Assessment of Solar-Hydro Based Renewable Energy System for Stabilization using Artificial Intelligence based Controller

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Abstract:- *Nearly every system element, including generation, transmission, and distribution as well as loads eventually, generates or consumes reactive power. Reactance, which can be either inductive or capacitive, contributes to reactive power in the circuit. This study introduces a solar-based renewable energy plan for analysis in a MATLAB/SIMULINK setting. The UPFC in the load line was coupled to the grid to construct the solar energy system. The technique was further hybridization using micro hydro technologies. A hybrid energy systems with a genetic algorithm-based compensating based on PI scaling was developed because it was discovered that the standard UPFC architecture was inefficient at stabilising the networks.*
Keywords: *Hybrid Renewable Energy System, UPFC, PI Controller, Genetic Algorithm*

I. Introduction

Due to the quick depletion of fossil fuels, there is an urgent need for alternative energy sources to meet the world's rising energy demand. The growing problem of global warming is yet another important justification for cutting back on our use of fossil fuels. Technology solutions for eco - accommodating generation will be crucial for the future of the power grid. Power from renewable energy energy sources, including wind, photovoltaic (PV) [1] , micro hydro (MH) [2] , biomass [3], ocean wave [4], geothermal [5] , and tides, is one of the renewable energy technologies [6].
The advantages of the aforementioned energy systems, such as supply security, reduced carbon emissions, improved power quality, dependability, and employment opportunities for the local population, are generally the main drivers behind their implementations. Hybrid configurations of two or more power generation systems, along with storage, can enhance system performance because RE resources are non - linear in nature.

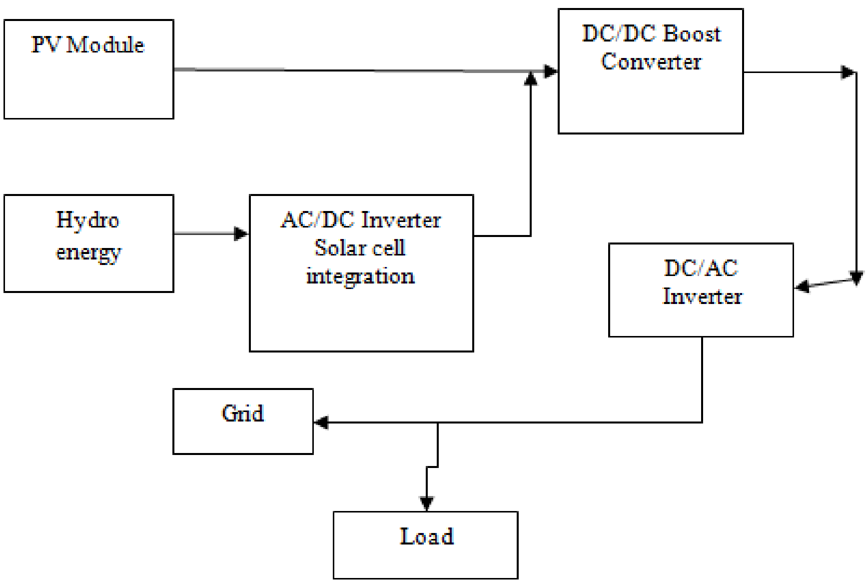

Figure 1 HRES System

Alternating current is produced, transmitted, distributed, and used to produce electrical energy (AC). Alternating current, however, has a number of drawbacks. One of these is the requirement for reactive power to be offered in addition to active power. It is possible for reactive power to lead or lag [11]. There is no additional need for reactive power in the transmission or distribution because the total power is made up of both active and reactive power. Nearly every system element, including generation, transmission, and distribution as well as loads eventually, generates or consumes reactive power. Reactance, which can be either inductive or capacitive, contributes to reactive power in the circuit. The large percentage of the loads are inductive and require lagging reactive power to be provided.

II. Literature review

(Z. Ali et al., 2018) [1] The grid voltage is typically monitored using phase-locked loop (PLL) synchronisation technologies. The dynamics of the RES grid side converter are directly impacted by the design and performance of PLL (GSC). The characteristics, design principles, and features of cutting-edge, PLL-based synchronisation algorithms are discussed in this work under grid settings that are normal, aberrant, and homophonic distorted. Following experimental evaluations of the chosen PLL algorithms in various grid scenarios, a comparison benchmark and selecting guide is provided. Finally, appropriate PLL tuning techniques are covered.

(Tani et al., 2015) [2] The focus of this paper's contribution is energy managing based on frequency approaches using the fluctuation power sharing between the load and the wind.

(Djebbri et al., 2020) [3]A fractional order MRAC control law is then developed to stabilise the voltage and current in the device. The proposed FO-MRAC control is particularly effective and robust even in the presence of clean renewable energy fluctuation and extra pressure, as demonstrated by numerically simulation studies.

(Sedo & Kasscak, 2018) [4]. This study aims to reduce phase current distortion of VSI and control power at grid as well as alternate existing power converting into network. A current control technique with correction for the third and fifth harmonic components is employed to reduce the current distortions.

(J. Ali, 2018) [5] The following section of the study builds a model of a coal-fired power plant before comparing the effectiveness of various compensation approaches in terms of the cost, efficiencies in terms of real energy losses, and performance capability in response time and reactive power. The trade-off between various approaches is then acknowledged in the article, and a collection of various techniques is then used to strategically plan the monitoring and control of techniques in relation to the requirements. In conformity with Italian legislation, a topology of this coordinate method of control is then designed.

(Ramos-Carranza et al., 2016) [6] In this work, a fix for the parallel resonance issue that may arise in real-world shunt Active Power Filter (APF) compensating applications is put forth. The suggested remedy is transforming the shunt APF compensation technique into a Shunt Hybrid Filter (SHF) arrangement. For this hybrid compensation scheme, a switched controllers based on a linear quadratic regulator (LQR) was created, keeping strict performance standards for both tracking filtered currents and draining harmonic ripple currents. Results from Matlab/Simulink® demonstrate an efficient and sound compensating mechanism that also lowers the required KVA ratings of the APF.

(Amiel et al., 2021) [7] This article describes a capacitor banks power-based method for effective voltage regulation. Distribution lines experience voltage instability when photovoltaic power systems and local grids are operating simultaneously. These voltage variations frequently exceed the permitted limits and result in monetary losses. The reactive power is created using a capacitor bank and applied at the load in the suggested technique. To enable the 2n equally scattered combinations, the capacitors are organized in a binary order of capacitances.
Researchers have turned their attention to a variety of energy sources, including solar, wind, hydroelectric, and others. If these devices are grid-integrated, Flexible Alternating Current Transmission Systems (FACTS) based on the Unified Power Flow Controller (UPFC) have the ability to control the power transfer, enhance transitory and dynamic stability, enhance the profile of the output power, and dampen oscillations in the power grid. Due to transient stress, the device must also manage the frequent current fluctuation. A hybrid solar-hydroelectric energy systems that is connected to the grid is suggested in the study. Changing the controlling pulses applied to the UPFC design can improve it. In the providing instructions, the harmonic level of the voltage and current level must be kept within bounds.

III. METHODOLOGY

A converter and transformer are used to link the large-scale solar power system to the grid. Power factor correction device UPFC is linked to grid to enhance the transitory voltage regulation of the large-scale solar system. The compensatory is suggested in order to improve the output parameters such as active power output and THD in current and voltage. This study gives a computational formula of hydroelectric power plants with a focus on the governors system model under various operating situations. The necessary formulas are embedded within the different locations that represent the different HPP components. By drag & drop the icons and entering the parameters, users could quickly design an HPP model.
According to Figure 2, UPFC is made up of two back-to-back GTO-based voltage source converters (shunt and series) connected by a single DC connection. The primary goal of a series converter is to generate an ac voltage Vc with

adjustable magnitude and phase angle as well as inject this voltage into a transmission network in series with the fundamental frequency while transferring real and reactive powers between its ac terminals via transformers connected in series. There has also been discussion of the different formulas used for the 14 bus system.

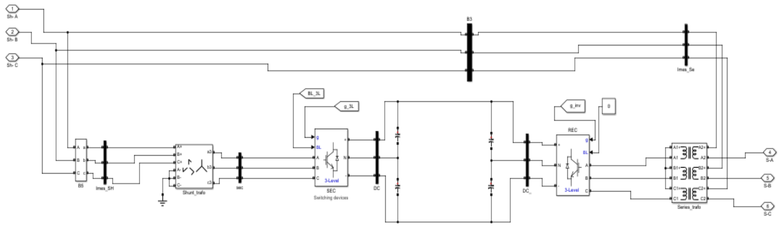

Figure 2 MATLB/SIMULINK Circuit of the Unified Power Flow Controller

Genetic Algorithm for Compensator Designing

The genetic algorithm approach uses two processes inside the general metaheuristic framework: I getting an initial set of solutions, and (ii) implementing an improved search that is guided by predetermined rules in order to produce new solution sets. In each step k of an evolutionary algorithms, the current state is represented as Sk S, where Sk stands for the set of solutions in step k and S for the solution space. This is a set-based technique.

A neighborhood N(Sk) is defined as all solutions arising from applying specific operators on the present solutions for each solution set Sk. From the vicinity N(Sk) of the current solution set, a candidate solution set C N(Sk) is chosen. The efficacy of the candidate solutions is then calculated or estimated in order to evaluate the chosen candidate solution set. Candidate solutions produce the solution set for step Sk+1 based on this evaluation. Up until a convergence condition is fulfilled, this process repeats. The general layout of a genetic algorithm within a metaheuristic framework is shown in Fig. 3.

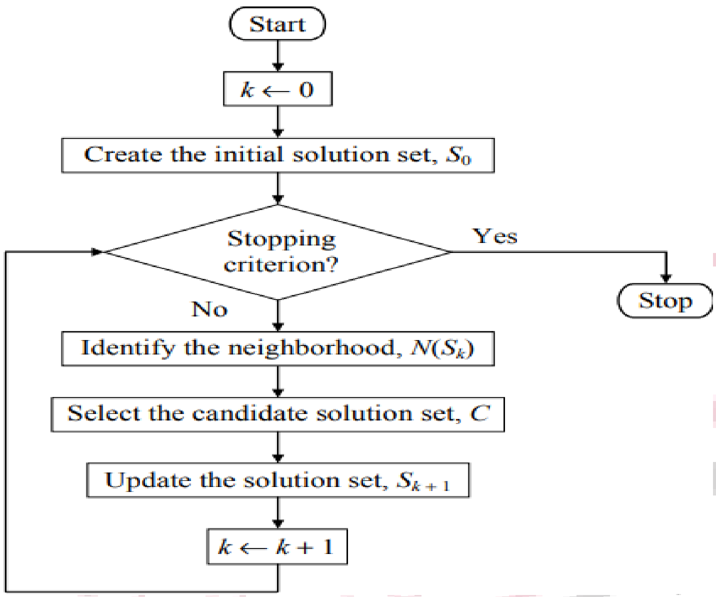

Figure 3 Genetic Algorithm Performance Flow Chart

The proposed genetic algorithm is started by randomly generating an initial population of binary coded individuals (V, I, frequency, and phase), where each individual represents a potential solution of power distribution parameters. The machine learning model is deliberately developed for power factor correction and reactive power balancing (Active and reactive power). Every member of the existing population is assessed for J, after which a foundation for the biased selection process is formed. Through a ranking mechanism, the objective values acquired for each person are converted into fitness values. The likelihood that an individual will pass on genetic information to succeeding generations increases with fitness. The next generation will be made up of descendants from chosen parents. Standard genetic algorithms use crossover and mutation to replace the existing population with offspring, whereas in the proposed genetic algorithms, the parents are chosen based on fitness value and the best parent chromosome is retained. By trying to compare the fitness values of the parents and the children, the best stings will be passed down to the following generations.

The GA comes to an end when it reaches a predetermined maximum number of generations or when the goal function's value, which is below a threshold, stays the same for a predetermined number of iterations. While the lower-level optimization simulates the network operator's response to the outages obtained at the higher level, the upper-level optimization finds a set of concurrent outages in the power system (frequency and THD levels). The system operator responds by figuring out how to operate the electricity system best under a situation. The only difference in the compensator's architecture is the device's controls.

IV. RESULT AND DISCUSSION

Case 1: Grid-Integrated Solar PV System with UPFC Powered By Conventional PI Controllers

The system in question is powered by solar energy and further integrated with the grid using UPFC converters that are controlled by PI controllers. Additionally, waveforms for voltage, current, active power, and power factor have been examined.

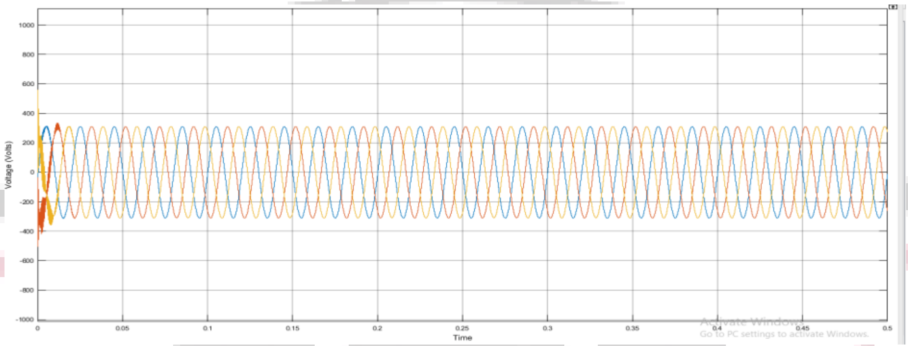

Figure 4 Voltage In Transmission Line In The Grid Connected System With UPFC Having PI Controlled Electronic Converters

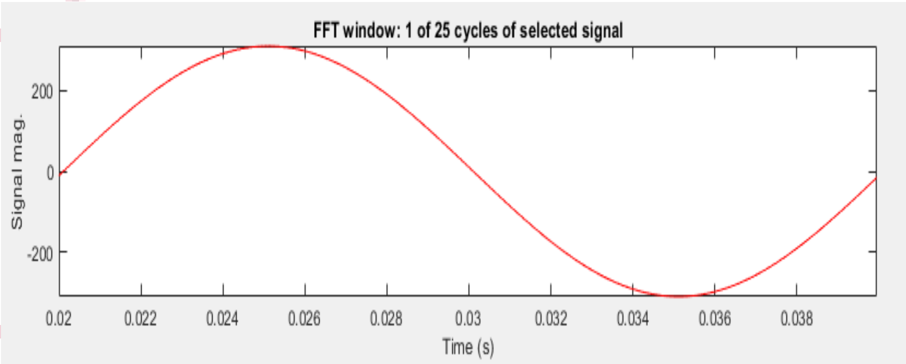

Figure 5 FFT Analysis Of Voltage In Transmission Line In The Grid Connected System With UPFC Having PI Controlled Electronic Converters

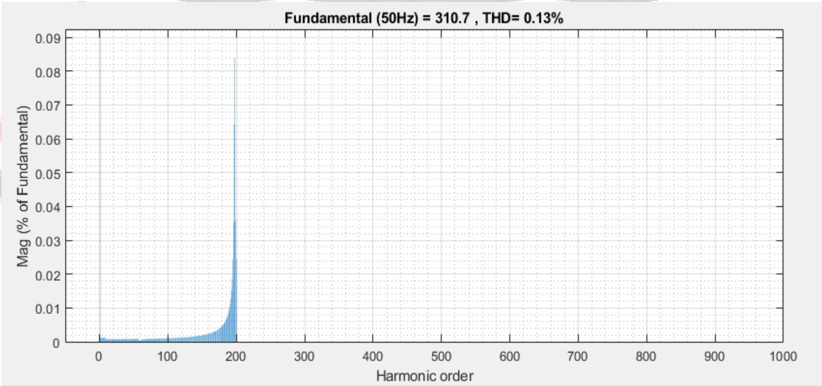

Figure 6 THD% Of Voltage In Transmission Line In The Grid Connected System With UPFC Having PI Controlled Electronic Converters

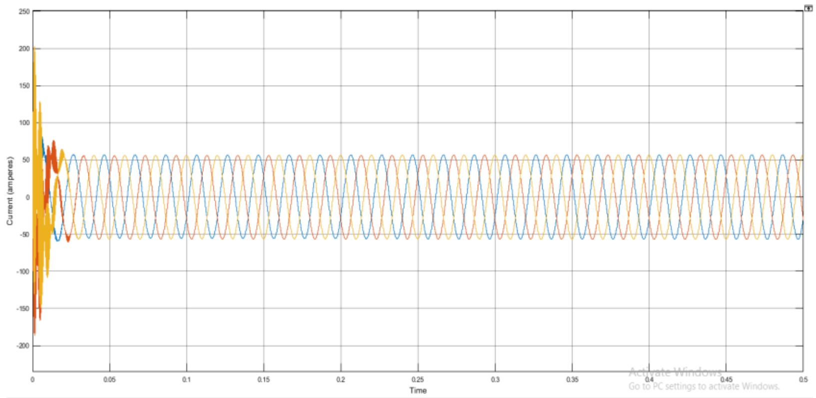

Figure 7 Current In Line In The Grid Connected System With UPFC Having PI Controlled Electronic Converters

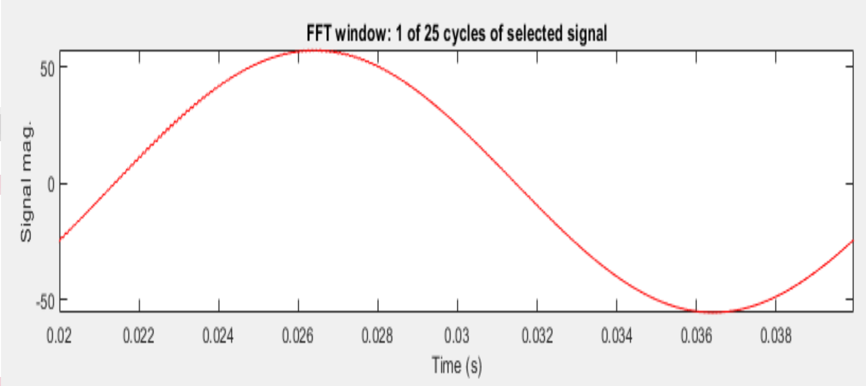

Figure 8 FFT Analysis of Current In Line in The Grid Connected System With UPFC Having PI Controlled Electronic Converters

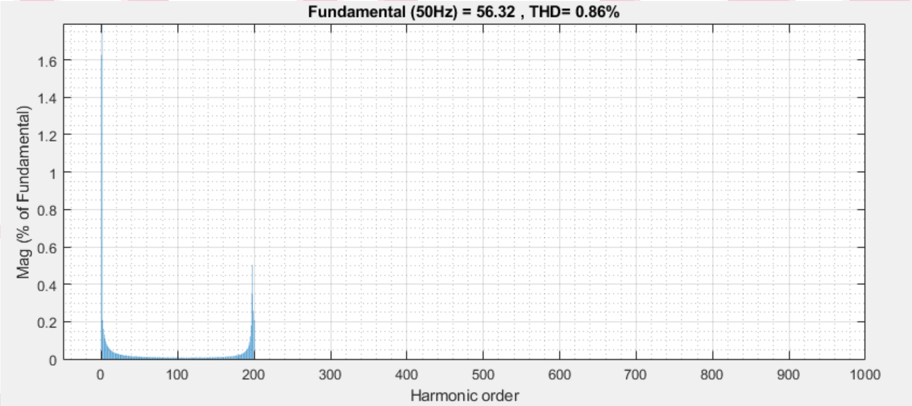

Figure 9 THD% of Current In Line In The Grid Connected System With UPFC Having PI Controlled Electronic Converters

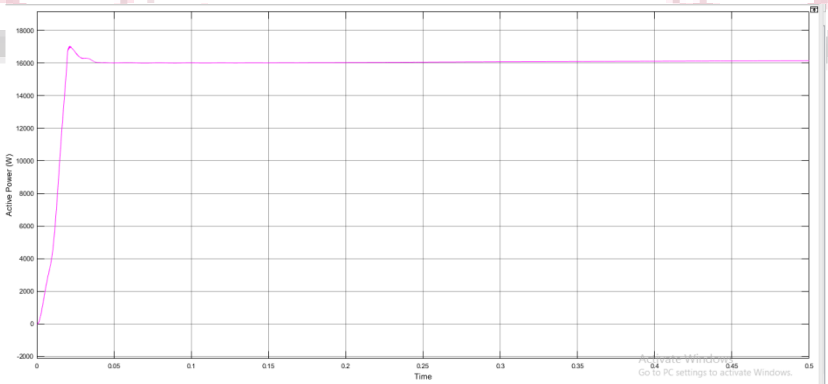

Figure 10 Active Power Available In The Grid Connected System With UPFC Having PI Controlled Electronic Converters

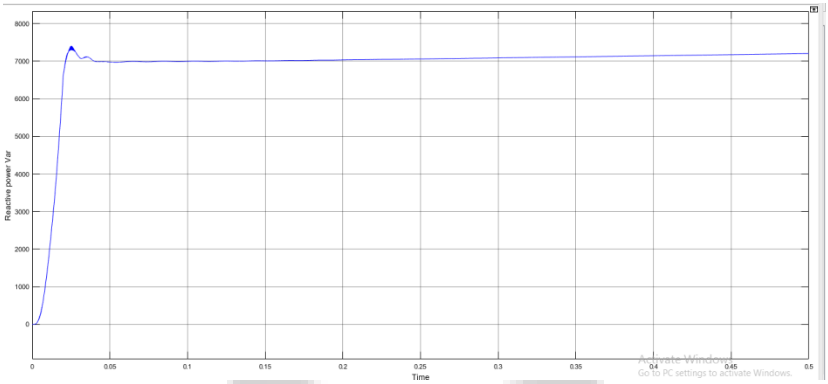

Figure 11 Reactive Power Available In The Grid Connected System With Upfc Having Pi Controlled Electronic Converters

The aforementioned waveforms display the voltage, current, active power, and reactive power outputs of a system with an in-line UPFC that is powered by PI-controlled converters. It has been determined that the voltage output will be close to 310 volts. It was discovered that the current was roughly 56.32 Amperes, with an active power output of 16130 Watts and a reactive power output of 7204 Volts.

Case 2: Grid-integrated hybrid solar PV/hydro system with UPFC powered by conventional PI controllers

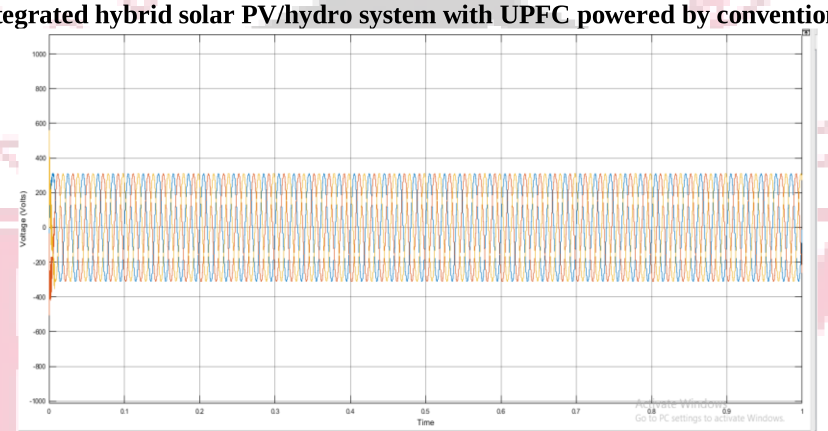

Figure 12 Voltage In Transmission Line In The Grid Connected Hybrid System With UPFC Having PI Controlled Electronic Converters

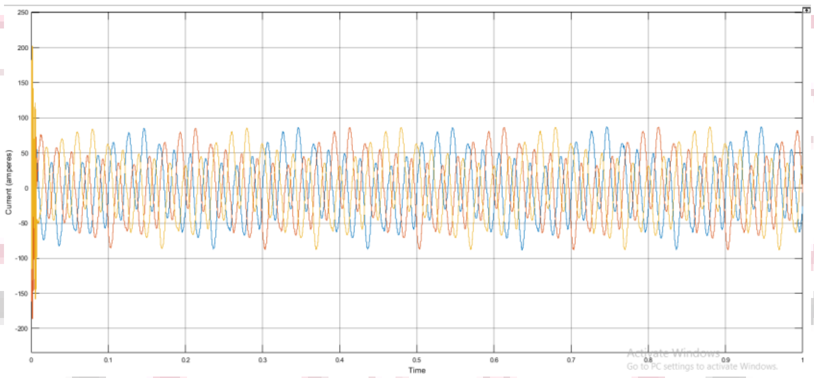

Figure 13 Current In Transmission Line In The Grid Connected Hybrid System With UPFC Having PI Controlled Electronic Converters

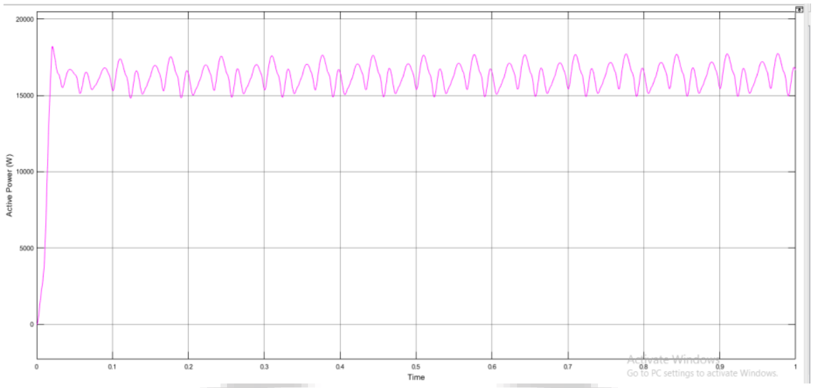

Figure 14 Active Power in transmission line in the grid connected hybrid system with UPFC having PI controlled electronic converters

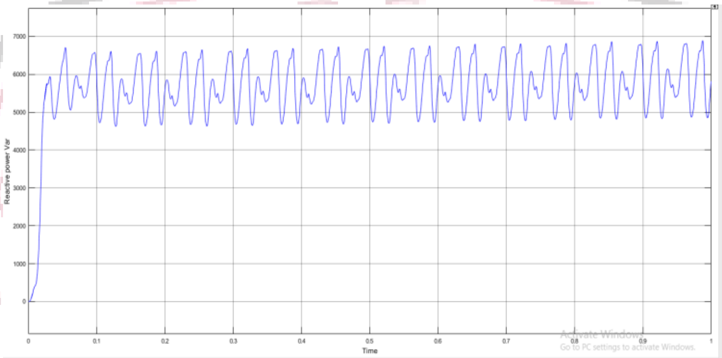

Figure 15 Reactive power in transmission line in the grid connected hybrid system with UPFC having PI controlled electronic converters

After being connected to the solar PV system, the hydroelectric power system's dynamic nature has been shown to lead to instability in the load line. It was observed that the traditional UPFC architecture using PI controllers did not automatically adjust to changing output parameters. As a result, the micro hydropower system was constructed with a compensating device and an optimising control.

Case 3: Genetic Algorithm-Based PWM Generation For Power Optimization Management Of The Compensator In A Hybrid Energy System With Proposed PI Scaling

The system in this instance is modeled with solar energy and a power flow compensator that has two conversion powered by PI scales, genetics algorithm-based PWM generating, and is further connected with the grid. Additionally, waveforms for voltages, current, active power, and reactive power have been examined.

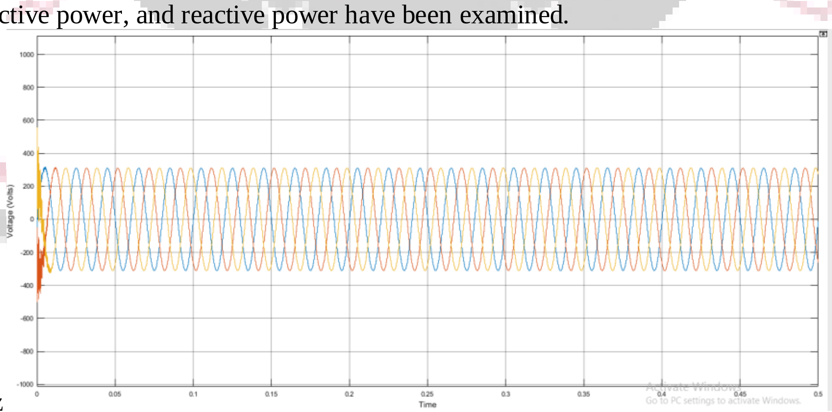

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Figure 16 Voltage in the transmission line in Hybrid Energy system with proposed PI scaling Genetic algorithm based compensator

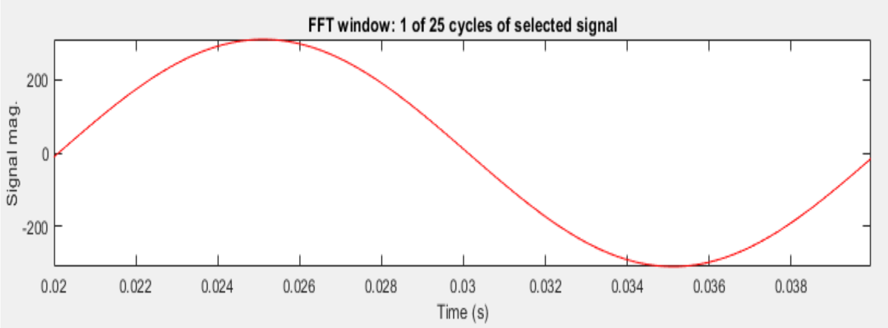

Figure 17 FFT analysis of Voltage in Hybrid Energy system with proposed PI scaling Genetic algorithm based compensator

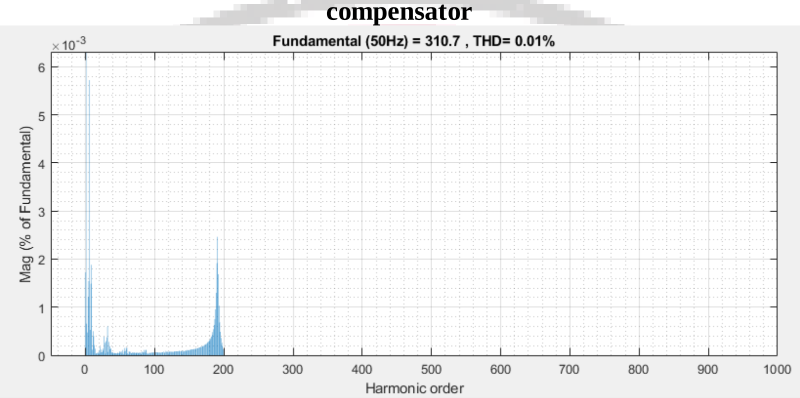

Figure 18 THD% of Voltage in Hybrid Energy system with proposed PI scaling Genetic algorithm based compensator

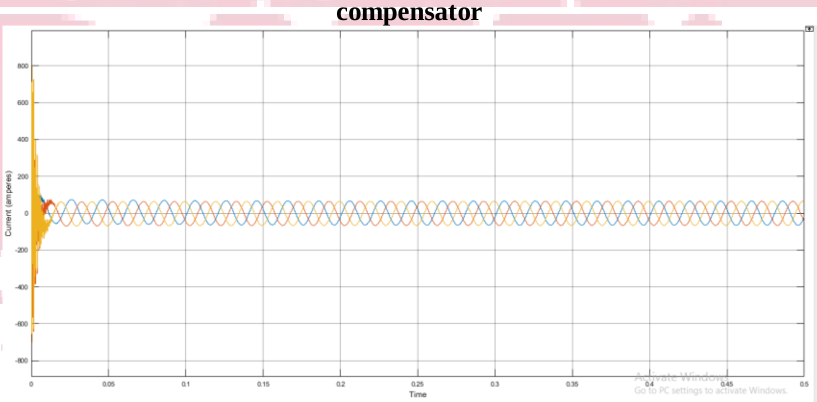

Figure 19 Current in Hybrid Energy system with proposed PI scaling Genetic algorithm based compensator

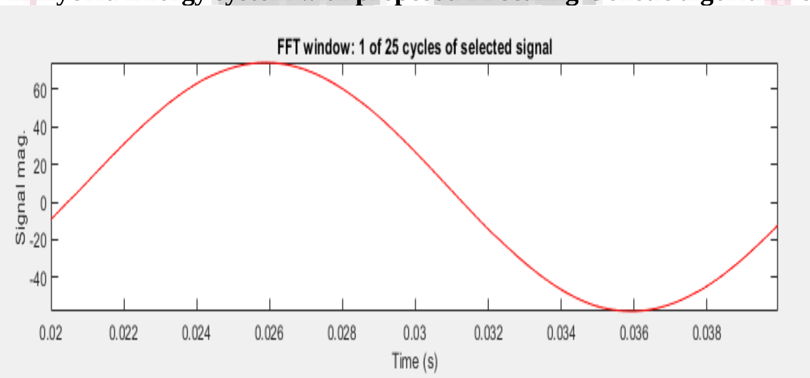

Figure 20 FFT analysis of Current in Hybrid Energy system with proposed PI scaling Genetic algorithm based compensator

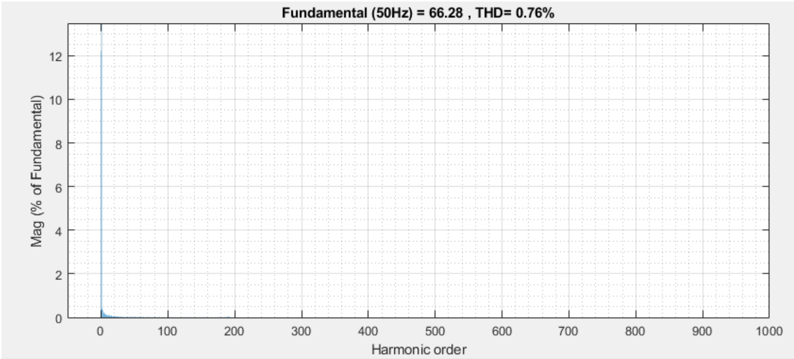

Figure 21 THD% of Current in Hybrid Energy system with proposed PI scaling Genetic algorithm based compensator

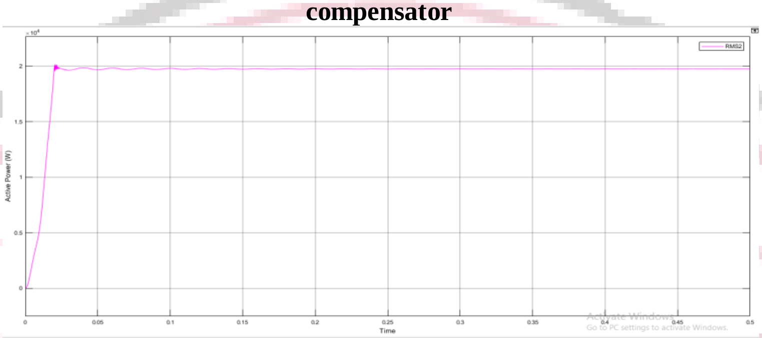

Figure 22 Active power available in Hybrid Energy system with proposed PI scaling Genetic algorithm based compensator

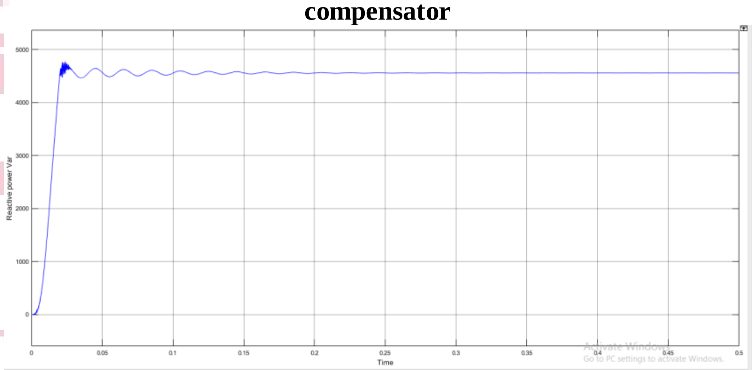

Figure 23 Reactive power available in Hybrid Energy system with proposed PI scaling Genetic algorithm based compensator

V. Conclusion

In this study, a solar-based renewable energy scheme is introduced for examination in a MATLAB/SIMULINK environment. The solar energy system was created by coupling UPFC in the load line to the grid. The micro hydro technology further hybridized the process. Since the typical UPFC design was shown to be ineffective at stabilizing the network, a hybrid energy system with a genetic algorithm-based compensation based on PI scaling was created. The major conclusions were as follows:

- The converter is controlled by a suggested controllers that is confined by a crow search algorithm, and the active power output of the system has increased to 19760 W from 16130 in systems with UPFC controllers regulated from PI controllers.
- The converter is controlled by a suggested controllers that is confined by a crow search method, and the active power output of the system has increased to 19760 W from 16130 in systems with UPFC controllers regulated from PI controllers.
- The metaheuristic GA algorithm optimized in a manner that the distortion level in the output electrical parameters is also reduced The voltage output distortion level from the solar energy system was found to be 0.01% which is less than 0.13 % of the system having UPFC regulated from PI controllers.
    - Using the suggested controllers, the current distortions level decreased from 0.86 percent in the solar system to 0.76 percent.
    - The system is connected with the electricity grid network as well. 310 Volts are being kept as the line voltage. The output of reactive power has also decreased. Additionally, the algorithms has shown to be more effective in compensating for reactive power.

According to the summary above, the solar system has been optimized to drive loads with increased terminal active output power. Less distortion in the voltage was made possible, and the current output's THD level also decreased.

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