Unified Power Flow Controller for Solar-Wind Energy Integrated System's Performance

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Abstract: - When using electricity, the need for proper voltage with excellent operational conditions is essential from the viewpoint of consumer appliances. Utilities normally adopt various quality measures such as adaptive filters, linear filters, conditioners and regulators, etc. to condition the voltage at the consumer end, current quality, and an increase in power to compensate for the voltage dips and dissipative losses including a certain level of fault tolerance. Where efforts are made to enhance power quality, efforts are also put into the utilization of power supply. On the other hand, the growing power demand can be processed with the renewable source integrated energy infrastructure and effective operating algorithm that play key roles in allocating the power supply adaptively to compensate for it. Here, the grid systems are either designed for multi-objective monitoring in deciding or for a concentric parameter. In multi-parameter monitoring, this study suggests intelligent parameter monitoring of power demand and scheduling, unlike the previous technique of a preference-based scheduler employs an ANT-LION optimization (ALO) algorithm. MATLAB/Simulink is used to simulate the suggested system, and the outcomes are shown.

Key-Words: - ANT-LION optimization algorithm (ALO), Smart Grid (SG), Unified Power Flow Controller (UPFC), Intelligent Controller, Power Demand, Power Scheduling, and MATLAB/Simulink.

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1 Introduction

Nonlinear loads and compensatory mechanisms make up the utilization portion of an electrical power system. The power system is directed towards an unstable energy source by this intricate arrangement. Modern energy supply systems, dubbed Smart Grids (SG), make use of two-way communication between loads and utilities to enhance voltage stability, make efficient use of renewable energy sources (RES), and give end users the ability to manage their electricity consumption and save both money and energy, [1]. Though most assaults are not easy to execute, the Energy station is one of the smart grid's most distinctive confrontational objectives, [2]. UPQC is a combined series and shunt compensator for better compensation. Upgraded maximum frequencies, voltage imbalance, voltage flicker, Voltage sag, voltage, and dynamic reactive and active energy regulation are all results of its use, [3].

Because of its durability and ease of use, user-friendly PV technology has emerged as the most alluring option even from an end-user standpoint, [4]. However, even when PI/PID controllers are completely aligned, scheme complexities like load fluctuations and parameter adjustments may cause them to behave strangely, [5].

These vibrations increase in intensity as a result of the power system's instability or disruption of synchronization brought on by a lack of dissipative torque, [6].

A significant factor in the development of the smart grid, aside from technological advancements, was the improvement of consumer energy supply services, [7]. When inspecting voltage fluctuations, flexible switching-up Controllers for modern gearbox systems are used to control the parts. Reactive power and voltage violations are not deceptive because the real concern is power line failures brought on by meteorological circumstances, [8].

The primary purpose of this research study is to develop a weighted parameter monitoring system for power scheduling inside a multi-parameter monitoring system, [9].

The ANT-LION Optimisation (ALO) algorithm-based UPFC is suggested, with a weight-specified parameter tracking power planning in multi-parametric monitoring, replacing the previous priority scheduler technique. Using an ANN in conjunction with an ALO-based controller can increase UPFC performance by alleviating worries about current and voltage PQ, [10].

2 Problem Formulation

To address the system's increasing load demand, industrialization, and performance issues, an integrated solution is being created to meet the energy requirements of a contemporary power grid. The suggested intelligent control strategy improves system stability and efficacy. The RES integrated distribution system may fulfill end-user load needs, but the power quality (PQ) flexibility and stability.

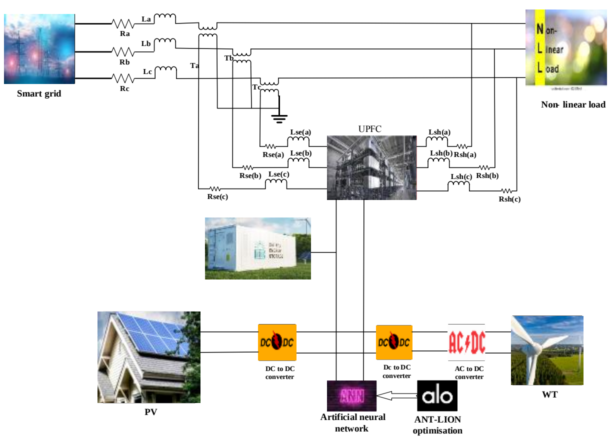

Fig. 1: UPFC structure with RES integrated smart grid

A UPFC used in a RES is one of the most feasible solutions to power quality challenges. The suggested UPFC may be the most effective control device for dealing with PQ concerns and lowering voltage drop in a RES-integrated smart grid as shown in Figure 1. The design of the ANN controller improves the effective regulation of UPFC.

3 Problem Solution

When RES power output is insufficient, battery energy storage systems are used to meet load demands. The battery energy storage system's capacity is given the following requirements for the system's necessary power consumption.

$$\text{Battery } y^{b} = \frac{ad^{*} \times P^{*}_{j}}{\varepsilon^{*}_{j} \times \varepsilon^{*}_{B} \times DOD^{*}} \quad (1)$$

ad^{*} = Autonomy Day, ε^{*}_{B}= Efficiency of Battery,

ε^{*}_{j}=Inverter Efficiency, P^{*}_{j}= Power Demand,

DOD^{*} = depth of the battery's discharge rate.

Autonomy day is the ability of the battery to produce enough energy to fulfill the needs every day.

The surplus energy from RES is used to charge the battery. The power of the battery is displayed in equation (2)

$$b^{*}_{P} = P^{*}_{PV}(t) + P^{*}_{WT}(t) - \frac{P^{*}_{l}(t)}{\varepsilon^{*}_{l}} \quad (2)$$

$P^{*}_{l}(t)$ = System load demand

b^{*}_{P} = Battery power.

The State of Charge (SOC), a crucial battery characteristic, is connected to RES's incapacity to provide adequate energy and excessive power output.

3.1 Equivalent PV Cell

The Solar PV cell analogous electrical circuit is shown in Figure 2. The anticipated power is provided by the PV module using a mixture of series and parallel cells. The relationship between the output current and voltage may be represented as

$$I^{*}_{PV} = N^{*}_{P} I^{*}_{G} - N^{*}_{P} I^{*}_{S} \left(exp\left[\frac{q^{*}}{AKT_{C}} \left(\frac{v^{*}_{PV}}{N^{*}_{S}} + \frac{R_{S} I^{*}_{PV}}{N^{*}_{P}} \right) \right] - 1 \right) \quad (3)$$

Photocurrent I^{*}_{G} is produced by sun radiation, as seen in the example below.

$$I^*_G = \left(I^*_{SC} + k_I(T_C - T_{ref})\right)\frac{S}{1000} \tag{4}$$

The connection below indicates that I* S, is a PV cell's temperature-dependent saturation current.

$$I^*_S = I^*_{rS}\left[\frac{T_C}{T_{ref}}\right]^3 exp\left[\frac{q^*E_g}{AK}\left(\frac{1}{T_{ref}} - \frac{1}{T_C}\right)\right] \tag{5}$$

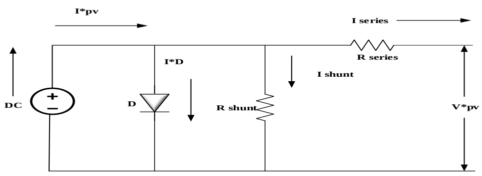

Fig. 2: Equivalent PV cell

3.2 Design of DC-DC Converter

Figure 3 demonstrates a circuit that is similar to a DC-DC boost converter. Switch 2 is originally in the open position, whereas Switch 1 is initially closed. The current of Inductor L (IL) is now beginning to increase from zero. At this time, switch 2 is closed and switch 1 is opened, and the inductor current flows to the load while the capacitor stores the charges. The ON/OFF states of switches 1 and 2 accurately reflect the contingent excessive value of the output voltage when the output voltage V*0 is steady.

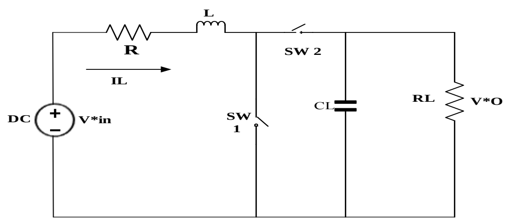

Fig. 3: DC-DC converter analogous circuit

4 Results and Discussion

The Simulink schematic for the suggested intelligent controller-based UPFC is displayed in Figure 4. The WT voltage is set at 85V, the battery current is reached at 51A, and the battery power is at 4335W, as shown in Figure 5. The WT parameter findings at 12 m/s wind speed are displayed in Figure 6. The torque is 2.8 Nm, the rotor speed is set at 2500 rpm, and the pitch angle is 1 degree. Figure 7 displays the DC link voltage, which is reached at 163 V. The real and reactive power of the source of the transmission line, as well as the real and reactive power of the load, are displayed in Figure 8 and Figure 9.

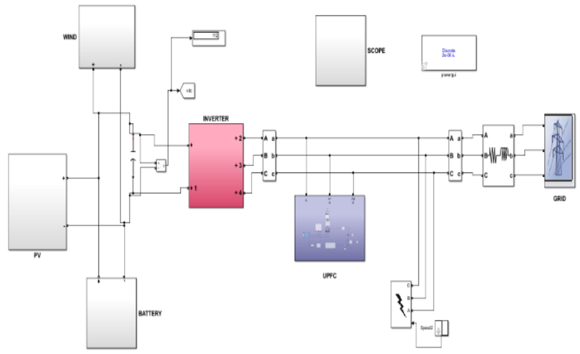

Fig. 4: Simulink diagram of the proposed circuit

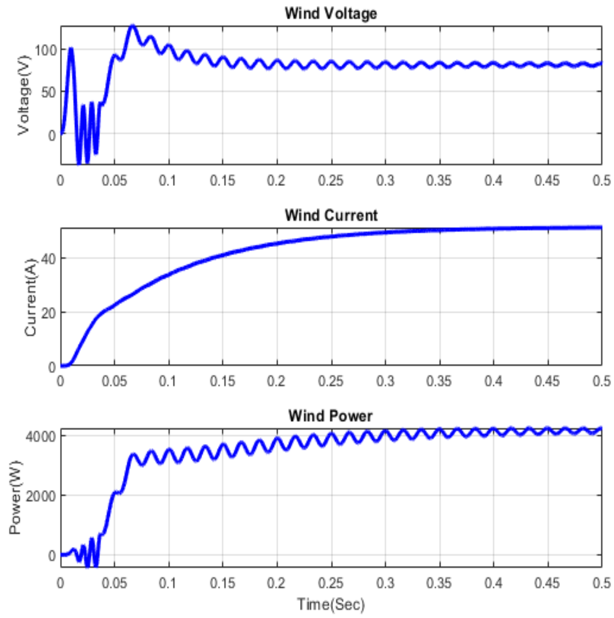

Fig. 5: Outcomes of WT

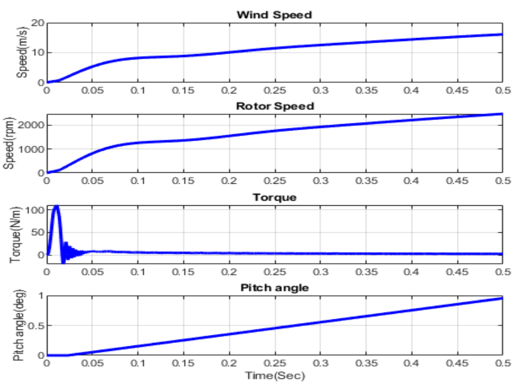

Fig. 6: Outcomes of WT parameters

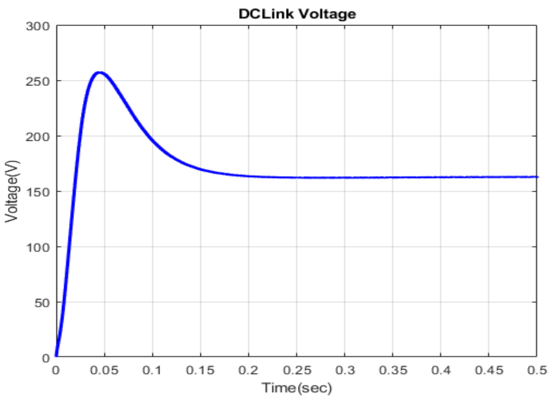

Fig. 7: Voltage of DC Link

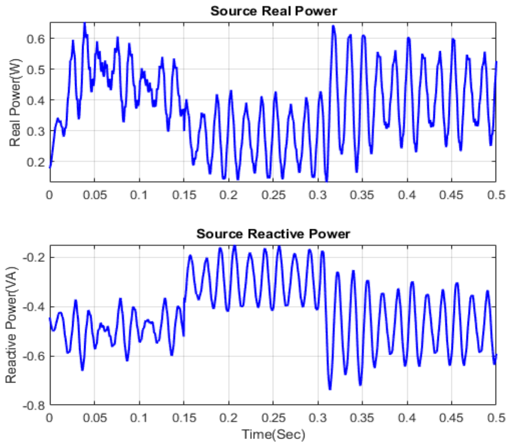

Fig. 8: The source waveform's actual power and reactive power

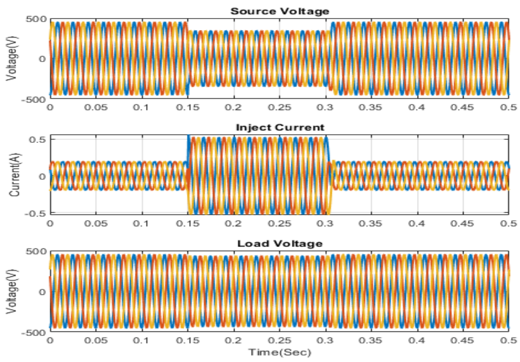

Fig. 9: Compensation of Sag Voltage

The real strength of the source is shown as 0 to 0.5 seconds, with the sag signal appearing between 0.15 and 0.3 seconds in between. The reactive power-related swell problem manifests in 0.15 to 0.3 seconds. Real and reactive power are displayed as significant concerns for a given time interval, ranging from 0.15 to 0.3 seconds. The voltage is rectified with the assistance of the UPFC. Fig.9 displays the voltage from the source, the voltage from the injection, and the voltage from the load. The source waveform's actual power and reactive power.

5 Conclusion

The research work demonstrated the improvement of performance by the proper design of a unified power flow controller for a grid-connected RES with the load. The irregularity of renewable energy output causes power quality problems. The ANT-LION optimization algorithm is used to analyze the performance and to prove how superior the proposed work is. The mitigation level is greater and the percentage of THD is 2.07%, which is examined. Hence the demonstrated UPFC with ANT-LION optimization algorithm in comparison to traditional algorithms is more effective.

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Contribution of Individual Authors to the Creation of a Scientific Article (Ghostwriting Policy)

Dr. P.V.V. Rama Rao implemented the algorithm and designed UPFC for the solar-wind energy integrated system.

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Dr. D. Chandra Sekhar, Mrs. K. Kumari, and Mrs Mariyam carried out the simulation and the optimization.

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Conflict of Interest

The authors have no conflicts of interest to declare.