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Designing UPFC with Controller Driving Dual Converter Topology in a Grid Integrated PV System

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Abstract Renewable energy source (RES)-based electricity generating plants are expensive and complicated, requiring controls to deal with the energy input's intermittent renewables and fluctuation. If the grid interface of these devices is not monitored and maintained within the norms, it presents a problem of providing electricity to the utilities. Thus researchers have discusses several grid interface and control strategies for RES-based generators. This paper discusses the technique of improving power quality by using UPFC (Unified Power Flow Control) having PI controller.

I. INTRODUCTION

The term "renewable energy source" refers to energy that is both sustainable and infinite, such as the sun. When the word "alternative energy" is used, it usually refers to solar and wind power as well. It refers to energy resources that are not as quasi as the most regularly utilised quasi resources, such as coal. Hydrogen electricity is not other, but it is carbon-neutral, meaning it emits little or no CO2, just like alternative energy sources. Nuclear energy has a consistent supply, which implies it is not affected by the environment, and it will play a significant role in achieving net zero energy in the United Kingdom.

The sun is a magnificent and renewable resource that has the ability to sustain life on Earth by providing clean, renewable energy to all of its occupants. In fact, the sun sends more energy to our globe in an hour than the complete world's population uses in a year. Solar photovoltaic (PV) modules turn the sun's energy into electricity (photo = light, voltaic = electricity).

We can move further away from other harmful and sustainable power sources by designing and installing PV systems on a broad scale. Because the solar sector is expanding, the demand for experienced people is increasing as well!

Figure 1. Solar Photovoltaic Cell

Wind is a plentiful source of environmentally friendly electricity. Wind farms are becoming more common in the United Kingdom, as wind power contributes more and more to the National Grid. Turbines are used to power generator, which subsequently feed energy into the Electricity Network, allowing wind energy to be harnessed. Despite the availability of household or "off-grid" generation solutions, not every property is appropriate for a personal wind generator.

Figure 2. Wind Energy

Hydroelectricity is one of the most available commercial renewable resources. A sizable pond can also be used to create a governed movement of liquid that will end up driving a turbine connected to a generator by erecting a dam or roadblock. This power source is frequently more consistent than solar and wind power (especially if it is tidal rather than river-based), and it also enables electricity to be stored for use when consumption peaks. Hydro, like renewable power, can be more practical as a business power source in some instances (depending on kind and contrasted to other sources of energy), but it can also be utilised for residential, 'off-grid' generating depending on what type of land.

Renewable energy (RE) sources are a great way to give cleaner energy and solve the world's energy crisis. Furthermore, during the last decade, advancements in power system technology for these sources have enhanced the utilization of renewable energy sources. Because of its capacity to generate power in a very clean, silent, and consistent fashion, solar photovoltaic (PV) systems have become a potential RE source. PV systems are solar electricity generation systems that can either deliver energy straight to an electric metre or feed power into the utility power grid when linked to the network. Solar bulk electricity production is predicted to be comparable with other forms of RE sources as the cost of PV panels manufacturing continues to fall due to developments in materials and PV array fabrication techniques. Solar power generation, on the other hand, suffers from low solar cell capacity factor, and the power flow of a PV array is affected by temperature and irradiance. As a result, maximum power point tracking (MPPT) electronics should be utilised to fully use the PV array .

The ability of electrical equipment to use the energy provided to it is referred to as power quality. Electrical components performance is impacted by a variety of power quality concerns, including electromagnetic harmonics, inadequate power factor, voltage fluctuations, and unbalance.

In today's world, the electricity sector is one of the most important variables affecting a country economically. The utility must provide more power as the population and living conditions rise. These concerns led to the development of renewable technology, with rising temperatures as the primary considerations. Renewable Energy are being developed to address these challenges. The impact of integrating sustainable energy units into the grid on the system's power quality is significant. Nonlinear loads linked to the line, as well as wind energy units, create injection harmonics in the line, requiring power factor on the line. Voltage sags will have an impact on utility and household devices.

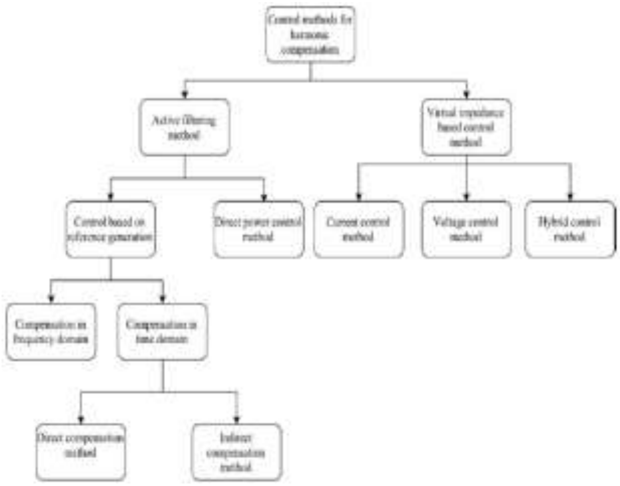

Figure 3. Control Strategies For Harmonic Compensation [4]

II. LITERATURE REVIEW

(Mahela & Shaik, 2017) [1] The possibilities for grid-connected solar photovoltaic (PV) system applications to provide an alternative to the existing fossil energy creation is drawing increasing interest of industrial and academic. This contributes to meeting rising energy demands while also limiting environmental pollution caused by fossil fuel emissions. This article presents a comprehensive summary of solar PV systems that are connected to the electric. The goal of this review is to give researchers, designers, and engineering firms on renewable radiation and its inclusion into the power system a broad overview of the architectural style of energy solar PV systems and their responsible for majority, such as solar cells, PV arrays, power factor correction, filters, DC-DC converters, single-phase rectifiers, and multiple inverters.A brief summary of solitary and three-phase power converter control mechanisms also has been introduced. Over 100 research papers on the configurations, combinations, and function leading of energy solar PV systems and their principal constituents elements have been evaluated and categorised for easy access.

(Kottayil & Engineering, 2014) [2] The development of a control scheme for energy multilevel inverter of renewable energy is presented in this paper (RES). In this project, Hysteresis Contemporary Control (HCC) is used. The outcomes of a computer model as well as a laboratory prototype are presented in this paper. The control agreement's simplification and serviceability are demonstrated by the experimental data using the equipment established. Active and reactive transmission from a solar PV panel to an energy alternator is also evaluated. As the DC link voltage rises, the amount of power delivered to the grid rises as well. On the secondary winding of a diesel generator, the converters is also evaluated on the point of common coupling.

(Kasa et al., 2016) [3] The generator is becoming increasingly diverse and complex. Incorporating alternative energy into the grid can efficiently control these temporal variations. The optimal use of alternative energy sources will affect the electrical utility's overall quality. Renewable energies and quasi loads grid connection have a negative impact on the actual power quality. This paper also presents a Dynamic Active Power Filter (DAPF) based on I cosine ANFIS control to continue improving grid power quality at the source side with efficient solar photovoltaic. The model anticipates the best use of renewable energy resources and avoids the use of batteries by substituting a solar energy unit (SEU). The DAPF is powered by the SEU and the wind turbine.

(Member, 2018) [4] The degradation of voltage stability at the point of common coupling (PCC) will become a major concern as more sustainable power distributed generation (DG) units are linked to utility power systems. Two types of harmonic components are associated with DG units, and when they combine, they can cause increased harmonic components at the PCC. The first type of harmonic distortion is produced by power semiconductor converters in DG units such as photovoltaic (PV) systems, which have resonance frequency harmonic currents that are multiples of the DG interprocess communication inverter's frequency band. The possible performance effect of LCL or LC filters installed at the inverter to ameliorate such harmonic frequencies is described in this article, which begins with a review of such harmonic currents.Other nonlinear local, PCC, and utility loads in the system generate the second type of harmonic currents, which are common example harmonic frequencies at multiples of the power network frequency, 50/60Hz. Chromatic countermeasure for such harmonics is analyzed and summarized using students utilize of the DG interprocess communication inverter acting as a voltage stability conditioner. This methodical review can help with a greater understanding of harmonic components in sustainable power DG units, as well as provide guidance on advanced control schemes for achieving ancillary chromatic recompense through DG interprocess communication multilevel inverter.

(Meral & Inci, 2019) [5] The most serious disturbances that decrease the performance of grid-connected inverter tightly integrated renewable resources are unbalanced grid faults (IIRESs). In this regard, this research proposes a novel regulate path to making the best use of the grid-connected IIRES' productivity and consequently during grid faults system disturbances. The proposal of an efficient and accurate improved Virtual Park (VP) pattern extractor to integrate the reference signal alternator is one of the major contributions to previous methods (RCG). The proposed VP sequence extractor has also improved the dynamic characteristics of the energy IIRES.To meet the aimed organizational objective, a new algorithms are based on the RCG is embedded in the computing of highest active and reactive injection and concurrently amplitude of phase voltage. Feedback control and minimization of active power perturbations are also developed and implemented using only one controller parameters. Another result of this study is the use of peak current limitation control to prevent residual current concerns. For overcurrent protection, the reference for active power is calculated online based on the maximum reactive power injection at power converter capacity. A considerable number of cases is used to validate the efficacy of the suggested solution and to demonstrate the limitations of previous related research.

(Prakash & Shaik, 2016) [6] Wind energy has grown in importance in recent years as a result of its donation to the power production industry's autonomy from conventional fossil fuel energy resources in the context of 106 MW of ongoing ready for harvest potential on the planet. This paper provides a thorough overview of grid-connected wind energy systems.This is intended to provide a broad range of information to researchers, designers, producers, and evaluators on the status of wind profiles, wind possible future estimation, configuration/design of wind energy systems, wind turbines, power converter network topology used for grid installation of wind power, energy storage for wind turbine applications, electricity softening methods, HVDC links used for wind assimilation, foreign grid codes, and power control methods. More than 200 research papers on grid-interfaced wind generation structures have been scrutinised, categorised, and listed for easy access.This overview is a fully prepared of important topics for renewable power grid integration and technical capabilities in this ground.

(L. G. Meegahapola et al., 2020) [7] Due to the rapid increase in power-electronic converter (PEC)-interfaced renewable energies in recent years, oscillations stabilisation has gotten a lot of attention. Phasor measurement innovation provides superior capability for measuring and monitoring power systems in real moment, and power system operators need a greater comprehension of how to use it to analyse and control oscillations effectively. This paper examines state-of-the-art oscillations stability surveillance, assessment, and function leading based on phasor measurement technology that have been found in the literature. The classification of power system fluctuations is revised, with a focus on fluctuations induced by Deltoid muscles renewable energy production.The use of synchrophasor-based oscillations accordance with the quality, analysis, and associated controls to characterise and mitigate PEC-induced oscillations is well founded in electricity system design, but more research is needed to effectively use tend to remember oscillations stabilisation tracking, analysis, and associated controls to characterise and mitigate PEC-induced oscillations. High scores particular concept, in particular, could be applied to synchronized phasor streaming data to create oscillatory stabilisation tracking, analysis, and shock absorbers technics.

(Gunaruwan, 2018) [8] Renewable energy generators (REGs) with power electronic converter (PEC) interfaces are beginning to integrate into the power grid. With high levels of renewable energy permeation, one of the key power distribution variables, reactive power, is impacted, causing issues with electrical installations and stability analysis. To ensure a consistent and predictable electricity network, it is critical to maintain and oversee adequate active and reactive reserves. A comprehensive study on reactive power administration in renewable electricity grids is presented in this paper. The reactionary power usage for REGs stipulated in various grid-codes are summarised in order to assess their suitability for future communication prerequisites.The voltage regulation processing capabilities and control schemes of PEC interfaced REGs are discussed in detail. Traditional active and reactive might sometimes (e.g. capacitor banks) and PEC tightly integrated active and reactive support devices (e.g. static synchronous compensators (STATCOMs)) play an important role in active and reactive administration in renewable electricity grids, and their functionality and constraints are thoroughly examined in this paper. Then, numerous different reactive power compensation schemes are examined, with a focus on their benefits and drawbacks. For an effective and reliable power grid administration, reactive current cooperation between supports and there ownoptimised capacity is critical.As a result, the paper critically examines and discusses the most popular reactive current coordination and mathematical programming. Finally, key issues concerning reactive power governance in renewable electricity grids are enumerated, along with some key technical suggestions for the electricity sector, lawmakers, and university researchers.

(Bajaj & Singh, 2019) [9] Summary The assimilation of short - term distributed generation (DG) units and the restructuring of power systems are motivated by increased energy requirements due to rapid industrial growth, environmental concerns with fossil fuel–based generation, lessening fossil energy supplies, transmission and distribution congestion, and technical performance deterioration. For both fossil and renewable energy resource–based DGs, optimising the technological benefits offered by Dg installation was a very well challenging issue for manufacturers and distributors (DNOs), but renewable DG systems also have many power quality (PQ) challenges.Because today's lots and lots are more responsive to Chaotic systems, and renewable energy and nonlinear loads are continuing to spread in distributed energy connections, power quality is an essential distinctive feature of renewable DG systems. As a result of continuous reformation of conventional distribution systems due to the penetration of renewable energy sources, the need for innovative power quality improvement (PQI) methodologies becomes unavoidable. This article presents a thorough examination of the voltage stability associated with the grid installation of renewable DG systems, as well as the current state of research on affiliated mitigation strategies. First, this paper focuses on theoretically illustrating all of the critical power quality obstacles sustainable and renewable energy grid connected, and second, a comprehensive survey of all PQI methodologies introduced to date.Furthermore, by designed to simulate a grid interconnected PV based DG system in MATLAB/Simulink, all of the critical power quality problems, the effect of high renewable power infiltration, and remediation methods on power quality are evidenced. This article is thought to be very useful for academics and business professionals who want to learn more about current PQ challenges, PQI methodologies, and recommendations for further studies for green technologies.

(L. Meegahapola et al., 2017) [10] This paper describes a novel distributed energy function and control method that allows for a smoother transition from grid connected to isolated operation, as well as utility supply reconstruction, with no loss or interruption to loads perceptive to harmonic frequencies or phase angle dynamic behavior. A microgrid with power converter sustainable energy generation and energy electronic fully integrated loads is the subject of a simulation study. As a result, the mesh topology has a low inertia by design, which will affect the microgrid's dynamic behavior, particularly during different in the different. To achieve synchronous island procedure, the mesh topology is governed by synchronized phasor data, which allows the mesh topology to monitor the utility regularity and phase difference.The model uses synchronized phasor procurement and telecommunications companies delays, allowing for a thorough examination of microgrid complexities under various mode transformation scenarios, along with the possibility of inverter reference converter failure. After transitioning to islanded mode, the proposed program effectively maintains a microgrid in synchronous machine with the main utility grid without causing significant damage to the microgrid's sophisticated machines. Low inertia microgrids can thus operate synchronously on islands. This study also revealed that if the mesh topology is operated as a simultaneous island, power supply can be restored in a seamless manner.

III. METHODOLOGY

A conversion and transformers link the massive solar power grid. The power factor correction device UPFC is linked to the grid to enhance the transitory voltage profile of the massive solar network. The compensation is being proposed to enhance various parameters such as THD in voltage, THD in present, and dynamic output power even more.

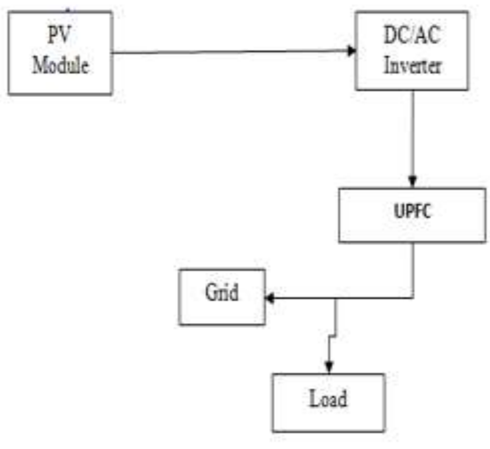

Figure 4. Hybrid energy system topology

UPFC comprises of two back-to-back GTO-based voltage source converters (shunt and series) connected by a shared DC connection. The main goal of a series converter is to generate an ac voltage Vc with a regulated magnitude and phase angle and inject it in series with the line at the fundamental frequency, swapping real and reactive energy at the ac terminals through connected in series converters. The many equations used in the 14-bus system were also addressed.

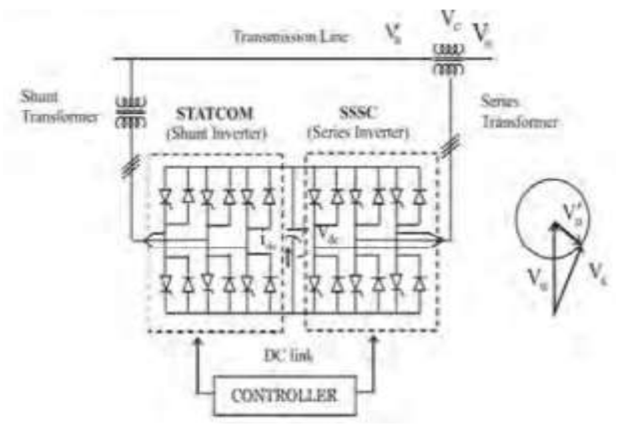

Figure 5Basic Circuit Configuration of the Unified Power Flow Controller.

By providing the appropriate actual power at the DC terminals, the shunt converter monitors or regulates the capacitor's DC voltage. By changing reactive power, it also regulates the voltage of theconnected in shunt point (generating or absorbing the reactive power). Without using the DC link, the two converters can create or absorb power individually. By adding the voltage Vc with the proper magnitude and phase angle to the terminal voltage Vu, UPFC may perform reactive value given, series recompense, and phases shifting, as well as achieve many organizational objective.

A synchronized machinery is connected to the network via a transmission line in the electricity system. The UPFC is linked to a bus near the device, and its model is represented in Figure 4 as an ideal transformers design. A power distribution model with UPFC is also available.

It is necessary to derive the dynamical rotor equations and its variables based on the dimensions of Fig. 5 in order to produce the simple block design. The equation for a moving rotor is:

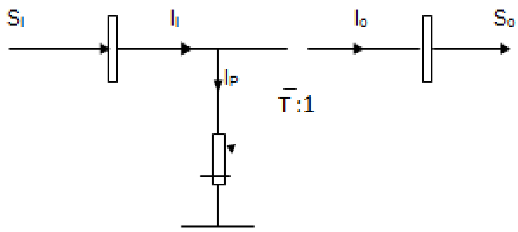

Figure 6Ideal transformer model of UPFC

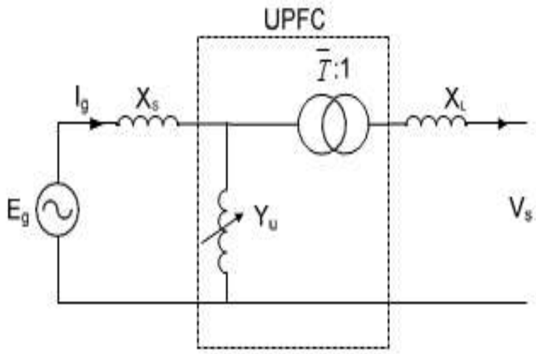

Figure 7Power system model including UPFC

CCSA algorithm

Engineering design challenges have traditionally been solved using traditional search methods. Although these methods show promise in a variety of real-world situations, they may fall short in more complicated design issues. The number of decision factors in real-world design challenges might be vast, and their impact on the optimization problem can be complex. The architect is interested in the global optimum, although the goal function may contain multiple local optima. Traditional methods that only discover local optima will not be able to solve such challenges. In these situations, effective optimization techniques are required.

Crows (or corvids) are said to be the most intellectual birds. They have the biggest brain in proportion to their body composition. Their brain is significantly shorter than a human brain in terms of brain-to-body ratio. There are numerous examples of crows' ingenuity. They've shown personality in mirror examinations and have the ability to make tools. Crows can recognise one other's appearances and warn one another when an unwelcome visitor arrives. They can also utilise tools, converse in complex ways, and remember the location of their meal up to the several months ' time.

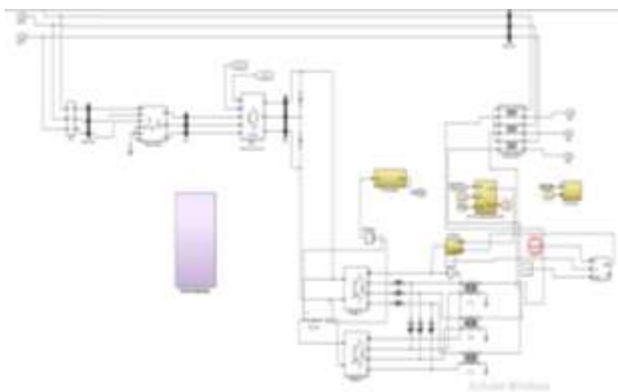

Figure 8. Compensator with proposed constrained crow search algorithm

IV. RESULT AND DISCUSSION

In a world where energy supplies are decreasing, the usage of renewable energy is critical to meeting future requirements. The best option for countering the use of finite resources is to generate electricity using solar and wind energy sources. The best aspect is that it is also a non-polluting source of energy. Our work on these assets will now be done in this area.

The project focuses on using MATLAB/SIMULINK tools to analyse a solar energy system. The technology is designed in collaboration with the power grid in order to maximise efficiency. The distortion level was computed for both currents and voltages without taking into account the system's initial transient. The solar/wind energy systems in the two following situations is covered in this section.

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

Temperatures and irradiance are the input signal to the solar array in a solar PV system. The inverter receives the DC output voltage from the solar energy system and converts it to AC.

PV arrays with 10 cells within every series and 40 parallel branches have been used to represent the solar panel, which together produce the DC output from the system. Variable illumination of 1000 lux is available, as well as a thermal gradient of 250 C. This output is then transferred to the inverter to be converted to AC. The DC output waveform is shown in the diagram below.

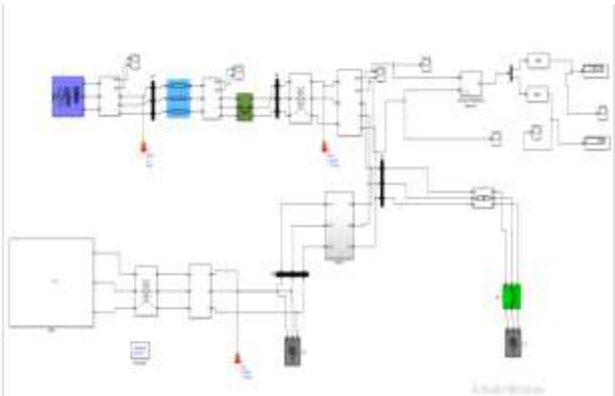

Figure 9. Matlab/SIMULINK model of the grid connected PV system with UPFC

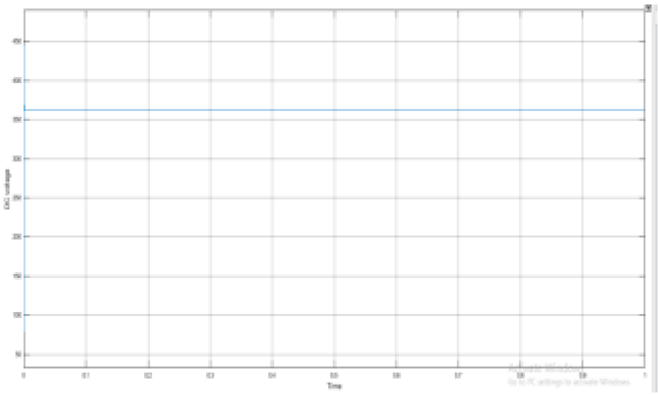

Figure 10. DC output voltage from the grid connected solar PV system

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

In this scenario, the system is modelled with renewable radiation and UPFC conversions controlled by a PI controller, which is subsequently connected to the grid. The waveforms of voltage present, power factor, and real and reactive have also been examined.

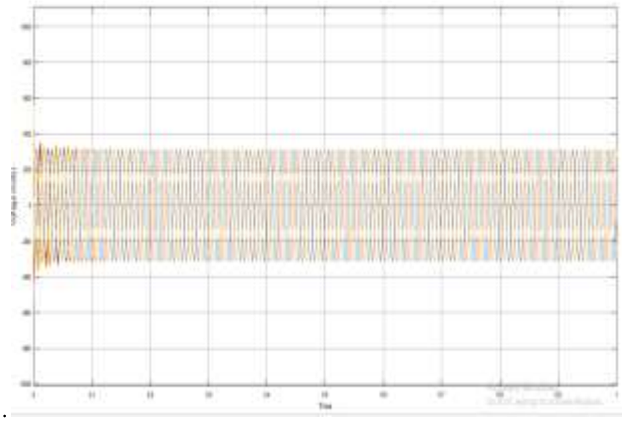

Figure 11. Voltage in transmission line in the grid connected system with UPFC having PI controlled electronic converters

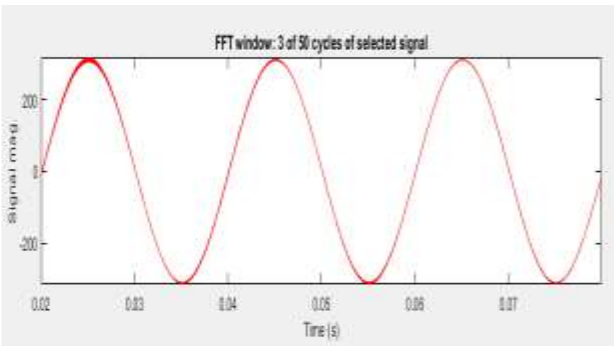

Figure 12. FFT analysis of Voltage in transmission line in the grid connected system with UPFC having PI controlled electronic converters

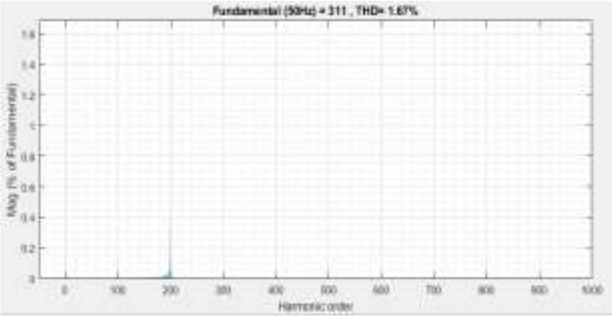

Figure 13. THD% of Voltage in transmission line in the grid connected system with UPFC having PI controlled electronic converters

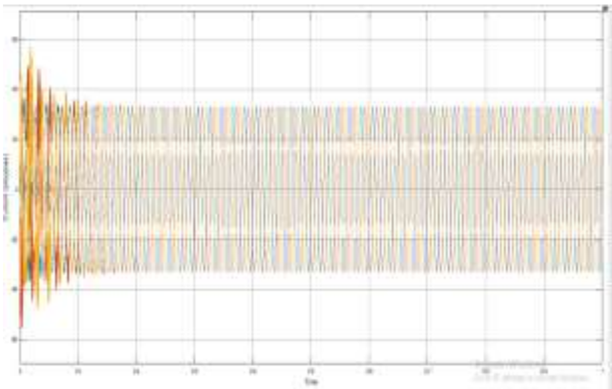

Figure 14. Current in line in the grid connected system with UPFC having PI controlled electronic converters

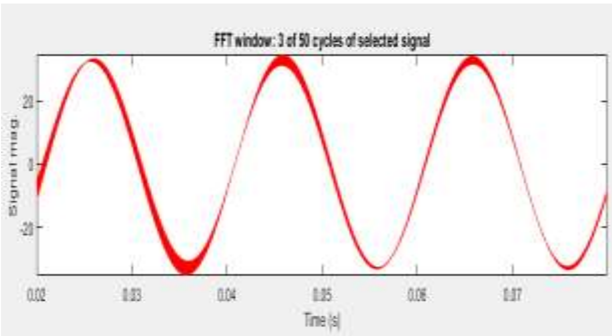

Figure 15FFT Analysis of Current in line in the grid connected system with UPFC having PI controlled electronic converters

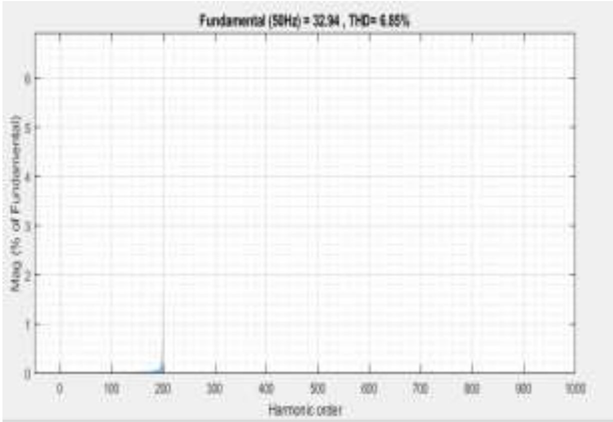

Figure 16THD% of Current in line in the grid connected system with UPFC having PI controlled electronic converters

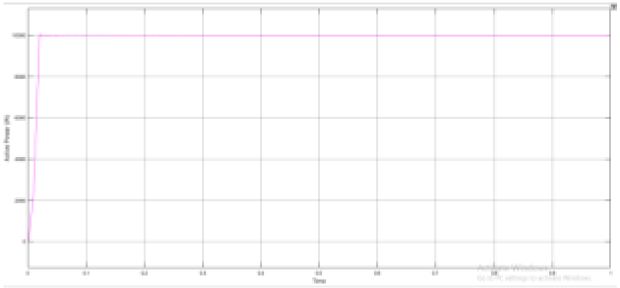

Figure 17. Active power available in the grid connected system with UPFC having PI controlled electronic converters

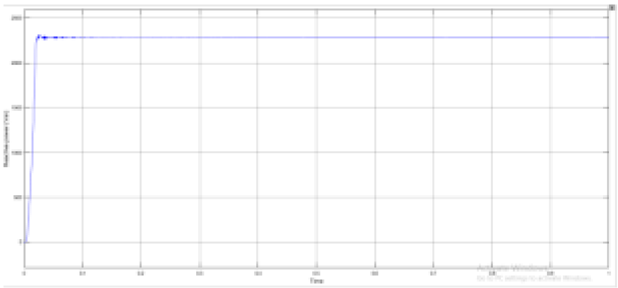

Figure 18. Reactive power available in the grid connected system with UPFC having PI controlled electronic converters

The above waveform depict the voltage, present, power factor, and reactive power outputs in a system with UPFC in line and PI regulated converter. It has been calculated that the voltage output will be around 310 volts. The current was estimated to be around 33 amps, with an effective output power of 9985 watts and a reactionary output power of 2283 volts.

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

In this scenario, the system is modelled with solar energy and a UPFC with power converters powered by electricity generation and CSA optimal control, which is subsequently connected to the grid. The waveforms of voltages present, power factor, and active and reactive have also been examined.

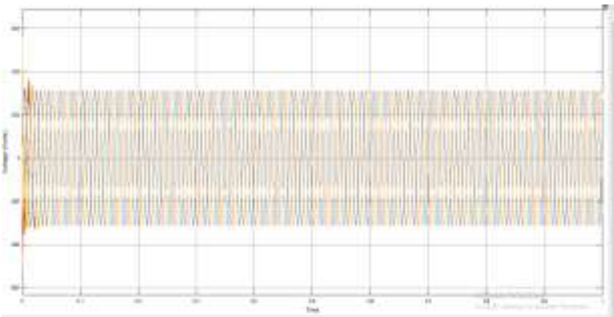

Figure 19. Voltage in the transmission line in system with UPFC having electrical power contrived CSA optimizing controlled dual bridge electronic converters

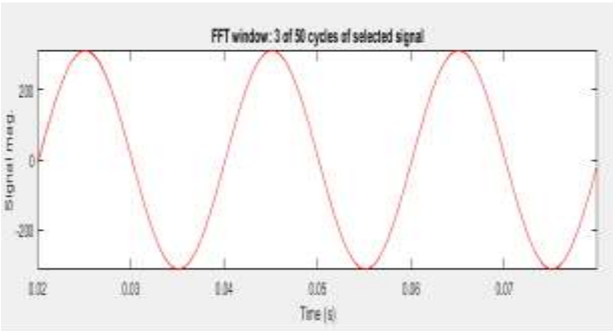

Figure 20. FFT analysis of Voltage in system with UPFC having electrical power contrived CSA optimizing controlled dual bridge electronic converters

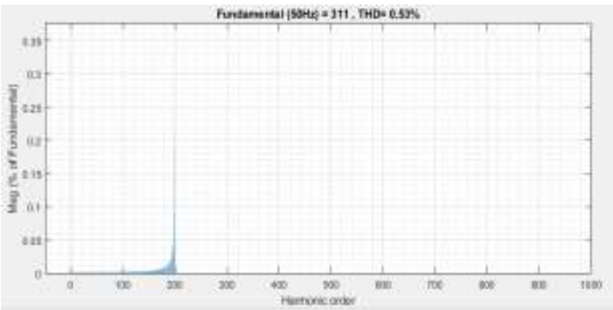

Figure 21. THD% of Voltage in system with UPFC having electrical power contrived CSA optimizing controlled dual bridge electronic converters

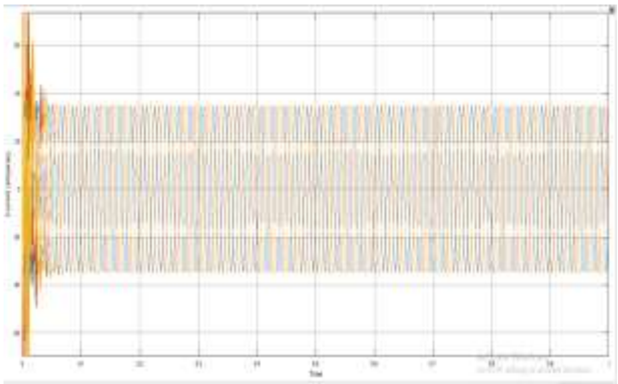

Figure 22Current in system with UPFC having electrical power contrived CSA optimizing controlled dual bridge electronic converters

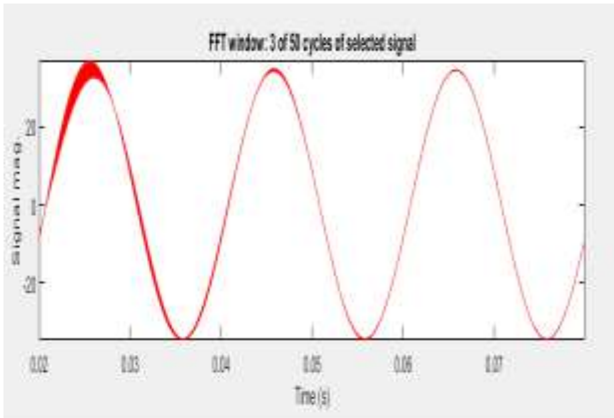

Figure 23FFT analysis of Current in system with UPFC having electrical power contrived CSA optimizing controlled dual bridge electronic converters

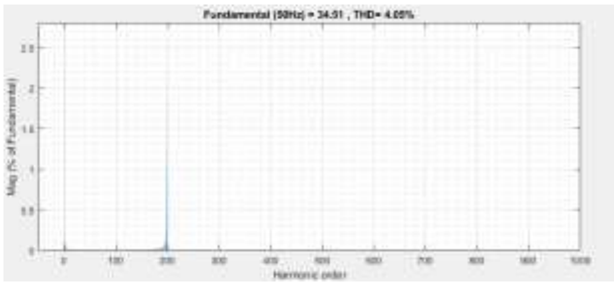

Figure 24. THD% of Current in system with UPFC having electrical power contrived CSA optimizing controlled dual bridge electronic converters

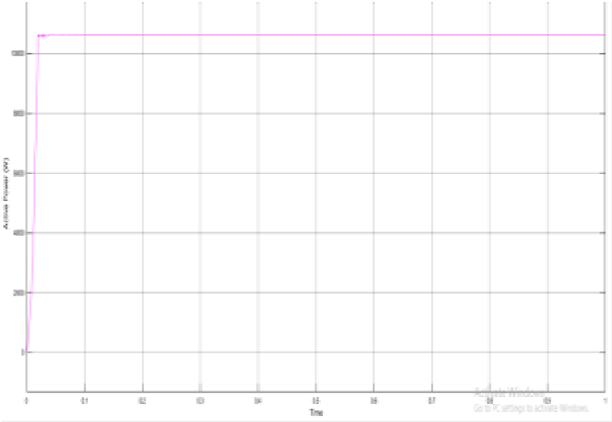

Figure 25. Active power available in system with UPFC having electrical power contrived CSA optimizing controlled dual bridge electronic converters

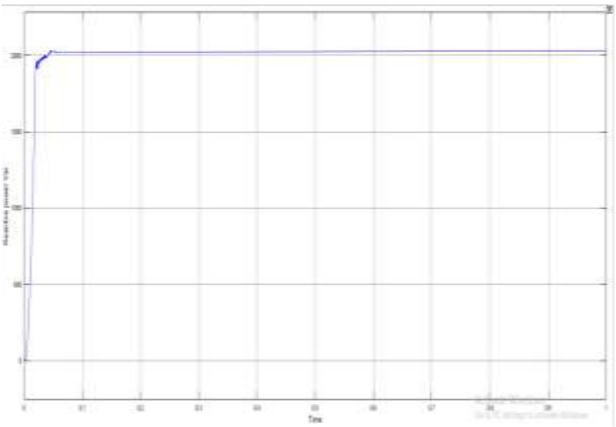

Figure 26Reactive power available in system with UPFC having electrical power contrived CSA optimizing controlled dual bridge electronic converters

Above that the waveforms depict the voltage, present, power factor, and reactive current outputs in a system with UPFC in line and electricity generation generated CSA optimally regulated twin bridge electronics converters. It has been calculated that the voltage output will be around 310 volts. The power was found to be around 34.5 Ampere, with a 10620 W active energy capacity and a 2029Var reactive energy density.

When compared to UPFCs with PI regulated converters, the UPFC modelled with a constructed pigeon searching optimization technique is projected to produce better results.

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	310V	310V
3	THD% in voltage	1.67%	0.53 %
4	THD % in current	6.85 %	4.05 %
5	Reactive Power output	2283Var	2029Var

The comparison readings of all the variables are shown in the following results. The active output power has been increased from about 9985 W at the UPFC with PI regulated converter at the bus in the system with STATCOM to 10620 W at the UPFC with electricity generation contrived CSA optimising controlled dual bridge electronics conversions in the system with STATCOM. The transmission line's reactionary output power was lowered from 2283 Var to 2029 Var in order to make it more stable.

V. CONCLUSION

The demand for electricity is increasing day by day, which cannot be fulfilled by non-renewable energy sources alone. Renewable energy sources such as solar and wind are omnipresent and environmental friendly. The renewable energy sources are emerging options to fulfill the energy demand, but unreliable due to the stochastic nature of their occurrence.

The work here presents a solar based renewable energy system in MATLAB/SIMULINK environment for analysis. We have designed a controller for the UPFC contrived crow search optimizing algorithm for dual bridge converters which is a part of artificial intelligence.

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