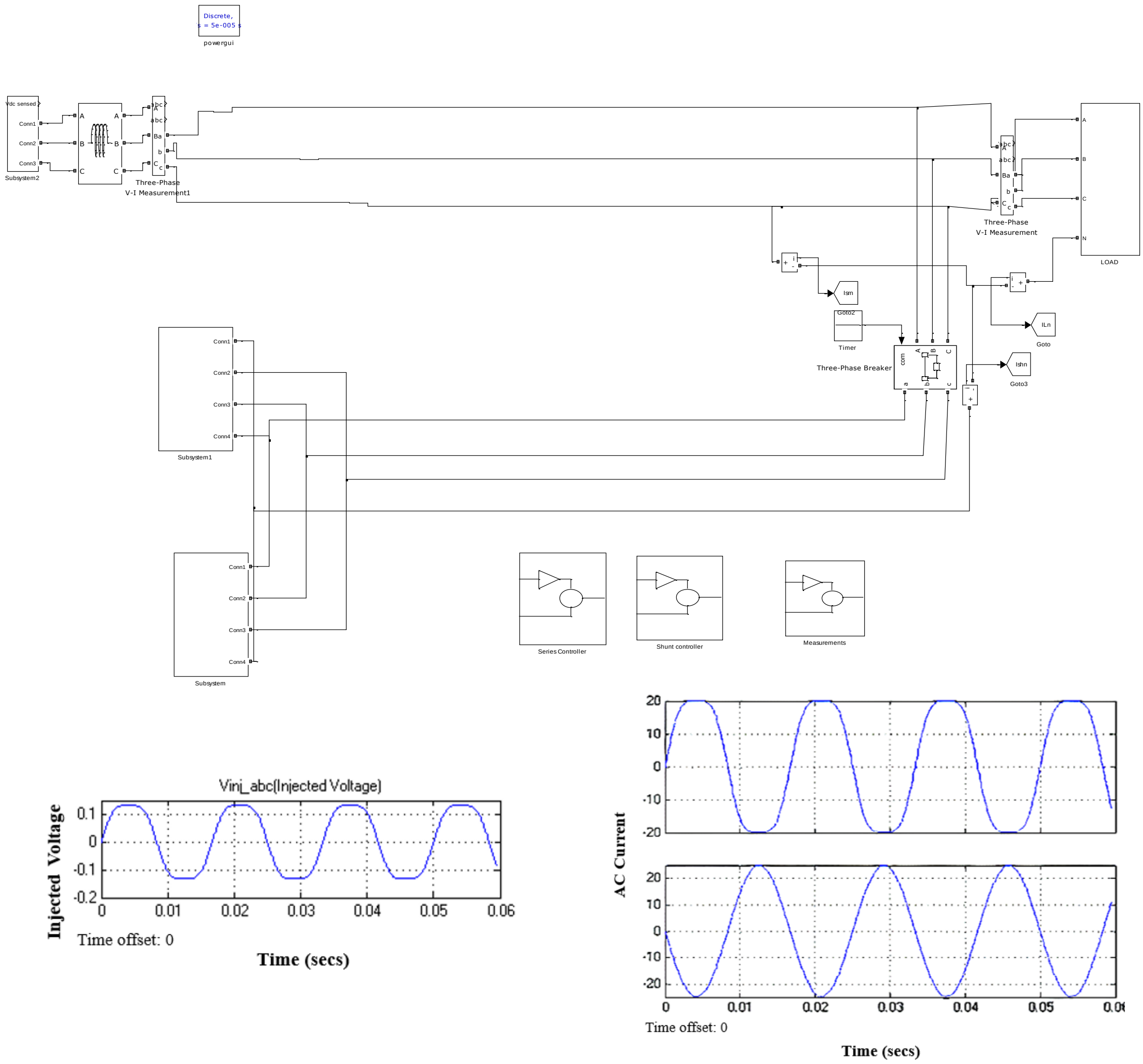

Figure 7. PV source model for STATCOM simulation with PI Controller and voltage injection over time (secs)

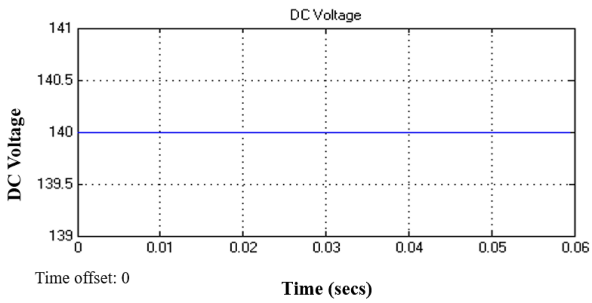

Figure 8. AC Current and DC voltage versus time (secs)

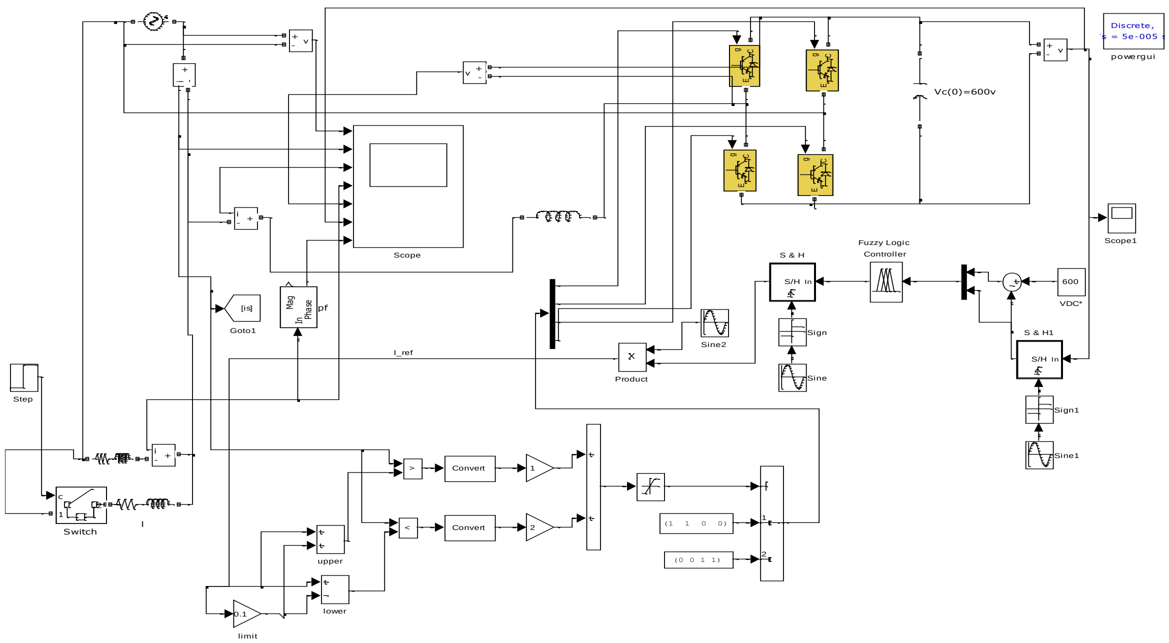

Figure 9. Simulation model of STATCOM with fuzzy logic controller

Analysis: From the Figure 6 simulations, it's observed that STATCOM compensator has less overshoot in real, reactive powers and DC voltage, THD as shown in Table 1.

- Genetic algorithm (GA) for tuning FLC parameters

Basic search techniques used in real-time applications [21]–[27] for solving various optimization problems, which are used to either minimum or maximize the control variables of an objective functions f(x) within the space of all 'x' values. As shown in Figure 10, the testing and its performance is obtained by iterative process. The results obtained for hybrid combination of FLC and GA are improved in terms of voltage THD as shown in Tables 2 and 3.

Table 1. Power flow, THD, voltage control for different controllers of FACTS devices

S.No	Category	Subcategory	Controller technique	Sub controller	Active power (W) (Overshoot)	Reactive power (Var) (Overshoot)	Harmonics (THD) (Overshoot)	Voltage control (V) (Overshoot)
1	Identification of specifications of grid connected system with source	PV source	Without FACTS controller	No	19.2	23.5	0.6025	42
			With FACTS controller (UPFC)	No	25.2	26.1	0.42	38
			STATCOM		18.23	20.1	0.4757	32
			SSSC		24	22	0.485	55

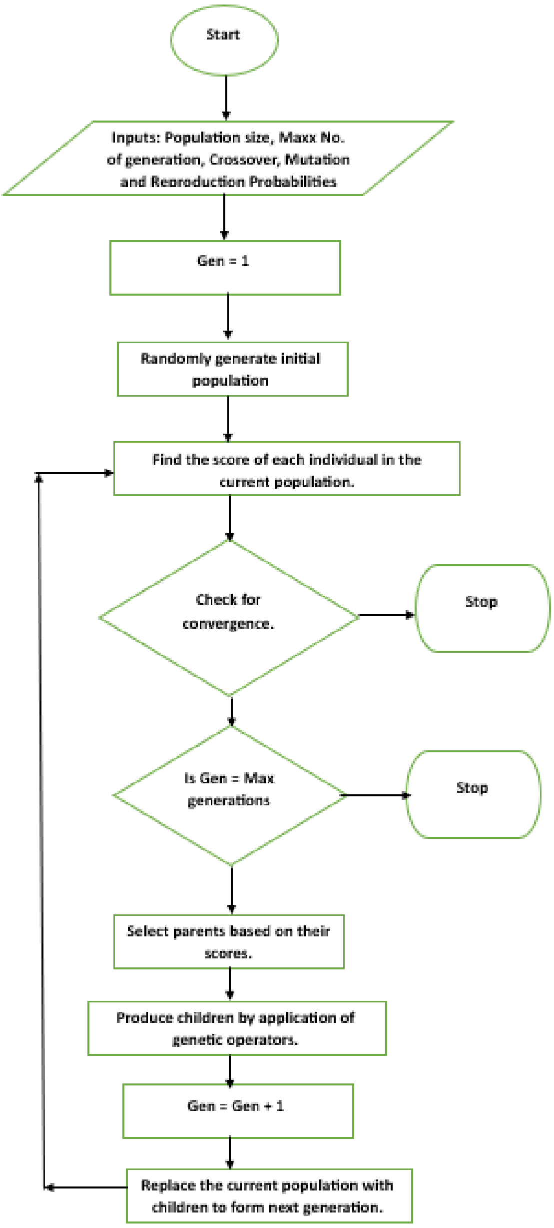

Figure 10. Flowchart of genetic algorithm

Table 2. Optimized values of scaling factors using GA

	Category and sub controller	X	Y
Parameters of the Controller to be optimized by GA		9.575	7.499
	STATCOM	9.889	9.469
		6.323	9.158

Table 3. Z-N method, fuzzy and GA method for PV based STATCOM connected grid

S. No	Category	Subcategory	Controller technique	Sub controller	Active Power (MW) (Overshoot)	Reactive power (MVar) (Overshoot)	Voltage Harmonics (THD) (Overshoot)	Voltage Control (V) (Overshoot)
1	Identification of specifications of grid connected system with source	PV Source	STATCOM	No	18.23	20.1	0.4757	32
				PI(Z-N)	208	32.8	0.589	42
				PI(GA)	17.1	20.1	0.35	26.1
				FLC (GA)	9.6	14.3	0.165	11

4. CONCLUSION

This research presents a novel framework for grid-integrated PV systems that significantly enhances their functional capabilities. To maximize power harvesting from the PV array and boost the system's power transfer efficiency, a few controller types have been presented in the literature. Among them, it is the cascaded control structure that has been considered and the simulated results with FLC (GA) controller. By using FLC (GA), the result is optimized and settings utilized in the power conversion system are improved in terms of performance variables like Overshoot of active power, reactive power, THD and voltage control.

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