A Comparative Study of UPFC Controlled with Programmable Integral Controller and RL Controls

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Abstract: *Fossil fuels, their byproducts, and trash from inorganic or fossil sources are not considered to be sources of renewable energy. Additionally, they can improve human health as research has shown that, in comparison to fossil fuels, they do not produce as many health issues due to their low GHG emissions. In order to achieve the independent management of the active power and reactive power sent concurrently through the line, the UPFC integrates the operations of numerous FACTS devices and is capable of performing voltage regulation, series compensation, as well as phase angle regulation at the same time.The assessment of a wind energy system and a diesel system operating load requirements in a low voltage line is the primary focus of the research. To increase its efficiency, the system is designed to work with the grid system.*

Keywords: Renewable Energy Sources, Hybrid Energy System, GHG, UPFC, FACTS

I. Introduction

Many related organizations have promoted vigorous investigations for more effective, environmentally friendly power plants using cutting-edge technology due to certain environmental issues. Both clean fuel technologies and novel energy are actively studied and researched as protection of the environment concerns rise. In fact, costs associated with environmental and social issues, the price of fossil fuels, and the price of renewable energy are all trending in the opposite directions, and the economic and policy frameworks required to support the wide adoption of sustainable markets for RES are changing raProgrammable integral dly. It is obvious that the new renewable energy regime will account for the majority of the energy sector's future growth [1,2]. There are many potential uses for and benefits of renewable energy.Since they generate little to no GHG emissions, they can enhance the quality of the environment. Because they are present practically everywhere on Earth and are a more dependable energy source than fossil fuels, they distributes energy fairly and address issues with energy security and energy poverty.

The primary drawbacks of RES are their greater initial cost, which can be prohibitive for consumers and excess, as well as the expense of storage systems, that is also rather high. Additionally, because renewable energy depends on weather, prolonged periods of unexpected weather may result in an energy shortage.

The transmission network is currently being stressed by the demand for electricity, which is steadily rising. Due to the financial and environmental realities of the new building center and the transmission circuit's complexity, the demand for electric power is rising quickly. To lower the price of electricity and increase supply dependability, the majority of the world's electrical infrastructure is heavily networked. Advantages of transmission interconnection include a diversity of load options, source accessibility, and cost-effective power delivery to loads.

The most efficient Flexible Alternating Current Transmission System (FACTS) device for maximizing the capacity of connected power systems to transfer power is the Unified Power Flow Controller (UPFC). [7] The line power flow and voltage bus can be managed separately or jointly using the UPFC. Currently, it is thought that the integration of FACTS devices into load flow algorithms is a necessary condition for planning, running, and controlling. In general, it is necessary to modify the current load flow routines to include these devices.

Flexible AC Transmission Systems (FACTS) are employed in the current deregulated electric market to transport more power across transmission lines as a result of the raProgrammable integral dly expanding research on power electronic components. Up to the largest extent possible, this will assist in enhancing the performance of the current transmission line. The FACTS devices will provide quick reaction, easily adjusted output, and responsiveness to frequent output fluctuations without breaching thermal or stability restrictions.

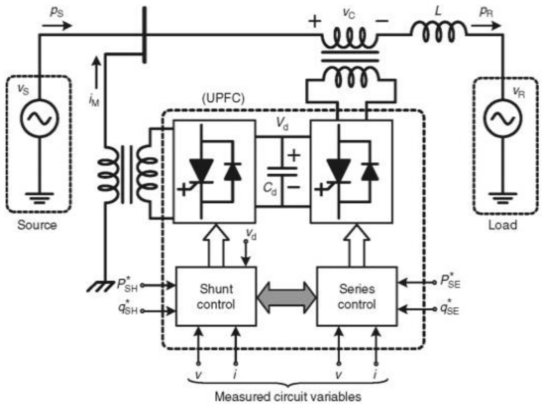

Figure 1 Unified Power Flow Controller

Series compensation, shunt compensation, as well as phase angle regulation alter the line's ability to manage power flow. Every series controller will introduce a voltage into the line in series. Series controllers will absorb or consume reactive power if the line voltage and the inserted voltage have a phase difference of 90º. Shunt controllers are able to supply or absorb the reactive power that the load requires. The amplitude and phase angle of a phase shifter are regulated sinusoidal ac voltage sources. The power flow in the line will change as a result of the phase angle regulator's voltage injection, which will alter the functional phase angle at the sending end.

If we decide that we want to manage power through one of the lines and that line becomes overloaded and I wish to lower the power flow, we can reduce the power flow by altering the parameters of what the UPSC can do. Therefore, it can be operated separately as SSSC or STATCOM with DC common link. Additionally, it has the benefit of providing continuous voltage regulation with changeable in phase and anti-face voltage injection.

II. RELATED WORK

A dynamic assessment of voltage stability is used by ***Fadi M. Albatsh [1]*** to examine a novel method for choosing the placements of unified power flow controllers (UPFCs) in power system networks. The most advantageous sites for UPFCs within the system are determined using voltage stability indices (VSIs) for power systems, such as the line stability index (LQP), the voltage collapse proximity indicator (VCPROGRAMMABLE INTEGRAL), and the line stability index (Lmn).Flexible alternating current transmission system (FACTS) is a solid state electronic device is capable to regulate the transmission of electrical power be flexibly used to overcome these problems**. *Chico Hermanu [2]***analyse the influence of unified power flow controller (UPFC) placement, as one of the types of FACTS on the buses or line of the most critical voltage stability of the power system by using case Java-Bali 500 kV by means of simulation using PSAT software. ***Pavlos S. Georgilakis [3]*** introduces a review of the state-of-the-art models and methods of UPFCs in smart power systems, analysing and classifying current and future research trends in this field. ***Sai Ram Inkollu [4*]** presents a novel technique for optimizing the FACTS devices, so as to maintain the voltage stability in the power transmission systems. Here, the particle swarm optimization algorithm (PSO) and the adaptive gravitational search algorithm (GSA) technique are proposed for improving the voltage stability of the power transmission systems. In the proposed approach, the PSO algorithm is used for optimizing the gravitational constant and to improve the searching performance of the GSA. Using the proposed technique, the optimal settings of the FACTS devices are determined. ***P. Balachennaiah et al. [5]*** proposes a Firefly algorithm based technique to optimize the control variables for simultaneous optimization of real power loss and voltage stability limit of the transmission system. Mathematically, this issue can be formulated as nonlinear equality and inequality constrained optimization problem with an objective function integrating both real power loss and voltage stability limit. Transformers taps, unified power flow controller and its parameters have been included as control variables in the problem formulation.
Hybrid technique based optimal location and sizing of UPFC to improve the dynamic stability is proposed by ***B. Vijay Kumar, N.V. Srikanth [6*]**. Here, the maximum power loss bus is identified at the most favorable location for fixing the UPFC, because the generator outage affects the power flow constraints such as power loss, voltage, real and reactive power flow. The optimum location has been determined using the Artificial Bees Colony (ABC) algorithm. **E. Nanda Kumar [8]** proposed the Optimal Location and Improvement of Voltage Stability in Electrical power transmission lines using Unified Power Flow Controller. Methods/Statistical Assessment: The optimization technique Genetic Algorithm is used to find the optimal location and rating of UPFC to improve the voltage stability of the system. The Unified Power Flow Controller is one of the important devices that are used to control the voltage magnitude and corresponding angle of sending end and receiving end bus.

The control of reactive power in the transmission lines will enhance the voltage stability of the power system network. **Brij Sunder Joshi [9]** presents the design and implementation of the Static V AR Compensator (SVC) in the transmission network for reactive power flow control to improve the voltage stability. The proposed method detects automatically the optimal number of SVCs required for the control of reactive power. The detailed simulation study has been carried out in MATLAB/Simulink environment.The objective of **Ping He [10]** is to demonstrate the capability of the UPFC in mitigating oscillations in a wind farm integrated power system by employing eigenvalue assessment and dynamic time-domain simulation approaches. For this purpose, a power oscillation damping controller (PODC) of the UPFC is designed for damping oscillations caused by disturbances in a given interconnected power system, including the change in tie-line power, the changes of wind power outputs, and others.

III. PROPOSED METHODOLOGY

Various modeling techniques are developed by researchers to model components of HRES. Performance of individual component is either modeled by deterministic or probabilistic approaches. This section discusses the basic modeling structures of diesel system, and Wind energy system along with modeling of PSS controls.UPFC consists of two back to back GTO based voltage source converters (shunt and series) via a common DC link. The main objective of series converter is to produce an ac voltage Vc of controllable magnitude and phase angle and inject this voltage at the fundamental frequency in series with the transmission line, exchanging the real and reactive powers at its ac terminals through the series connected transformers. The various equations implemented for 14 bus system has also been discussed.

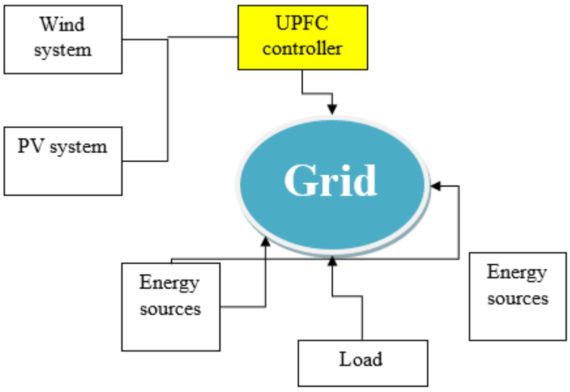

Figure 2 Proposed Hybrid Energy System Topology

The shunt converter regulates the real power or it controls the capacitor's DC voltage by providing the required real power at the DC terminals. It also provides the voltage regulation of the shunt connected point through adjusting reactive power (generating or absorbing the reactive power). The two converters can generate or absorb the power independently without flowing through the DC link. Thus, UPFC can fulfill the functions of reactive shunt compensation, series compensation and phase shifting and meet multiple control objectives by adding the voltage Vc with appropriate amplitude and phase angle to the terminal voltage Vu.
Many power system controls are designed as the solution of multi-stage decision optimal control problems. Dynamic programming is natural framework to solve these problems. Dynamic programming, reinforcement learning and deep reinforcement learning are only briefly presented in this section
It considers dynamic programming as one of four canonical models to solve multi-stage decision optimal control problems in power systems. Dynamic programming is formulated in the framework of discounted infinite time-horizon optimal control for a short description of dynamic programming.

IV. RESULT ASSESSMENT

In this world of depleting energy resources the use of renewable based source of energy is highly required to meet the demands of future. The use of solar and wind energy resources for the generation of electricity is the best choice for combating the use of the exhaustible resources. The best part is that it is also a clean source for generating electricity. This field is henceforth chosen for our work on these resources.

The work focuses on assessment of a wind energy system and diesel system driving local loads in a low voltage line. The system is made to get integrated with the grid system also in order to enhance its efficiency. The chapter here discusses the hybrid energy system in the following two cases.

Case 1: UPFC controlled with traditional Programmable integral controls in the hybrid system.

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

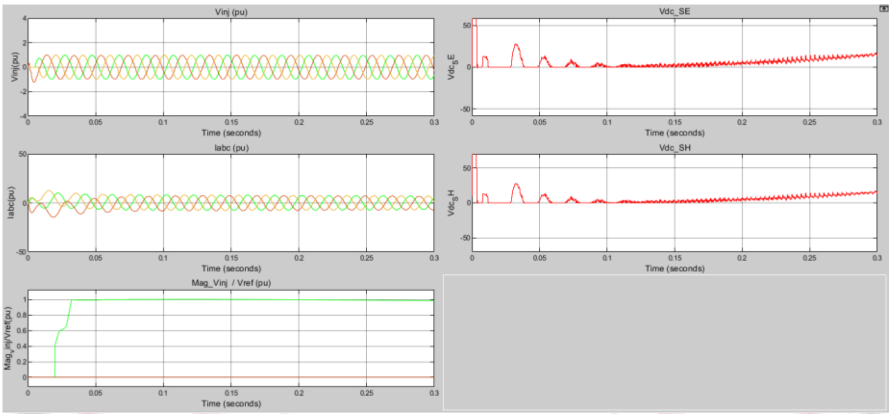

Figure 3 Series converter voltage outputs from the system with UPFC having Programmable Integral controller

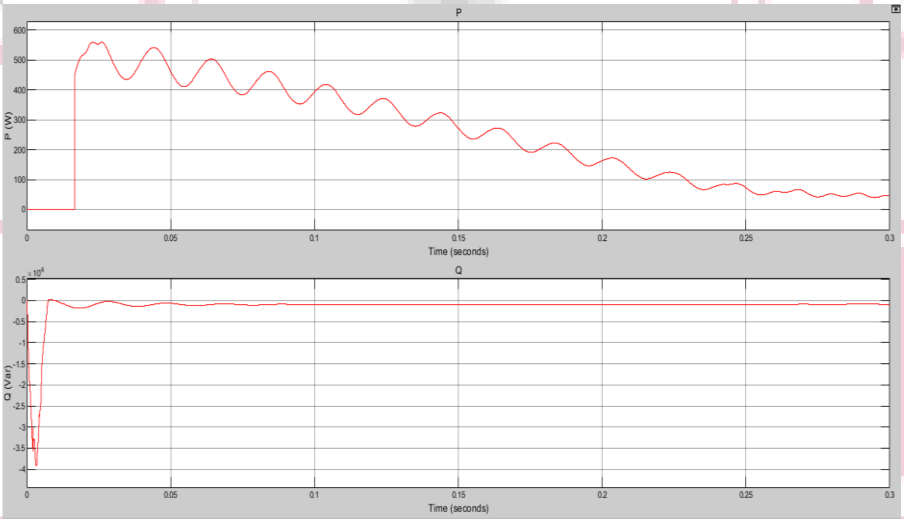

Figure 4 Active and reactive power at the line in system having UPFC with Programmable Integral control

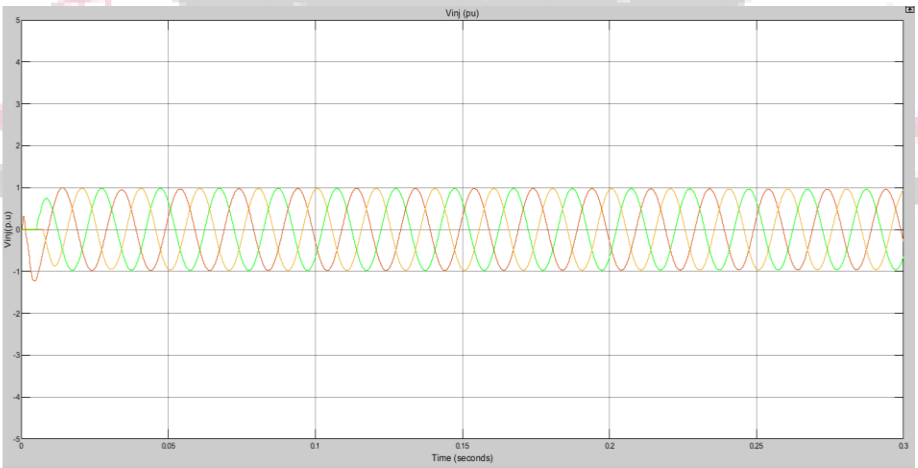

Figure 5 Voltage inserted in p.u at the line from the UPFC with Programmable Integral control

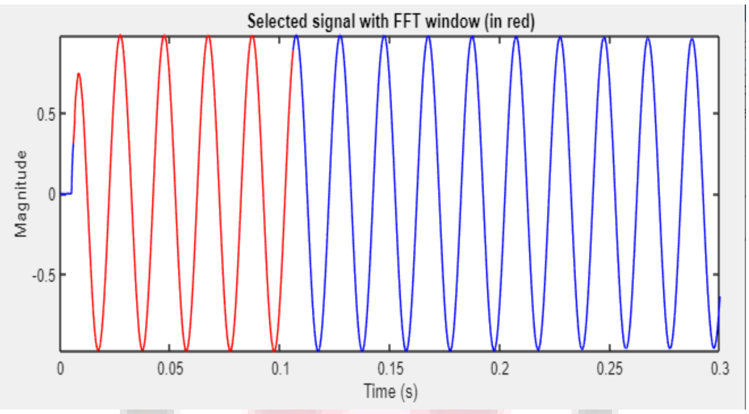

Figure 6Voltage insertion from the UPFC line was analyzed using FFT and Programmable Integral control.

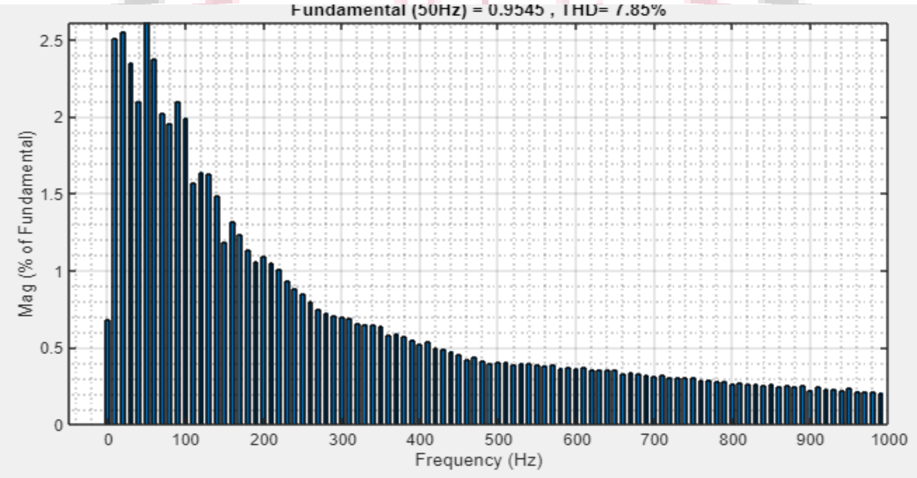

Figure 7Voltage injection from the UPFC line having a Total Harmonic Distortion (%) under Programmable Integral control

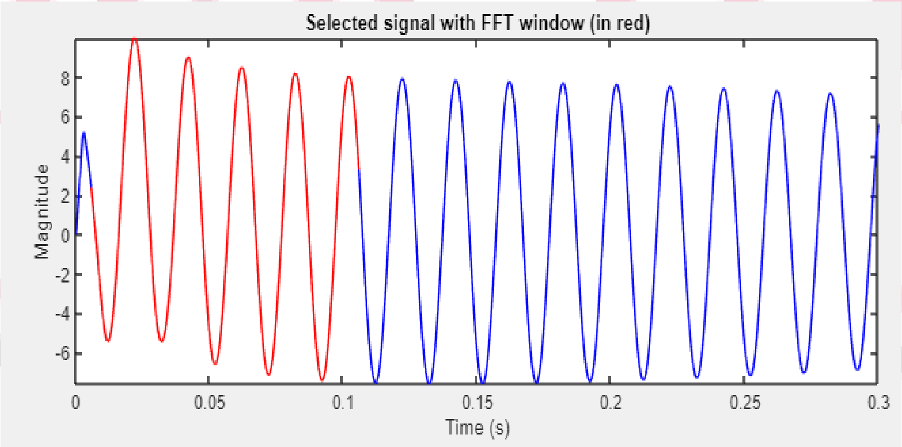

Figure 8FFT assessment of the current that was inserted using Programmable Integral control into the p.u. at the line from the UPFC

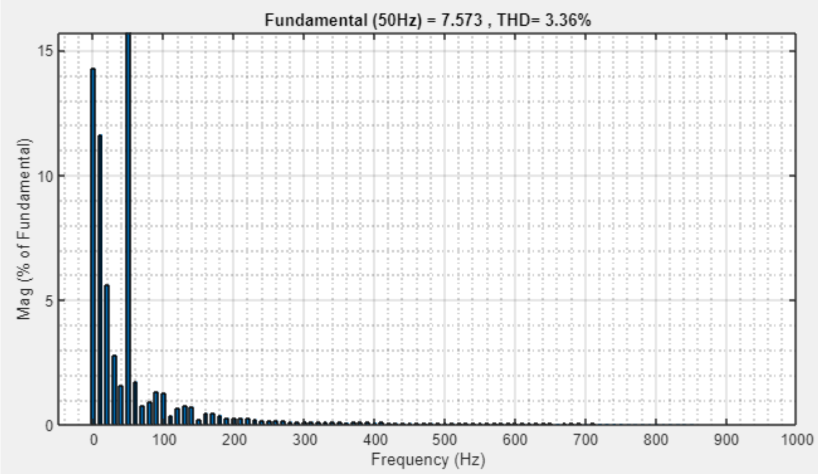

Figure 9 THD% of Current inserted in p.u at the line from the UPFC with Programmable Integral control

Case 2: UPFC controlled with proposed RL controls in the hybrid system.

The system in this case is modeled with hybrid system with UPFC having 48 pulse converters driven by electrical power contrived RL controller which is then further integrated with the grid. Further the voltage current, active power and reactive power waveforms have been analyzed.

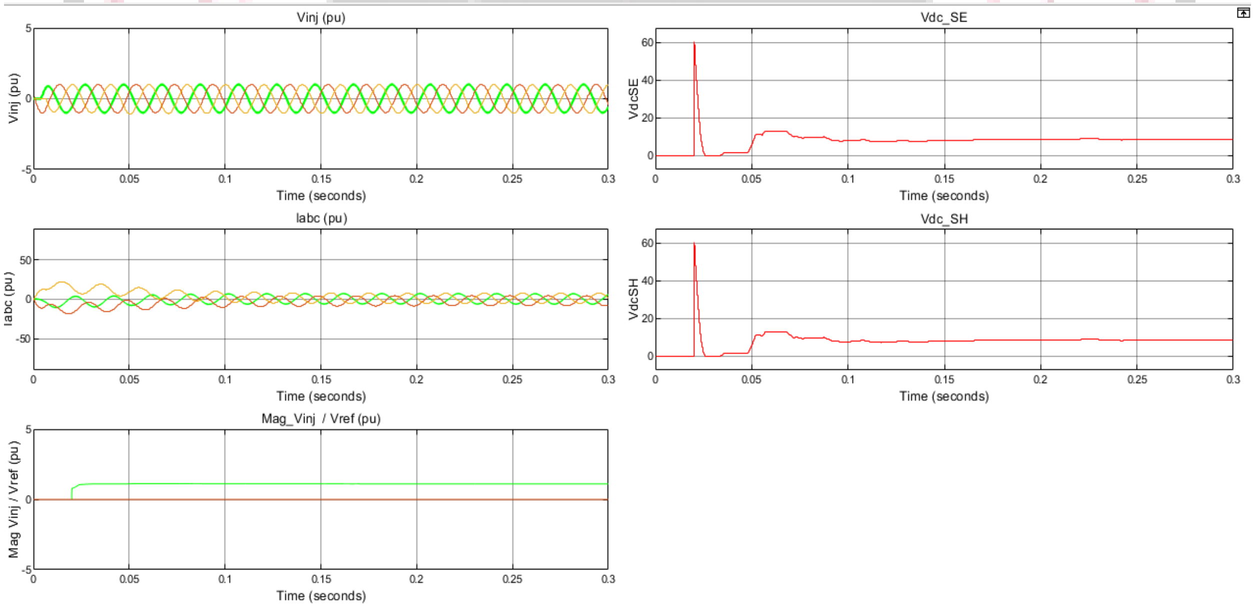

Figure 10 Series converter voltage outputs from the system with UPFC having RL controller

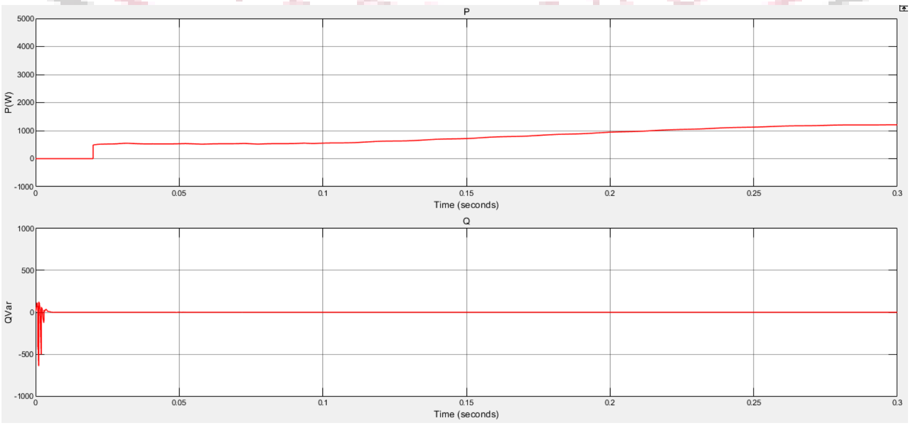

Figure 11 Active and reactive power at the line in system having UPFC with RL control

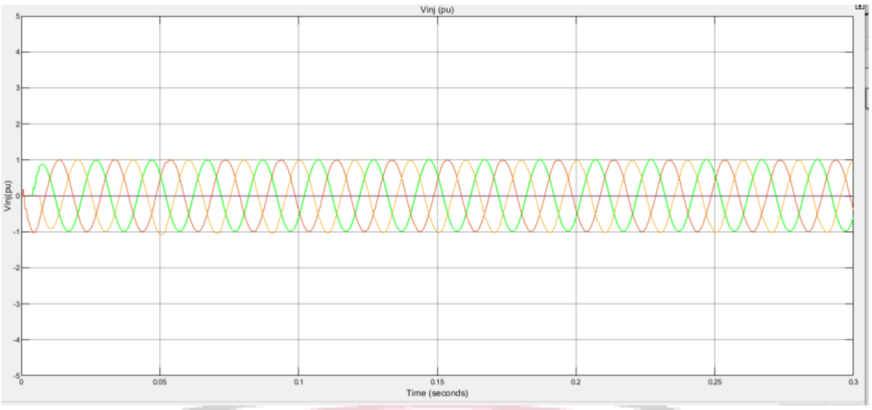

Figure 12 Voltage inserted in p.u at the line from the UPFC with RL control

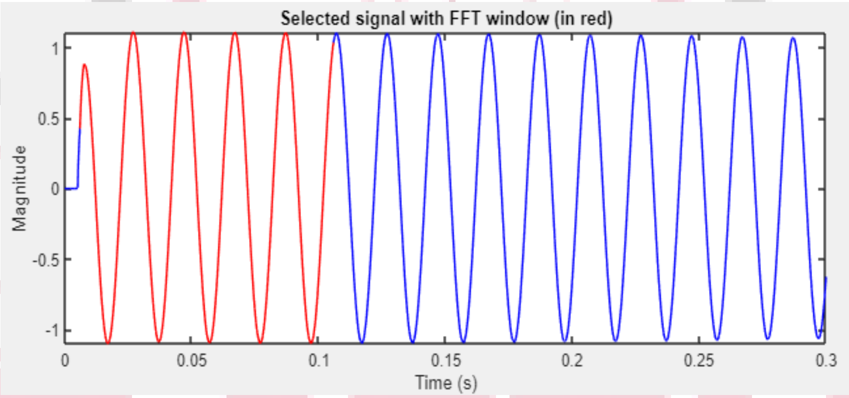

Figure 13 FFT assessment of voltage in UPFC with RL control

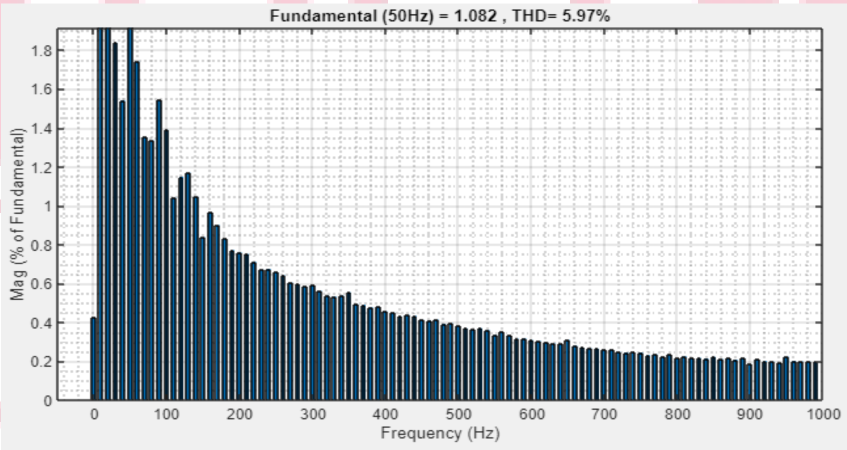

Figure 14 THD% of voltage in UPFC with RL control

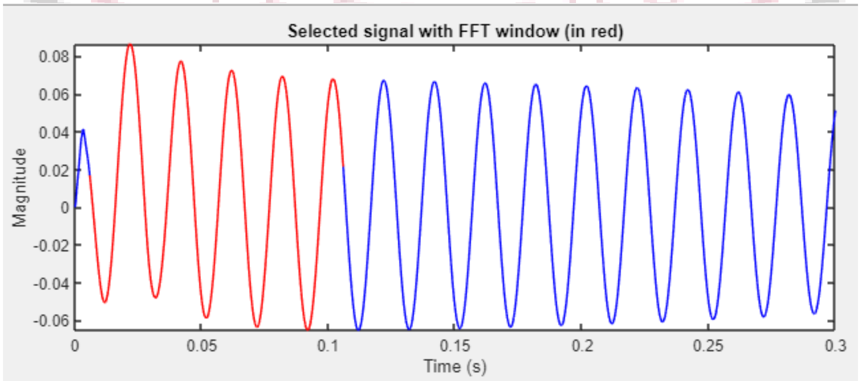

Figure 15 FFT assessment of current in UPFC with RL control

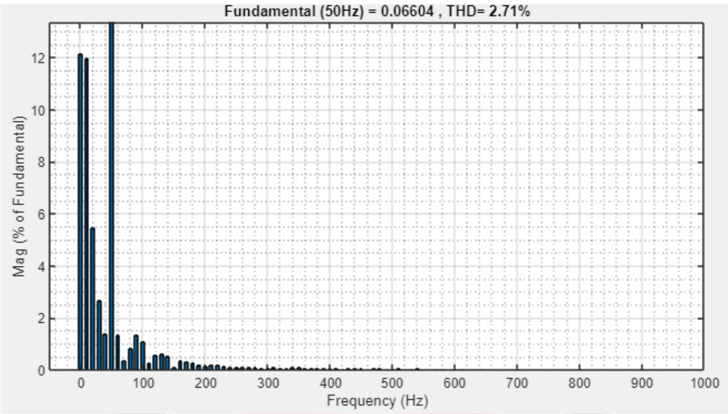

Figure 16 THD% of Current inserted in p.u at the line from the UPFC with RL control

The above waveforms shows the voltage output, current output, active power output, and reactive power in the system having UPFC in line, having RL controller optimizing controlled dual bridge electronic converters. It is concluded that the voltage output is coming to be approximately 1p.u. The active and reactive power outputs are stable with reactive power in line is 0 Var. The THD% in voltage inserted by the UPFC is 5.97%.

V. CONCLUSION

The focus of this research is to investigate if UPFC and associated controller can be used to achieve the stable operating conditions in a hybrid power system comprising of wind energy resources and a diesel generator set feeding the low voltage line. The work investigated the models made on the MATLAB/SIMULINK software and has been shown to provide voltage support and power flow control both more efficiently and effectively with the learning process implemented in place of the standard Programmable Integral regulation control.

Results show the positive changes in the system parameters with the loading line and it is quite evident that the reactive Power management of the hybrid system is achieved. The compensation in case of proposed Q learning based RL UPFC controlled system is more robust than the conventional power system. The proposed RL controller based hybrid system shows better results and rising time, reduced THD% in inserted voltage as well as in the current and better settling time get improved by the proposed controller. Also the controller is adaptive to the wind energy system unstable output as compared to the system with Programmable Integral controllers. The advantages of UPFC with proposed RL based Q learning controller is well established which include its versatility, flexibility and multi-functionality provided by more than one degrees of freedom.

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