AI Based Optimizing Control of UPFC with dual Converter Technology for Grid Integrated PV System

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Abstract: *Electricity suppliers and electricity end-users are increasingly concerned with meeting the growing energy needs. The work has been focused on obtaining the following key objectives -Designing of a solar system with UPFC controlled by PI controller as well as integrating it with the grid system in MATLAB /SIMULINK environment. Designing a compensating device and compare it with the UPFC compensator for active power output and reactive power output improvement in the system. The compensating device control has to be designed with an AI-based linear crow optimizing algorithm to obtain a smooth voltage and current waveform. And this concludes that the solar system is made efficient for driving the loads having enhanced active power output at its terminal. The voltage available has been made less distorted and the THD level in current output has also come down.*

Keywords: *UPFC, Solar System, THD, DG.*

I. Introduction

Power providers and power end clients are progressively worried about gathering the developing energy needs. 75% of the world's energy needs are met by the burning of petroleum derivatives. Notwithstanding, rising air contamination, worries about an Earth-wide temperature boost, petroleum product exhaustion and increasing expenses have made it important to consider renewables as a future energy arrangement. Sustainable power has produced huge interest in power age in numerous nations over the previous decade. Market advancement and government motivations have additionally sped up the development of the sustainable power area. The sustainable power source (RES) incorporated at the conveyance level is called decentralized creation (DG). The organization is worried about the high entrance of discontinuous sustainable power sources into dissemination lattices, as this can represent a danger to the network as far as security, voltage guideline and force quality (PQ) issues. Accordingly, the DG's frameworks should follow severe specialized administrative structure conditions to guarantee protected, solid and proficient activity of the whole organization. With progresses in power hardware and advanced control innovation, DG frameworks would now be able to be effectively controlled to further develop framework activity through better PQ to the PCC. Notwithstanding, the inescapable utilization of force gadgets based gadgets and non-straight loads in PCCs makes symphonious flows that can corrupt force quality. Normally, inverters with a current controlled voltage source are utilized to interface the irregular RES in an appropriated framework. Some control techniques have as of late been proposed for inverters associated with the matrix with PQ arrangement. An inverter functions as a functioning inductor at a specific recurrence to ingest symphonious current.

II. Related Work

Ritesh Dash et al. [1] This article talks about the fast industrialization and energy request that entangle the conveyance framework. To take care of this issue, a vigorous control framework is being produced for new ideas of miniature networks and savvy lattices. These control frameworks are an intricate construction that joins sustainable sources to conventional wellsprings of energy creation. The force quality issues that emerge from the interconnection of the quantity of variable age frameworks make it more unique and shortcoming focused.

Priya M et al. [2] This paper proposes a multi-work inverter associated with the lattice and MFGCI works on both voltage and current issues identified with power quality. Utilizing a Shunt Series MFGCI (SSS-MFGCI). The SSS-MFGCI is associated in series or corresponding to the network, which makes up for the matrix voltage. The proposed framework is carried out and the reproduction result is approved.

Bhupendra Singh Niranjan et al. [3] In this article presented, power quality becomes a crucial factor due to the wide application of power electronics based devices. In industry and distribution, devices based on power electronics are widely used and pose greater power quality problems. Power quality is poor for a few reasons. This thesis is interested in a way to improve the voltage compensation performance of the APF series. This improvement is achieved by improving the conventional hysteresis control system.

Abdulkerim Karabiber et al. [4] This article presents environmentally friendly power sources that can be associated with power matrices utilizing AC and DC reconciliation strategies. AC reconciliation is an advantageous and savvy strategy because of its basic construction. Nonetheless, the force quality security is powerless. The DC reconciliation strategy furnishes miniature matrices with high force quality because of the extra AC/DC voltage transformation, however is less productive than the AC combination technique

III. Objective

The work has been focused on obtaining following key objectives:

- Designing of a solar system with UPFC controlled by PI controller as well as integrating it with the grid system in MATLAB /SIMULINK environment.
- Designing of a compensating device and compare it with the UPFC compensator for active power output and reactive power output improvement in the system
- The compensating device control has to be designed with AI based linear crow optimizing algorithm to obtain a smooth voltage and current waveform.
- Reduction in the distortion level of the voltage output at the grid system is to be done by using the proposed optimizer.

IV. Methodology

This study comprises with an analytical and numerical description of proposed algorithm for sentiment analysis of UPFC which is simulated to obtain the performance of the proposed algorithm.
In order to evaluate the performance of proposed algorithm scheme, the proposed algorithm is simulated in following configuration:
Pentium Core I5-2430M CPU @ 2.40 GHz
4GB RAM
64-bit Operating System
Matlab Platform
The large-scale solar system is connected to grid via a converter and transformer. In order to improve the transient voltage stability of the large-scale solar system, reactive power compensation device UPFC is connected to grid. The compensator is being proposed for further enhancement in the output parameters like THD in voltage, THD in current and active power output.

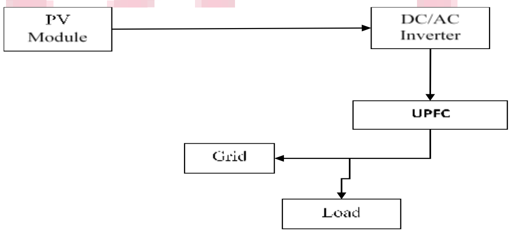

Fig. 1 Hybrid energy system topology

As shown in Fig. 1, the wind power generation system consists of PV system and AC/DC inverter and UPFC connected with the grid system.

A. PV Module modeling

PV cells have single operating point where the values of the current (I) and voltage (V) of the cell result in a maximum power output. These values correspond to a particular resistance, which is equal to V/I. A simple equivalent circuit of PV cell is shown in Fig. 2.

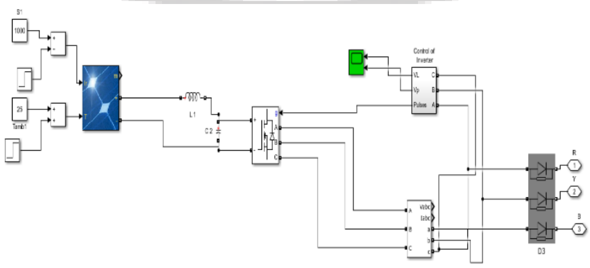

Fig. 2 Modeled solar system

A cell series resistance (Rs) is connected in series with parallel combination of cell photocurrent (I_{ph}),exponential diode (D), and shunt resistance (R_{sh}) , I pv and Vpv are the cells current and voltage respectively. It can be expressed as

$$I_{pv} = I_{ph} - I_s\left(e^{q(V_{pv}+I_{pv}*R_s)/nKT} - 1\right) - (V_{pv} + I_{pv} * R_s)/R_{sh}$$

Where:

I_{ph} - Solar-induced current

I_S - Diode saturation current

q - Electron charge (l.6e^{-l9}C)

K - Boltzmann constant (l.38e^{-23}J/K)

n - Ideality factor (l~2)

T - Temperature ^{0}K

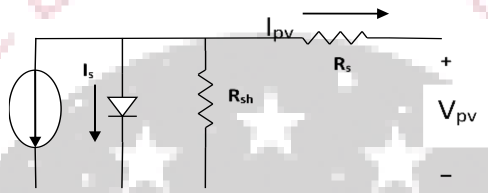

Fig. 3 Equivalent circuit of solar pv cell

The solar induced current of the solar PV cell depends on the solar irradiation level and the working temperature can be expressed as:

$$I_{ph} = I_{sc} - k_i(T_c - T_r) * \frac{I_r}{1000}$$

Where:

I_{SC} Short-circuit current of cell at STC

k_i Cell short-circuit current/temperature coefficient (A/K)

I_r Irradiance in w/m

T_C ,T_r Cell working and reference temperature at STC

A PV cell has an exponential relationship between current and voltage and the maximum power point (MPP) occur at the knee of the curve as shown in the Fig 4.

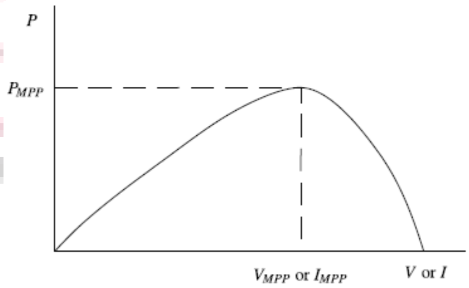

Fig. 4 Characteristic PV array power curve

The P&O algorithm will track the maximum power to supply the DCMGs system. The assumptions for model derivation are that the ideal current source can be presented as the PVs behavior. In addition, all power converters are operated under the continuous conduction mode (CCM) and the harmonics are also ignored.

Table 4.1 : PV module Parameters

Maximum Power	213.5 Watts
Number of parallel strings	40
Number series modules	10

Open circuit voltage	36.3 Volts
Shot circuit current	7.84 Ampere

B. UPFC Working

The UPFC consists of two back-to-back GTO voltage converters (shunt and series) via a common intermediate circuit, as shown in Fig. 5. The main goal of the series converter is to generate an alternating voltage Vc with a 'controllable amplitude and phase angle and this voltage at the fundamental frequency in series with the transmission line, the active and reactive power being exchanged at their AC connections via transformers. connected in series. The different equations implemented for the 14 bus system were also discussed.

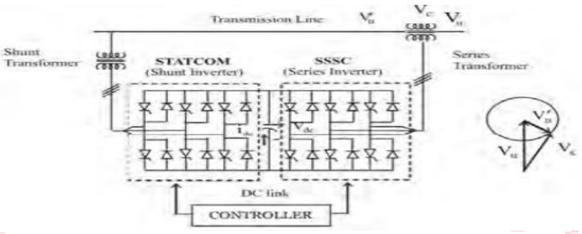

Fig. 5 Basic Circuit Configuration of the Unified Power Flow Controller.

The shunt converter adjusts the active power or controls the DC voltage of the capacitor by supplying the required active power to the DC terminals. It also offers regulation of the branch point voltage by regulating reactive power (generation or consumption of reactive power). The two converters can generate or absorb power independently of each other without going through the intermediate circuit. Thus, the UPFC can perform the functions of reactive shunt compensation, series compensation and phase shift and achieve various control objectives by adding voltage Vc with an amplitude and phase angle appropriate to the voltage across Vu.
The electrical network consists of a synchronous machine connected to the network via a transmission line. The UPFC is connected to the bus near the machine and its model is shown as an ideal transformer model in Fig. 6. The network model including the UPFC is also shown in FIG. 7.
To obtain the simplified block diagram it is necessary to derive the dynamic equation of the rotor and its parameters from the parameters of figure 7. The equation of the dynamic rotor is:

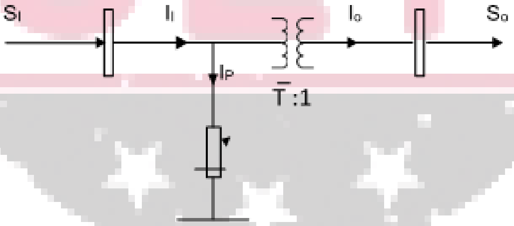

Fig. 6 Ideal transformer model of UPFC

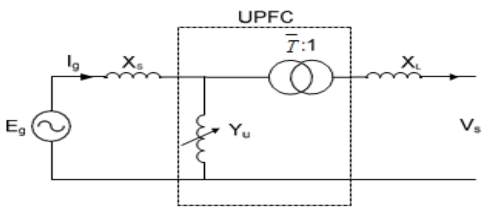

Fig. 7. Power system model including UPFC

$$M\frac{d\omega}{dt} = P_m - P_g - D\frac{d\delta}{dt}$$

Where
M:Momentum of rotor
Pm: Input mechanical power
Pg: Output generator power
D: Friction coefficient
ω: Rotor speed

δ: Load angle

It is necessary to calculate Pg based on UPFC and network parameters. Pg is Eg times Ig, therefore current generator must be calculated.

$$\begin{bmatrix} E_g \\ I_g \end{bmatrix} = \begin{bmatrix} 1 & \frac{1}{Y_s} \\ 0 & 1 \end{bmatrix} \begin{bmatrix} \bar{T} & 0/1 \\ \bar{T}Yu & \dot{\bar{T}} \end{bmatrix} \begin{bmatrix} 1 & \frac{1}{Y_s} \\ 0 & 1 \end{bmatrix} \begin{bmatrix} V_s \\ I_s \end{bmatrix}$$

$ABCD_i$ $ABCD_u$ $ABCD_k$

Eg:Internal voltage of generator

ABCD: Transmission matrix

T: Complex ratio of transformer

Yu: UPFC admittance

Ys:Generator admittance

YL: Line admittance

Equation (2) can be written as (3).

$$\begin{bmatrix} E_g \\ I_g \end{bmatrix} = \begin{bmatrix} A & B \\ C & D \end{bmatrix} \begin{bmatrix} V_s \\ I_s \end{bmatrix}$$

$$A = \frac{\bar{T}\,Y_s + \bar{T}Y_u}{Y_s}$$

$$B = \frac{\left||\bar{T}|^2 Y_s + |\bar{T}|^2 Y_u + Y_L\right|}{\dot{\bar{T}}\;Y_L Y_s}$$

$$C = \bar{T}\,Y_u$$

$$D = \frac{\left||\bar{T}|^2 Y_u + Y_L\right|}{\dot{\bar{T}}\;Y_L}$$

And generator current is:

$$I_g = V_s\left(C - \frac{DA}{B}\right) + \frac{D}{B}\,E_g$$

The basic modeling of the UPFC is done in the manner stated above by utilizing the equations.

CCSA algorithm

Conventional research methods have long been used to solve design problems. While these methods give promising results for many real-world problems, they can fail for more complex design problems. In real design problems, the number of decision variables can be very large and their influence on the objective function can be very complicated. The objective function can have many local optimums, while the designer is interested in the overall optimum. Such problems cannot be treated with conventional methods which find only excellent premises. In these cases, efficient optimization procedures are required.

Crows (family of ravens or corvids) are considered to be the most intelligent birds. They contain the largest brain for their size. Based on a brain-to-body ratio, your brain is slightly smaller than that of a human brain. Evidence of the ravens' prowess is abundant. You have demonstrated self-confidence in mirror tests and have the ability to create tools. Crows can remember faces and warn each other of the approach of a hostile crow. Plus, they can use tools, communicate ingeniously, and remember where food is hiding for months later.

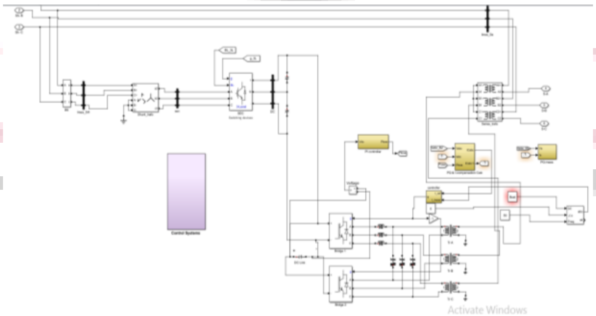

Fig. 8 Compensator with proposed constrained crow search algorithm

V. Results

In this world of depleted energy resources, the use of renewable energy sources is urgent to meet the needs of the future. Using solar and wind energy resources to generate electricity is the best choice to counter the consumption of depleted resources. The best part is that it is also a clean source for generating electricity. This area will now be retained for our work on these resources.

The thesis focuses on the analysis of a solar energy system through its implementation in the MATLAB / SIMULINK software. The system is designed to be integrated into the network system, also to increase its efficiency. The distortion level was calculated for the voltage and current waveforms, neglecting sudden transients at system startup. The chapter deals here with the solar / wind system in the following two cases.

Case 1: solar PV system with UPFC having PI controlled electronic converters

Case 2: solar PV system with UPFC having electrical power contrived CSA optimizing controlled dual bridge electronic converters

The photovoltaic solar system is made with two inputs for the solar panel, i.e. temperature and irradiation. The DC output voltage from the solar system is passed to the inverter for DC to AC conversion.

The solar panel was modeled with photovoltaic panels with 10 cells connected in each row with 40 parallel branches which together provide the DC output of the system. The 1000 lux variable illumination is provided with a variable temperature of 250 C. This output is fed to the inverter for conversion to alternating current. The DC output shaft is shown in the figure. Between,

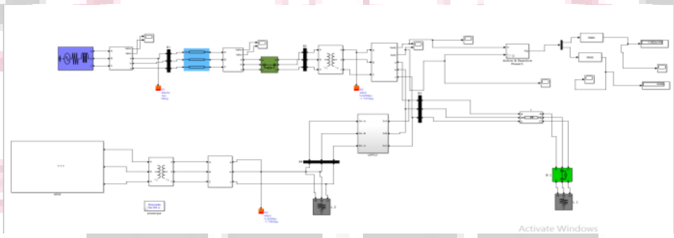

Fig. 9 Matlab/SIMULINK model of the grid connected PV system with UPFC

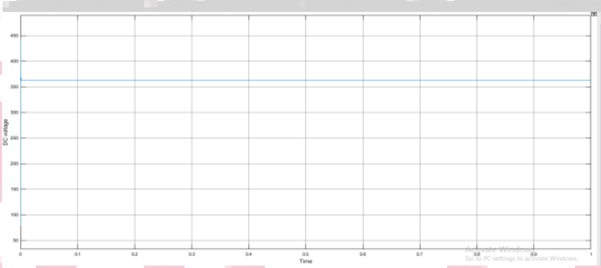

Fig. 10 DC output voltage from the grid connected solar PV system

Case 1: solar PV system with UPFC having PI controlled electronic converters

The system in this case is modeled with solar energy with UPFC having converters driven by PI controller which is then further integrated with the grid. Further the voltage current, active power and reactive power waveforms have been analyzed.

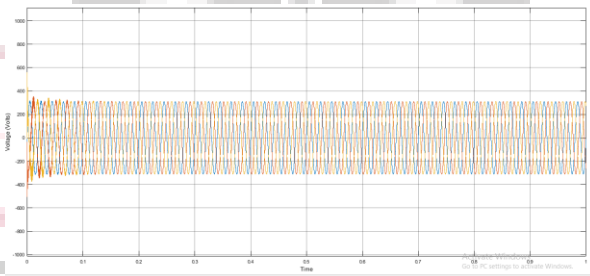

Fig. 11 Voltage in transmission line in the grid connected system with UPFC having PI controlled electronic converters

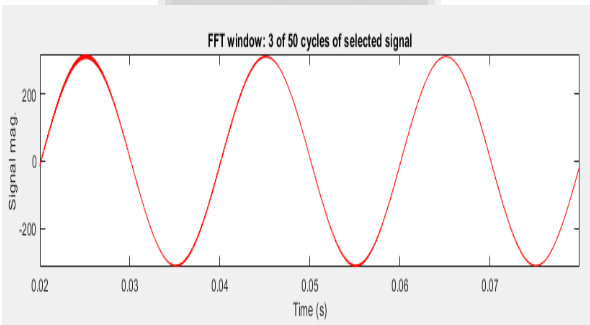

Fig. 12 FFT analysis of Voltage in transmission line in the grid connected system with UPFC having PI controlled electronic converters

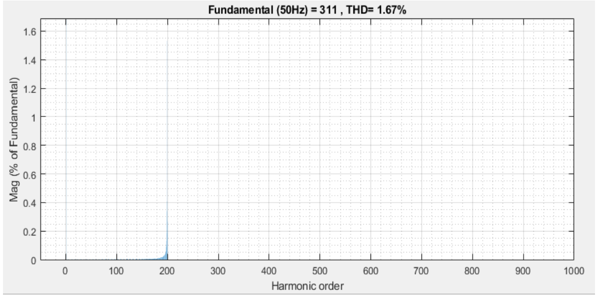

Fig. 13 THD% of Voltage in transmission line in the grid connected system with UPFC having PI controlled electronic converters

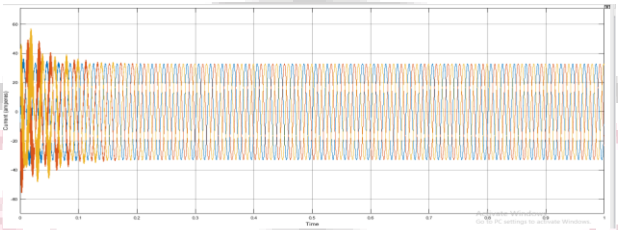

Fig. 14 Current in line in the grid connected system with UPFC having PI controlled electronic converters

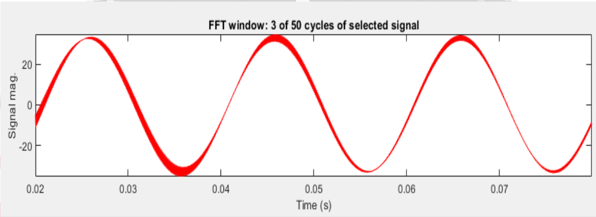

Fig. 15 FFT Analysis of Current in line in the grid connected system with UPFC having PI controlled electronic converters

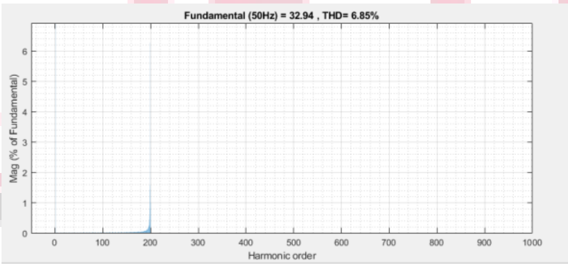

Fig. 16 THD% of Current in line in the grid connected system with UPFC having PI controlled electronic converters

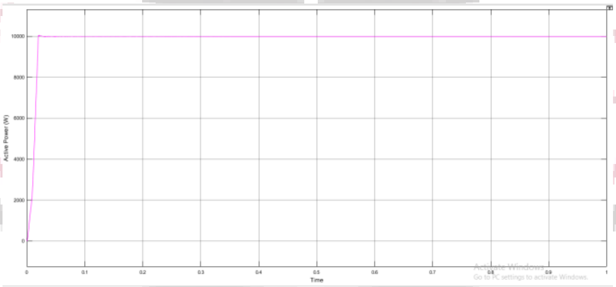

Fig. 17 Active power available in the grid connected system with UPFC having PI controlled electronic converters

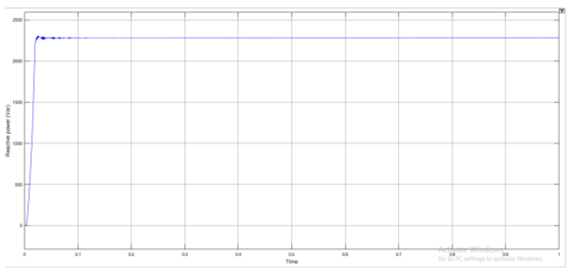

Fig. 18 Reactive power available in the grid connected system with UPFC having PI controlled electronic converters

The waveforms above show the voltage output, current output, actual output power and reactive power in the system with serial UPFC driven by PI controlled converters. We deduce that the output voltage is about 310 volts. A current of approximately 33 Amps was determined with an active output power of 9985 W and a reactive output power of 2283 Var.

Case 2: solar PV system with UPFC having electrical power contrived CSA optimizing controlled dual bridge electronic converters

In this case, the system is modeled with solar energy, the UPFC has two converters driven by electricity, and the CSA is optimally controlled and thus integrated into the grid. In addition, the waveforms of voltage, current, active power and reactive power were analyzed.

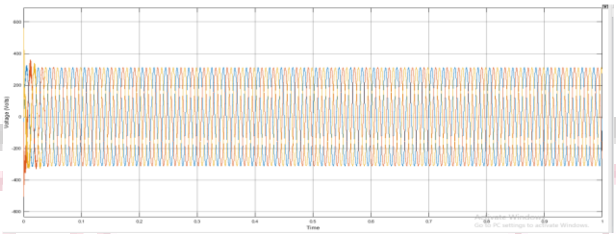

Fig. 19 Voltage in the transmission line in system with UPFC having electrical power contrived CSA optimizing controlled dual bridge electronic converters

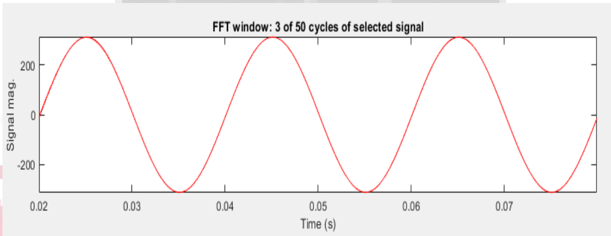

Fig. 20 FFT analysis of Voltage in system with UPFC having electrical power contrived CSA optimizing controlled dual bridge electronic converters

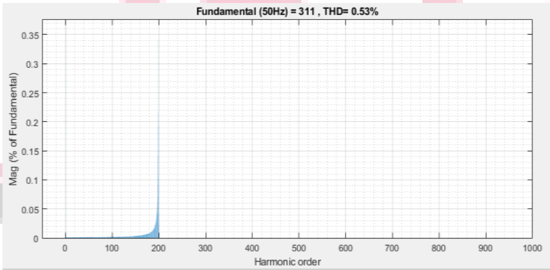

Fig. 21 THD% of Voltage in system with UPFC having electrical power contrived CSA optimizing controlled dual bridge electronic converters

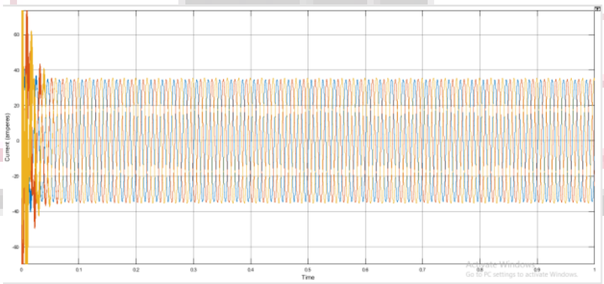

Fig. 22 Current in system with UPFC having electrical power contrived CSA optimizing controlled dual bridge electronic converters

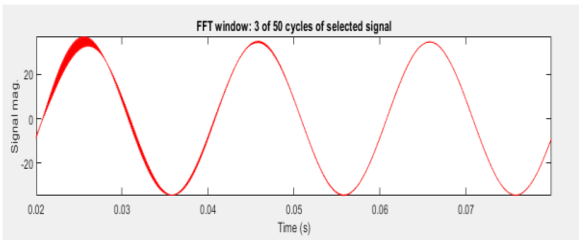

Fig. 23 FFT analysis of Current in system with UPFC having electrical power contrived CSA optimizing controlled dual bridge electronic converters

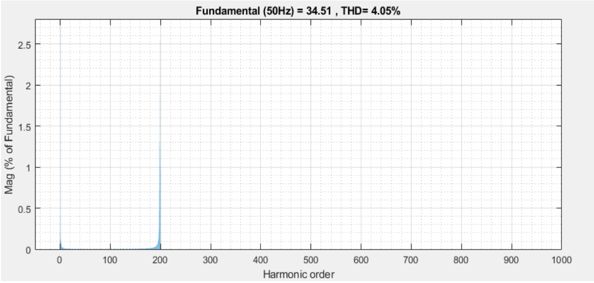

Fig. 24 THD% of Current in system with UPFC having electrical power contrived CSA optimizing controlled dual bridge electronic converters

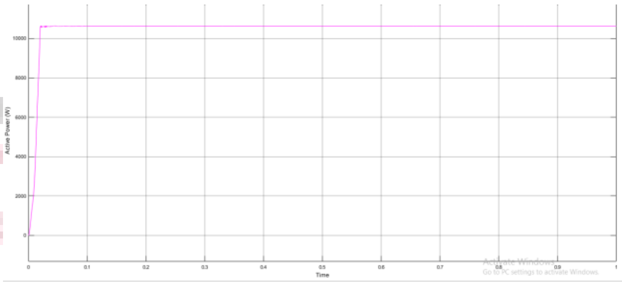

Fig. 25 Active power available in system with UPFC having electrical power contrived CSA optimizing controlled dual bridge electronic converters

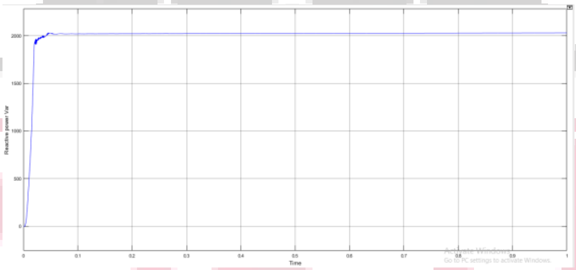

Fig. 26 Reactive power available in system with UPFC having electrical power contrived CSA optimizing controlled dual bridge electronic converters

The waveforms above show the output voltage, output current, actual output power and reactive power in the system with UPFC in series, CSA optimized double bridge controlled electronic converters built with electric power. We deduce that the output voltage is about 310 volts. A current of approximately 34.5 Amps was generated with an active output power of 10620 W and a reactive output power of 2029 Var. Find.

Validation:

The UPFC modeled with contrived crow search based algorithm is expected to produce better results as compared to the UPFC with PI controlled converters

S.no	Parameters	system with UPFC having PI controlled electronic converters	UPFC having electrical power contrived CSA optimizing controlled dual bridge electronic converters
1	Active power output	9985 W	10620 W
2	Voltage Output	310 V	310 V
3	THD% in voltage	1.67%	0.53 %
4	THD % in current	6.85 %	4.05 %
5	Reactive Power output	2283Var	2029Var

The above results show the comparative values of all parameters. The available active power has been increased from approximately 9985W in the UPFC with PI-controlled converters on the bus in the system with STATCOM to 10620W in the system, which is transformed into UPFC with optimized double-bridge electronics CSA converters. It has been studied that the reactive power delivered in the transmission line is reduced to make it more stable from 2283 Var to 2029 Var.

VI. Conclusion

The demand for electricity is growing day by day, which cannot be satisfied only with non-renewable energy sources. Renewable energy sources such as the sun and wind are ubiquitous and environmentally friendly. Renewable energy sources are new options for meeting energy needs, but they are unreliable due to their stochastic nature.

The work here presents a solar-based renewable energy system in a MATLAB / SIMULINK environment for analysis. We have developed a controller for the UPFC Contrived Crow Search optimization algorithm for double bridge converters, which is part of artificial intelligence. The following main conclusions were drawn:

- The active output power of the system has been increased to 1020W in the system with UPFC controlled by the proposed controller, which has a limited raven search algorithm of 9985W in a system with UPFC controlled by the PI controllers.
- The Crow search algorithm is designed to also reduce output voltage and current distortion. The output voltage distortion level of the solar power system was found to be 0.53%, which is less than 1.67% of the system with UPFC controlled by the PI controllers.
- The raven search algorithm has also proved collectively effective in reducing the distortion level of the output power. With the proposed controller, the current degree of distortion has increased from 6.85% in the solar system to 4.05%.
- The system is also integrated into the grid energy system. The mains voltage is maintained at 310 Volts. The reactive output power also decreased. The algorithm was also found to be more effective in compensating for reactive power.

The above description concludes that the solar system for driving the loads is made efficient with improved effective output power at its port. The available voltage was less distorted and the THD value in the current output also decreased.

VII. Future Scope

The modulation technique is easy and simple to be implemented; use of proper facts devices can make it more robust and easy to handle inverter. With the advent of more powerful artificial intelligence, the requirements for low computational complexity and memory consumption of the algorithms will drop and it might be even possible to implement more complicated and more efficient algorithms. The proposed controller has proved to be effective while designing the compensator. This algorithm can further work in an enhanced manner by making a hybrid technique for this algorithm. Therefore, it is certainly true that the area of compensator is and for a long time will remain widely opened sphere for scientific research and commercial applications.

VIII. References

[1] RiteshDash, Sarat ChandraSwain “Effective Power quality improvement using Dynamic Activate compensation system with Renewable grid interfaced sources” Ain Shams Engineering Journal, Volume 9, Issue 4, December 2018, Pages 2897-2905.

[2] Priya M, Vivekananda Sibal T “power quality improvement of multifunctional grid connected inverter with renewable system”, Volume 10, Issue 1, January – February 2019, pp. 46–51, Article ID: IJEET_10_01_007, International Journal of Electrical Engineering & Technology (IJEET).

[3] Bhupendra Singh Niranjan , Dashrath Kumar “Power Quality Improvement by Using UPQC in Wind Energy Conversion System”, International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering, Vol. 8, Issue 3, March 2019.

[4] Abdulkerim Karabiber, “Controllable AC/DC Integration for Power Quality Improvement in Microgrids” Advances in Electrical and Computer Engineering (Vol. 19, Issue 2), May 2019

[5] Ashwani Kumar, Nitin Kumar Saxena “Dynamic Reactive Power Compensation and Cost Analysis for Isolated Hybrid Power System”

[6] Digvijay B Kanase; A. R Thorat; H. T Jadhav, “Distribution Static Compensator for Power Quality Improvement Using PV Array” National Conference on Power Quality Resources on 2018.

[7] V.Kamatchi Kannan, N.Rengarajan “Photovoltaic based distribution static compensator for power quality improvement” International Journal of Electrical Power & Energy Systems, Volume 42, Issue 1, November 2012, Pages 685-692.

[8] Lavanya Viswanathan, Senthil Kumar “A Review: Control Strategies for Power Quality Improvement in Microgrid” International Journal of Renewable Energy Research-IJRER, Vol 8, No 1, 2018.

[9] Jaber Alshehri, Muhammad Khalid “Power Quality Improvement in Microgrids Under Critical Disturbances Using an Intelligent Decoupled Control Strategy Based on Battery Energy Storage System” IEEE, 08 October 2019.

[10] Sibtain ul Hassan; Zain ul Abideen; Tahir Izhar “Advanced control techniques for micro-grids power quality improvement” 2017 Asian Conference on Energy, Power and Transportation Electrification (ACEPT).