Analysis of Solar-based Renewable energy System with Unified Power Flow Controller

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Abstract **–In this paper, we analyse a solar-based renewable energy system in a MATLAB / SIMULINK environment. The solar-plant was implemented with the help of the grid development with Unified Power Flow Controller in the load line. Micro-hydro technique was also incorporated into the system. The UPFC and its controllers are searched for on the system. To regulate line control, the suggested technique employs a genetic algorithm. According to the findings, AI is efficient in achieving the hybrid system is composed of the UPFC control and in driving loads to their terminal including superior real power. The available voltage was minimum &disorganized, and the THD in the current output was reduced as well.**

Keywords: **hybrid system, UPFC, Genetic algorithm, PI controller, micro hydro system, solar PV system**

I. INTRODUCTION

Electricity is necessary in a modern, civilized society. Electricity demand rises every year as urban and technological innovation progresses. Advancement of power generation and electric power transmission systems of power grids are essential solutions for meeting electricity consumption. Environmental variables, on the other hand, limit the scope for such expansion. Concerns about global rising temperatures, environmental impacts caused by the use of fossil fuels, and fossil fuel depletion are also growing. As a result, traditional power grid systems are being supplemented with new and renewable energy systems such as wind and solar power. However, the weather has a significant impact on the power creation of novel and renewable energy systems. Furthermore, the erratic power supplies of new and renewable energy systems have negative consequences for power grid systems, such as voltage, frequency, and transient state instabilities.As an outcome, the overabundance of electricity that these mechanisms can produce is constrained. Traditional power grid systems suffer from the following issues, which reduce their efficiency: (1) low transmission line utilisation [5] and (2) load unequal distribution due to control limitations. To address these issues, one approach is to use a flexible alternating current transmission system (FACTS), which would be a power electromechanical device, in conjunction with other stationary machinery to maintain one or multiple AC transmission system features to enhance controlling ability and power circulation capability.

A network that transmits electricity at high voltage, a unified power flow controller (UPFC) is electrical device that provides fast-acting reactive power compensation. It generates current with a pair of three-phase controllable bridges and injects it into a transmission line via a series transformer. In a transmission line, the control system can control both active and reactive power circulation.The mostly advanced FACTS option is the Unified Power Flow Controller (UPFC), which controls the transmitting system's active and reactive power independently. The UPFC is made up of a static synchronous compensator (STATCOM) and a static synchronous series compensator (SSSC) that are connected by a single DC voltage link.

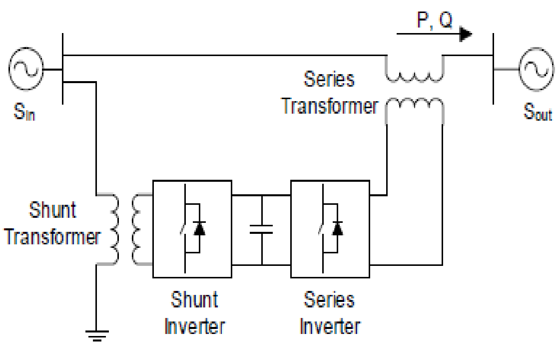


Figure 1 Conventional UPFC

A traditional UPFC is made up of a STATCOM and SSSC with a common DC link capacitor. The standard UPFC system, that consists of two transformers and two power converters, is depicted in Figure 1. The series inverter is a type of power converter that regulates power circulation and enhancing stability analysis in the transient state by regulating voltage levels in the stable state. The parallel inverter, on the other hand, needs to compensate for reactive power and distributes the power needed by the series inverter. Even so, since a huge portion of transmission-line current passes via them, the series transformer and inverter are complex and costly [23]. As a result, despite their excellent performance, the use of traditional UPFCs has been restricted.

II. LITERATURE REVIEW

(Sen et al., 2020) [1] This article performs a detailed analysis of the performance between two different Distributed Power Flow Controller (DPFC) models. The first type is the normal distributed power flow regulator using batteries and the second type is achieved by using an additional three-phase converter instead of batteries. The system in question is a hybrid solar wind generation system integrated into the grid. The effect of the two models on the hybrid system is examined in detail using the results of the MATLAB / Simulink platform. A comparative analysis of two different types of DPFC models is performed. It is observed that the inrush current for the three-phase DPFC mode is higher (i.e. 20 amps) than the DPFC with batteries.

(Saberi et al., 2018) [2] A DG unit, which consists of a Photovoltaic system, a DC-DC and DC-AC converter, is modelled and managed to act like a traditional synchronous machine. Then, to stabilise the DG unit in the micro - grid surroundings, a lowest expected UPFC system is illustrated and managed by an innovative optimal nonlinear control strategy. Vibrations in the system could be effectively dampened with the proposed scheme. The envisaged approach is appropriate to typical UPFCs in power systems, despite the fact that it is implemented to a limited UPFC framework in a micro - grid surroundings. The innovative model was applied for the very first time and experimental studies will be managed to carry out to illustrate the performance of the control framework.

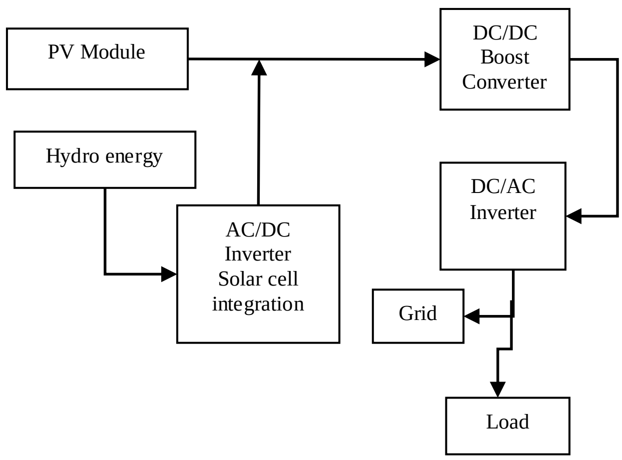
(Devassy & Singh, 2018) [3] In this work a new technique based on adaptive filtering is proposed for the control of a three-phase universal active power filter with a photovoltaic solar panel integrated in its DC bus. Two adaptive filters along with a zero crossing detection technique are used to extract the amplitude of the active fundamental component of the distorted load currents, which is then used in estimating the reference signal for the active bypass filter. This method uses a simplified numerical calculations to retrieve the active compound from the three stages. In the incident of voltage instability and rises, the active series filtration monitoring, which is predicated on the symmetric validated model, controls the load voltage and maintains it in phase with the voltage at the common coupling point. The system's evaluation is performed in the lab on an exploratory process under a wide range of developmental conditions, including lowering and ramping up voltage at the common coupling point, load asymmetry, and different versions in solar radiation.

(Shahriar et al., 2018) [4] The main objective of this article is to investigate the real-time performance of the connected UPFC coordinated PSS power system which is exposed to low frequency vibrations. The support vector regression model estimates the PSS parameters coordinated with UPFC in real time. The performance of the proposed technique is tested for three different load conditions. Furthermore, the results obtained are compared with the fixed gain PSS coordinated with the UPFC. The analysis of the eigenvalues and the time domain representation of the system parameters show that the proposed controller outperforms the conventional controller in all respects. It can also be seen that the time taken by the SVR model to set the controller parameters is less than two cycles of a 60 Hz network.

(Nahak et al., 2021) [5] In this work an adapted fractional IPFC RGWO is proposed and a SMIB system with gradual and random variations in solar power generation is considered with several case studies. In case I, it was observed that a sudden increase in SPV penetration improves the vibrations of the system and shifts the eigenvalues to the right half of the complex plane. The proposed regulator works much better than the others in damping vibrations. In case II there is a random variation of the SPV generation and a detailed analysis of the reaction time. A detailed analysis showed that the presented IPFC damping effect is, in contrast to the fractional and conventional PSO and GWO regulation controls, very robust against fluctuations in solar radiation.

III. METHODOLOGY

The large solar plant is connected to the grid via a converter and a transformer. To improve the transient voltage stability of the large solar plant, the UPFC reactive power compensation system is connected to the grid. The compensator is used to further improve the output parameters such as voltage THD, current THD and active output power.

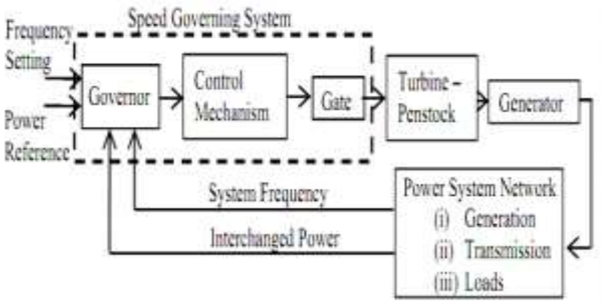


Integration with hydropower technology

Micro Hydroelectric Power (MHEP) is a type of hydroelectric power plant capable of generating up to 100 kW of electricity from the water flow [1]. It's a great way to use renewable energy (RE) from small streams and rivers. It is transforming into a clean, attractive and very popular globally popular renewable energy source that has some advantages over its counterparts in large hydroelectricity. Renewable DGs are relatively small compared to other generations and / or conventional energy sources in the network. Their integration into the existing electricity grid infrastructure can lead to instability of the interconnected grid due to the irregular and intermittent nature of power generation. Therefore, the list of problems encountered while integrating MHEP schemes into the network is as follows:

- Fluctuations and frequency regulation.
- Increase in voltage and reverse power flow.
- Voltage imbalance.
- Fluctuations and voltage regulation.
- Fluctuations and regulation of the output power.
- Power factor correction (PF).
- Harmonic distortion.

The performance of the drive system is affected by the dynamic properties of turbines with hydraulic regulators during and after each malfunction, such as the occurrence of a fault, the failure of a transmission line or a rapid change in load. Accurate modeling of hydraulic turbine controllers is essential for characterizing and diagnosing the system's response to an emergency. Simple hydraulic systems with proportional-integral-differential and proportional-integral controllers are modeled. This model examines their transient behavior for disturbances through simulation in Matlab / Simulink.



Internal operation of HTG system in hydro power turbine

FThe figure shows a functional diagram of the control-turbine-hydraulic system connected to an electrical network. The main source of electricity supplied by utilities is the kinetic energy of water, which is converted into mechanical energy by the main engines. The electrical energy to be supplied to the end user is then converted into mechanical energy by the synchronous generators.

$$M\frac{dO\omega}{dt} = P_m - P_g - D\frac{d6}{dt}$$

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

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

$$A = \frac{\bar{T}Y_S + \bar{T}Y_u}{Y_S}$$

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

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

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

And generator current is:

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

The proposed genetic algorithm, which was developed specifically for reactive power correction and reactive power compensation, is initiated by the random generation of an initial population of binary encoded individuals (V, I, frequency and phase), with each individual which represents a possible solution for the grid parameters (active and reactive power). For every participant in the existing estimate is given a J rating, which serves as the foundation for the biassed screening process. A classifier is used to map the target values acquired for each participant into best fitness value. The increased an individual`s fitness, the more likely he is to pass on genetic codes to succeeding generations. Youngsters of chosen family members will make up the next generation. The conventional genetic algorithm substitutes the overall population with infant via intersection and genetic variation, whereas the envisaged genetic algorithm selects family relying on best fitness values and the best familial chromatids by going to compare the parameter estimates of children and parents., the best bites would go to succeeding generations.

RESULTS

The research relies on the evaluation of a solar energy system using the MATLAB / SIMULINK software. The framework is made in collaboration with the network system to increase effectiveness. The level of disturbance for the voltage and current waveforms was derived without taking into account spontaneous transients at boot up. This methodology is suitable that integrates a hybrid hydroelectric as well as solar power generation system with the distribution grid. The hybrid system's charging capacity is around 20 kW. The hydro-electric system's weakness is its inability to regulate voltage and frequency.

As a result, a dependable technique for maintaining a steady voltage and frequency irrespective of load and load categories is required. In the following two cases, the solar/hydraulic system is covered in this section.

Case 1: Evaluation of conventional UPFC procedure in a solar-based system motivated by PI regulators.

In this scenario, the model is predicated on solar energy and UPFC, including the converter configurations managed by a PI Control strategy and then incorporated into the grid. The shapes of voltage, current, actual power, and reactive power too were looked at.

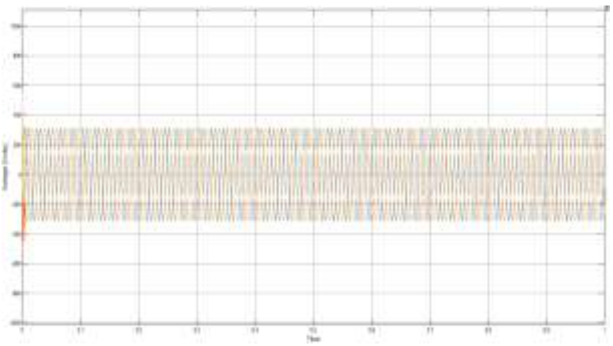


Figure 3: Transmission line voltage inside a grid linked structure with UPFC electronic converters controlled by PI.

The three-phase voltage exists in the line including solar system and UPFC with PI controlled control is shown in Figure 3. The system is really not incorporated with differing micro hydro energy sources in this case.

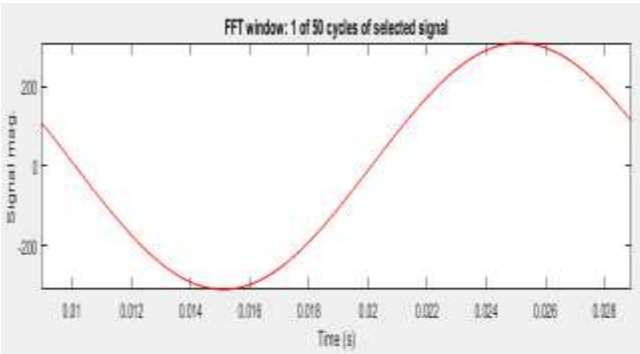


Figure 5: Fourier transform assessment of power transmission voltage in a grid-connected system with UPFC and PI-controlled electronic commutation

The Fourier transform assessment of the three phase System voltage for every cycle in the photovoltaic only system is illustrated in Figure 5, which is analysed with a control system motivated by PI oriented regulators.

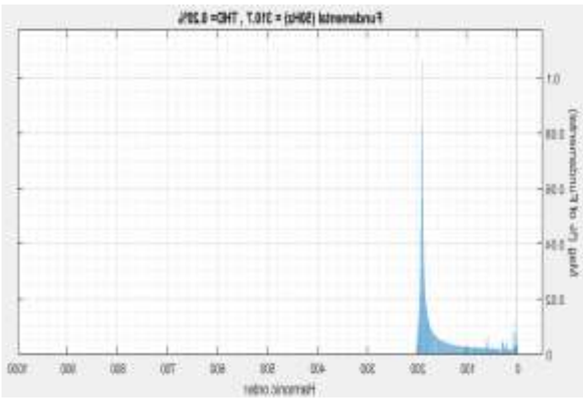


Figure 6: THD percent of voltage in transmission line in grid-connected system with UPFC power commutation managed by PI

In a photovoltaic system with UPFC driven by a PI-based conventional product, the THD percent is determined in the software and emerges out to be 0.20 percent in the voltage waveform, as shown in figure 6.

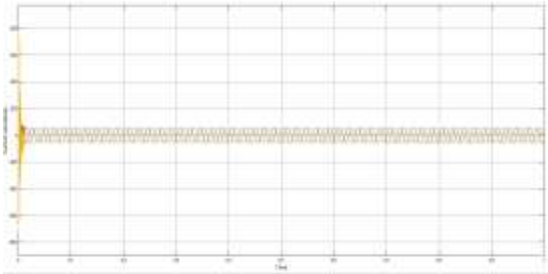


Figure 7: Current in line in a grid-linked system with UPFC electronic commutation managed by PI

The figure represents the three phase current available in the line having solar system and UPFC with PI regulated control. Here the system is not integrated with varying micro hydro energy. The further analysis is carried on to calculate active and reactive power outcomes from this system.

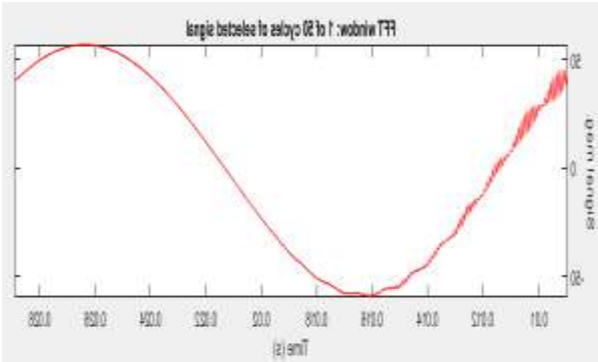
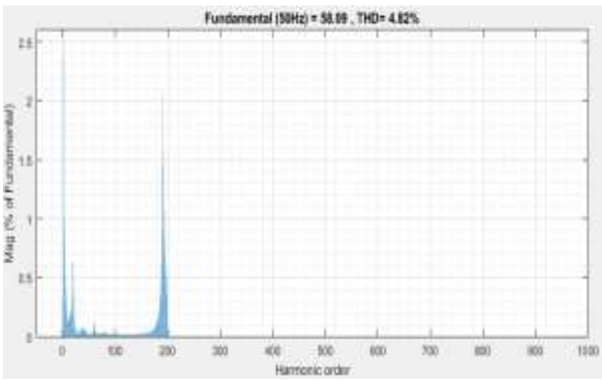


Figure 8: Fourier transform Assessment of Current in Line in a Grid-Connected System with UPFC Electronic Converter topologies Managed by PI

The figure 8 depicts the FFT analysis of the three phase AC current for each cycle in the solar only system which is analyzed with controller driven by PI based regulators which is used for THD% determination.



system with UPFC having PI controlled electronic convertersThe THD% is calculated in the software which comes to be 4.82% in current waveform in solar based system having UPFC driven by PI based standard approach which is represented in figure 8.

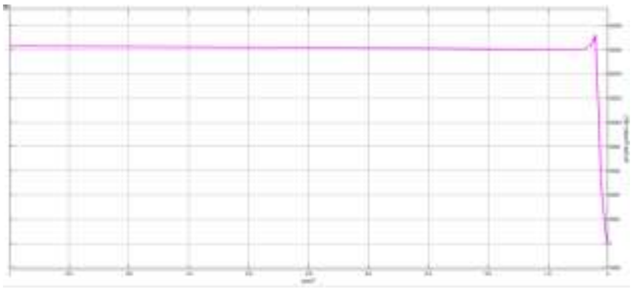


Figure 9: Active power available in the grid linked system with UPFC including PI managed electronic converters

Figure 9 has the result of active power present in solar framework where the UPFC is brought to use and its controllers are designed with standard PI regulators to regulate power in the line.

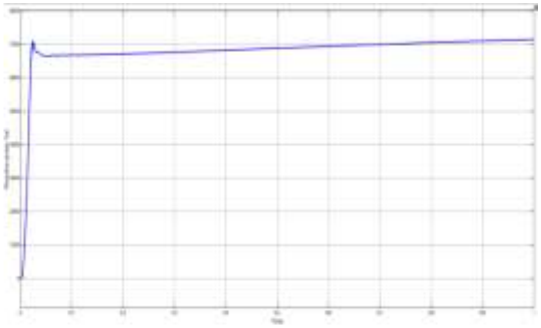


Figure 10In a grid linked framework with UPFC and PI-controlled electronic compensators, reactive power is produced.

Figure 10 shows the result of the reactive power available in the solar system where the UPFC is used and whose controllers are designed with standard PI controllers to regulate the power in the line.

The voltage outcome, current outcome, actual output power, and reactive power in the framework with sequenced UPFC driven by PI controlled inverters are shown in the output waveform earlier in this section. The outcome voltage is estimated to be around 310 volts based on this. Including an active outcome power of 16.3 KW and a reactive outcome power of 7145 Var, a current of approx 58 amperes was ascertained.

Case 2: A comparison of the consequences of PI regulator-driven UPFCs and UPFC controllers with GA-based regulatory standards on the procedure of UPFCs throughout the incorporation of micro hydro energy with solar systems.

The arrangement in this case is demonstrated with solar energy with the integration of a micro hydroelectric power plant with variable input and the system is equipped with a power flow compensator, which has two converters, which are controlled by a UPFC controller with an approach of GA -based regulation for Pulse width modulation formation is used to stabilise throughput and is then incorporated into the system. The framework with the UPFC benchmark piloted by the PI controllers was used for the comprehensive study. The voltage, current, active power, and reactive power curvatures were also studied.

The benchmark UPFC proposal with PI controller was not taken into account to take into account the different output parameters. The solar-powered hybrid hydroelectric micro system was then restructured with an optimization control system for a compensation equipment.

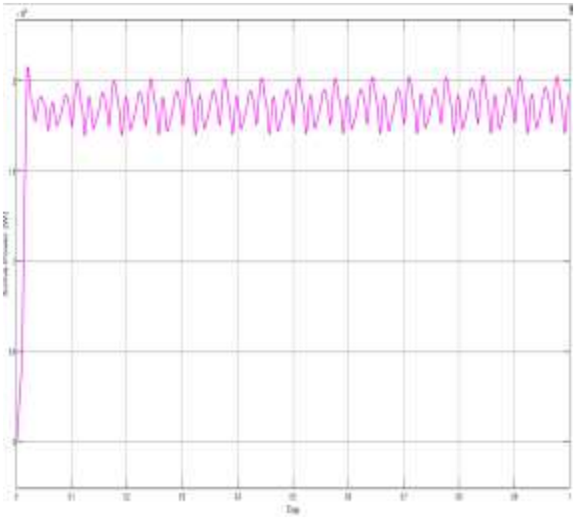


Figure 11: Active power measurement in the line in hybrid system where standard UPFC with PI regulators is installed

The figure 11 shows the active power output from the system having UPFC driven by PI regulators for overcoming the effects of hydro energy system in the hybrid system

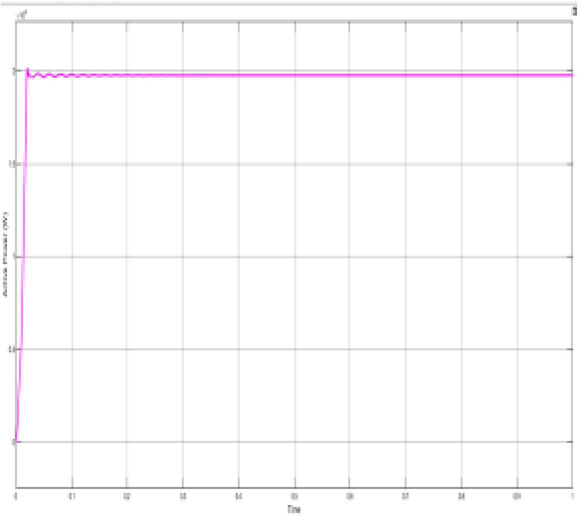


Figure 12: Active power measurement in the line in hybrid system UPFC with GA based regulatory approach is installed

The figure 12depicts the current output power from a hybrid system with UPFC driven by PI regulators to overcome the consequences of the hydropower generation structure, which is stabilized at 19760W.

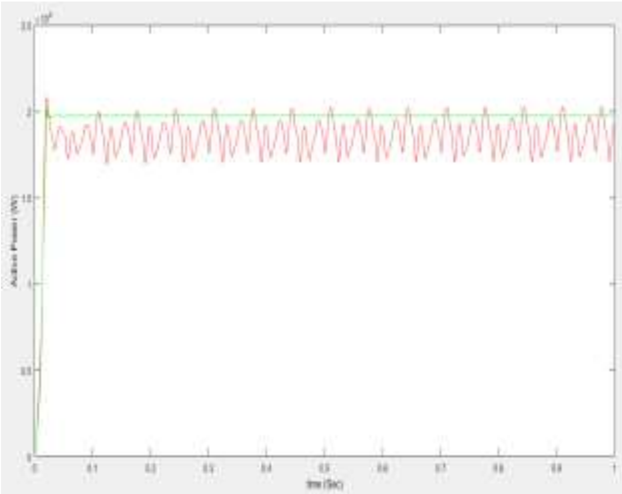


Figure 5.12: Comparative analysis of active powers in the hybrid systems utilizing two controllers

The green diagram is the active power output of the system with UPFC, whose output is controlled by a GA-based regulation approach and as can be seen from the comparison, has the highest stabilization compared to other UPFCs with standard PI controllers, which are subject to fluctuations. The red waveform of the proposed project becomes more variable due to the variation of the input speed fed to the hydroelectric generators during the simulation, which is exceeded by the regulator proposed in the green graph..

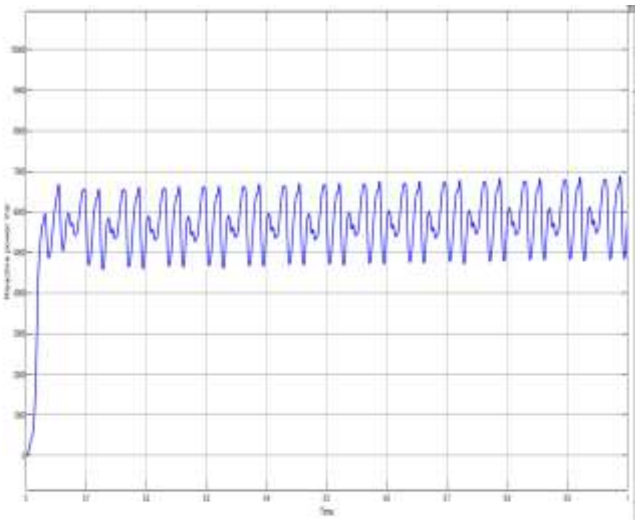


Figure 5.13: Reactive power measurement in the line in hybrid system where standard UPFC with PI regulators is installed

The figure 5.13 shows the active power output from the system having UPFC driven by PI regulators for overcoming the effects of hydro energy system in the hybrid system

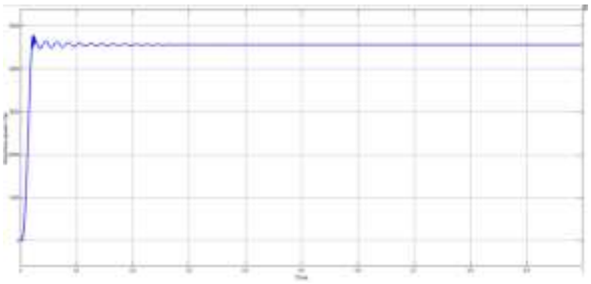


Figure 5.14: Reactive power measurement in the line in hybrid system UPFC with GA based regulatory approach is installed

The figure 5.14 shows the reactive power output from the system having UPFC driven by PI regulators for overcoming the effects of hydro energy system in the hybrid system and is stabilized to 4558 Var

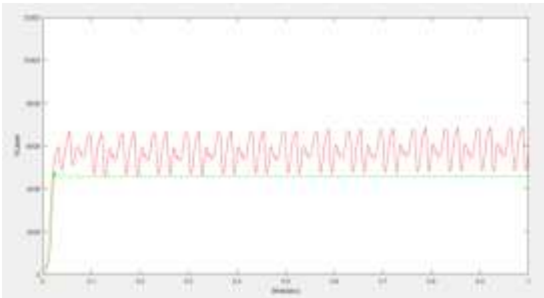


Figure 5.15: Comparative analysis of reactive powers in the hybrid systems utilizing two controllers

The green graph is the reactive power output of the system with UPFC, the output of which is controlled by a regulatory approach based on GA, and shows, as the comparison shows, the maximum stabilization compared to other UPFC with regulatory standard PIs which are subject to fluctuations. The green waveform of the proposed design also has a smaller amplitude, which makes the line more stable than the other system with the red graphics output.

Table 5.2: Comparison of distortion percentage values

S.no	**Parameters**	**Hybrid system driven by UPFC with standard PI regulators**	**Hybrid system with proposed GA based regulatory approach for UPFC**
3	**THD% in voltage**	1.48 %	0.28 %
4	**THD % in current**	5.90%	4.90%

IV. CONCLUSION

In this research work, we use MATLAB and SIMULINK to model a photovoltaic RES (renewable energy system). The solar power plant was built as component of a grid expansion that included UPFC in the load line. Micro-hydro technique was also incorporated into the system. It was discovered that the benchmark UPFC design could not stabilize the framework, so a hybrid energy system with a compensator based on an envisaged genetic algorithm from AI technology was created. The following are the major observations:

• In a Genetic algorithm depending compensated system, the active output power of the inverters has been expanded to 1,760W, that is controlled by a control system, which is decided to offer by 16600 in a system with incorporated 'UPFC-regulated PI controller is, and is also stabilized.

• The GA algorithm has been tweaked to mitigate the impact of electrical output parametric disturbance. .

• Employing the controller, the current deformation level is minimized from 5.90 percent to 4.90 percent.

•The framework is also wired into the power grid. The mains voltage is maintained at 310 v. Reactive power was reduced as well. In terms of compensators, the methodology has also proven to be more efficient.

• The solar/hydraulic system is proficiently meant to work loads with enhanced active output power at its door, from the abovementioned description. The obtainable voltage was less irregular, and the total Harmonic distortion in the output current was reduced as well.

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