Grey Wolf Optimized PI Controller for Grid Tied High Gain Converter for Solar Power Generation

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***Abstract*—The high gain DC-DC Landsman converters and Grey Wolf Optimized (GWO) Proportional Integral (PI) controller for PV systems are proposed in this paper. An environmental condition are frequently variable, so that a solar irradiation is not continuous. A DC-DC Landsman converters is used to increase an output of the PV systems. A GWO optimized PI controller based closed loop approach is used to ensure constant DC link voltage at converter's outputs. A photovoltaic (PV) system's effectiveness is improved using GWO. An inverter, which converts DC power produced by Modules to AC power needed for standard power supplies for electrical devices, enables photovoltaic systems to be linked to the grid. For a PV system that is connected to the grid, the inverter system is crucial. It is also necessary to produce high-quality electricity for AC utility systems at an affordable price. High current factor and low harmonic distortions power can be produced by high frequency switching of semiconductors utilizing PWM (Pulse Width Modulation) technology. An additional voltage source inverter is used to supply an obtained Voltage levels to a grid. High gain and low switching losses are obtained with the defined work. This paper is implemented by MATLAB simulation.**

Index Words — **DC-DC Landsman converter, Grey wolf optimization, PI controller**

I. INTRODUCTION

Renewable energy sources including solar, wind, ocean waves, fuel cells, and others are increasingly being used by energy managers today. This type of situation seems destined for the use of DC-DC converters. Consequently, it is crucial to propose new, novel topologies with benefits like high voltage gain and dependability [1]. Due to the finite amount of fossil fuel available, demand for renewable energy sources is increasing. The pure and pollution free renewable energy sources. After combustion, renewable energy sources produce no harmful gases. Photovoltaic (PV) systems, fuel cells, wind turbines, tidal energy, etc. are examples of renewable energy sources. Although renewable energy has many benefits, there are also drawbacks [2]. The Cuk converter has drawbacks, including a high proportion of reactive elements and significant current stresses on switch. An extra inductor and capacitor are used by the Cuk converter to store energy. Since that the feedback loop need to continue a regulated, some form of compensation is necessary to maintain loop stability [3]. Moreover, converters with an active clamp circuit recycle an energy from leakage and address an aforementioned issues. But they make circuits more complex. High voltage conversion ratios are possible using cascaded converters, but the primary drawbacks are complexity and increased cost. Stability is another issue with these converters [4]. A buck-boost converter is appropriate when a low output voltages fluctuation [5].

An operational efficiency, size, and operational cost of each boost converter are evaluated. Although interleaved boost converter and conventional boost converter topologies are frequently employed in solar systems, they have drawbacks such as variable efficiency levels under weather variations [6]. Eventually, algorithms based on soft computing were created to find the overall best answer in a variety of environmental circumstances. To find an optimum solutions, particle swarm optimization (PSO), a method based on swarm intelligence, is used. PSO's popularity is due to the fact that there are relatively few variables that need to be changed [7]. Convergence speed and a prevention of premature convergence are two critical elements for the evaluation of the strategic plan used for MPPT of PV systems. To improve stability of the PV system and prevent premature convergence, which drastically lower an amount of energy generated by PV system, but a very quick and precise reflexes are required [8]. PSO is a novel MPPT approach that has been suggested. These techniques have cheaper costs, greater overall efficiency, and ease of use because they only require one pair of sensors to regulate PV arrays. Although these techniques not effectively operate in quickly changing atmospheric circumstances [9]. To improve a PV power generation prediction performance of the model, however, a binary genetic algorithm based method of selecting features for regression tasks is required [10].

This paper proposes a Grey Wolf Optimized Pi Controller for Grid Tied High Gain Converter for Solar Power Production to solve an aforementioned issues. The proposed technique uses a Grey Wolf optimization (GWO) algorithm based PI controller to maintain constant DC link voltage. This paper is organized as follows: In part I, an introduction is explained. In Part II, a system model is explained. Part III presents the simulation findings, while Section IV presents the conclusion.

II. PROPOSED MODEL

Modern technology as well as novel developments, such as an integration of large scale distributed renewables, advanced control and monitoring techniques, and enormous storage capacity, are causing major changes in the power production and distribution sectors. Because to its compact size, static design, and nearly maintenance free operation, solar PV (Photovoltaic) based energy generating systems are among the most widely used renewable resources. The world has become increasingly interested in solar energy as a new form of green energy due to environmental degradation and the depletion of conventional sources of energy. The most popular way to use solar energy is to generate PV power. An individual PV cell, which serves as the foundational building block for the production of PV power, has a low output power. It is important to connect many PV modules in parallel and series to create a PV array in real applications due to the voltage and power needs. An output current and voltage of a PV array are modified by weather factors (irradiance, temperature, etc.), giving them a nonlinear appearance. Continuous modifications are also applied to its output power. To increase the solar system's effectiveness, GWO is applied. Figure 1 shows the block diagram of the suggested system.

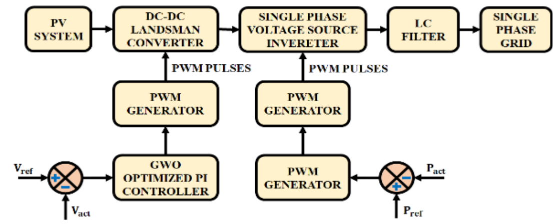

Figure 1. Proposed System Block Diagram

In a proposed system, a DC-DC Landsman converter is used to supply grid with solar PV electricity. A GWO optimized PI controller has been attached for controlling a Landsman converters. This controller improves the dc voltage by analyzing the voltage level and the voltages produced from the converter. A GWO algorithms based closed loop method is used to maintain a steady DC link voltage at source of DC-DC converter. GWO is a recent meta-heuristic optimization technique. The idea behind it is to model cooperative hunting after the behavior of grey wolves in the wild. The behavior of grey wolf, which hunts enormous prey in packs and relies on inter wolf cooperation, served as the model for this algorithm. An output of the converters is then supplied to a single phase VSI, which converts DC supply into an ac supply and transmits it to the single phase grid throughout an LC filter.

A. PV System

A sustainable and dependable energy source that is always available is the sun. By photovoltaic, the energy that the sun emits is directly captured for the purpose of generating electricity. Solar cells are the fundamental component of photovoltaic modules, which use the photovoltaic effect to generate electricity from light energy. A PV panel is based on load ratings. Equivalent circuit of PV cell is presented in Figure 2.

An electrical equivalent diode of the PV cell is represented by the following:

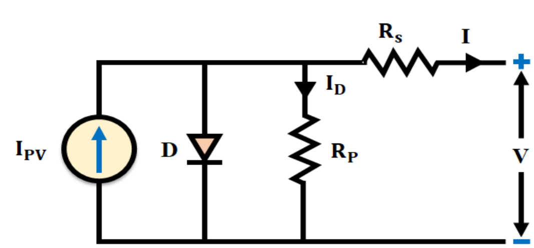

Figure 2. PV Cell Equivalent Circuit

PV model constitutes, diode Shunt resistanceR_{sh}, current sources, Series ResistanceR_s. The cell surface leakage through the edges is represented as Shunt Resistance R_{sh} .

$$I = I_{ph} - I_d - I_{sh} \quad (1)$$

Shunt Resistance current I_{sh} and a Diode current I_d is given by Equations (1.2) and (1.3)

$$I_d = I_0 \left\{ exp\left[\frac{q}{mkT_c}(V + IR_s)\right] - 1 \right\} \quad (2)$$

$$I_{sh} = \frac{V+IR_s}{R_{sh}} \quad (3)$$

I_0= Cell reverse saturation current

m= Idealizing factor

T_c= Absolute temperature of cell

K= Boltzmann constant

V= Potential across cell

q= Charge of electron

By utilizing Equations is shown below

$$I = I_G - I_0 \left\{ exp\left[\frac{q}{mkT_c}(V + IR_s)\right] - 1 \right\} - \frac{V+IR_s}{R_{sh}} \quad (4)$$

Generally shunt Resistance R_{sh} in PV cells is high hence $\frac{V+IR_s}{R_{sh}}$ is removed,

$$I = I_G - I_0 \left\{ exp\left[\frac{V+IR_s}{A}\right] - 1 \right\} \quad (5)$$

B. DC-DC Landsman Converter

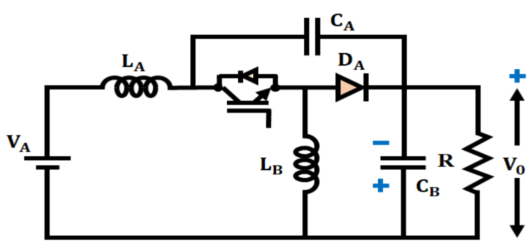

Figure 3. Landsman Converter

Figure 3 presents the connecting diagram for the proposed landsman converter. V_A is an input voltage and $V_O$is the output voltage. S is denoted as switch and R is an output resistance. A current across an inductorsL_A, L_B and voltage across C_A are continuous in nature. When duty ratio is more than 50%, it has the capability of increasing output and operates in boost converters.

Operating Mode 1 -Switch ON

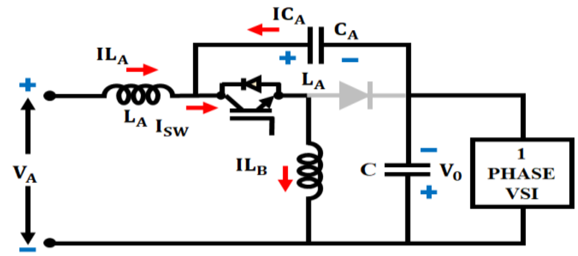

Figure 4. Landsman Converter Mode 1

In operating mode 1, voltage of capacitor C_A denoted as V_{CA} reverse biases diode and switch is in ON condition which results in configuration of circuit as known in figure 4. A current across L_B termed as I_{LB} flows along switch. Since C_A discharges with switch, $V_{CA}$is greater than resultant voltageV_O, transmitting energy to an output and inductorL_B. Hence, V_{CA}decreases and I_{LB} increases and input supplies energy to an input inductor L_A.

Mode 2 –Switch OFF

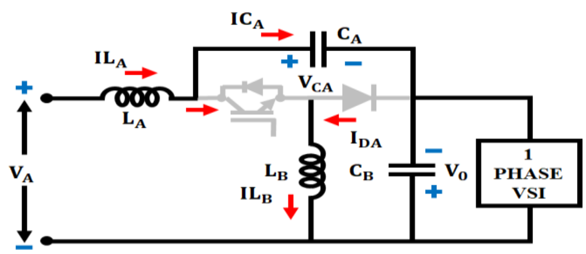

Figure 5. Landsman Converter Mode 2

When the switch is in operating mode 2, the circuit is set up as shown in figure 5 owing to a forward biasing of the diode. Through a diode, an inductor L_B sends an energy it has stored for output. Subsequently, when I_{LB} decreases and V_{CA} increases.

C. Grey Wolf Optimization

A novel meta heuristic optimization technique is called GWO. Its guiding premise is to model cooperative hunting behavior after that of grey wolves in the wild. A grey wolf, which hunts enormous prey in packs and depends on cooperation, provided an inspiration for this algorithms.

This behavior has two intriguing aspects:

1) Hunting mechanism
2) Social hierarchy

A grey wolf has a complicated social hierarchy as a result of being a highly social animal. A term "dominance hierarchies" refers to this system of ranking wolves based on their size and power. There are the alphas, betas, deltas, and omegas as a result. GWO social hierarchy is presented in the figure 6.

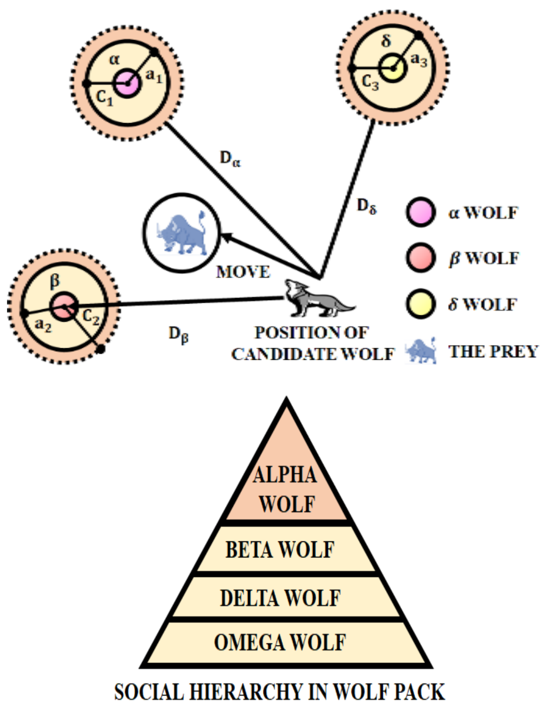

Figure. 6 GWO Social Hierarchy

In addition to having a distinct social structure, grey wolves have a highly particular hunting style. They hunt together and cooperate to separate the prey from the herd. One or two wolves will then pursue and attack the victim, while the others chase off any stragglers. Similar to this, the GWO method is used to arrive at an ideal voltage, maintaining a constant DC link voltage at the DC-DC converter's output.

D. GREY WOLF OPTIMIZATION ALGORITHM

A metaheuristic optimization technique called GWO algorithm is based on the natural hunting techniques used by wolves. For fine tuning the system parameters for a DC-DC converter, the GWO algorithms was presented in this paper. GWO flow chart is presented in Figure 7. This population based optimization approach is one that is used to fine tune the PI controller. The typical behavior of grey wolves serves as the inspiration for this programme. The GWO algorithm's leadership order is divided into four clusters:

1) Alpha (α) Male or female dominant wolves both have the ability to make decisions.
2) Beta (β) Helping the alpha wolf make decisions is the subordinate wolf.
3) Omega (ω) Lower ranking wolf.
4) Delta (δ) Alpha and beta should be reported and dominating omega.

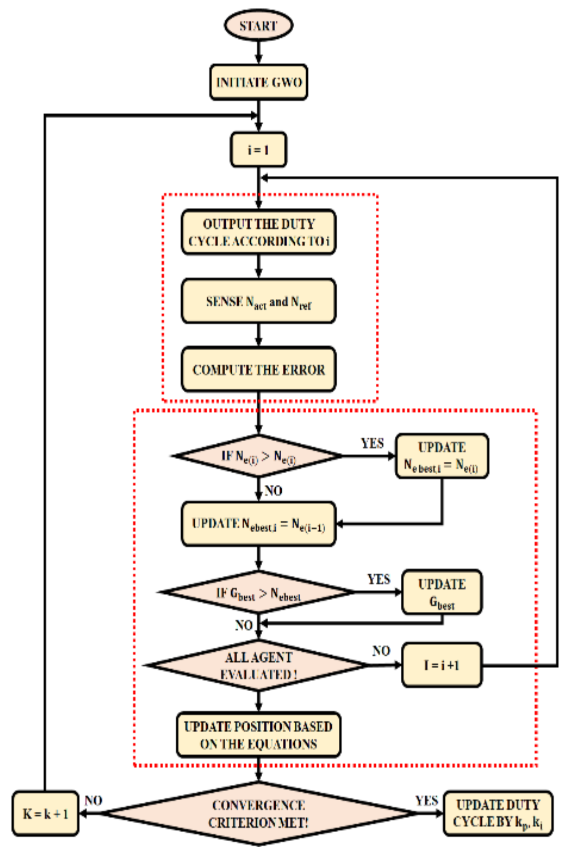

Figure 7. GWO Flowchart

E. PI Controller

A feedback controller is the PI controller. Using a weighted total of errors and the integral of that value, it controls the plant that must be regulated. From motion control to aerospace, from slow to fast systems, PI Controllers have been used to control practically every operation currently in use. Although this progress has been important, the issue of tuning PI controllers has continued to be a focus of research. Also, it is important to periodically return PI

Controllers due to differences in operating points and changes in system dynamics.

F. PWM Generator

The switch found in the Landsman converter produces and applies the pulse width modulated signal. PWM generator really divides the average power reduction into individual components. The grid side is given the average voltage and current levels by keeping the switch on for a longer period of time than it is off. The power delivered will be more as a result of this extended ON time. To achieve high peak power values, the PI controller with GWO optimization feeds the PWM generators. The PWM generator's primary job is to create pulse width modulating gate pulse signals, which are then sent to the LANSMAN converter's switch.

III. SIMULATION RESULTS

A mathematical model simulating a proposed system is presented and then easily simulated in SIMULINK. A MATLAB SIMLINK output voltage waveforms are represented below.

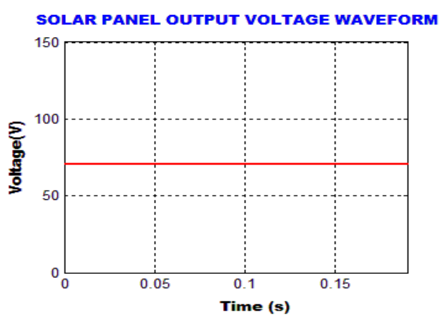

Figure 8. Waveform of Solar Panel Output Voltage

PV panel voltage is shown in Figure 8 and 9 shows a waveform with a constant DC voltage. When there is sufficient sunshine irradiance, it typically stays constant.

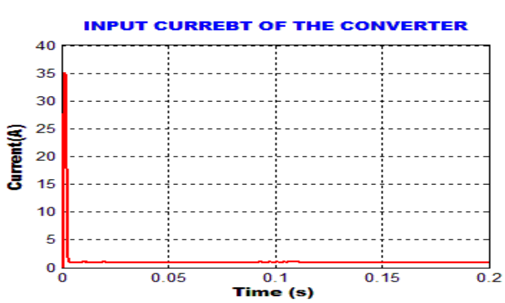

Figure 9. Input Current of the Converter

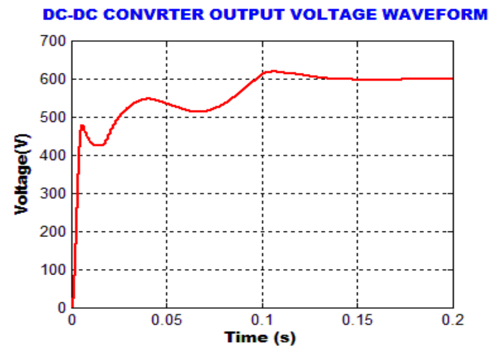

Figure 10. DC-DC Converter Output Voltage Waveform

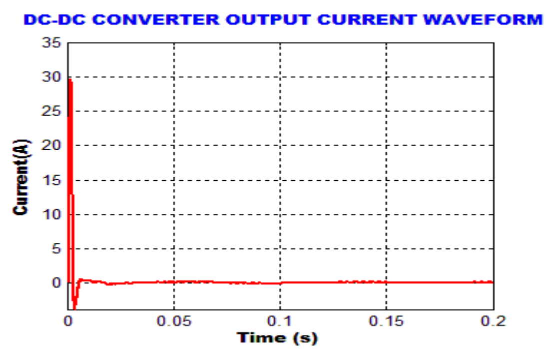

Figure 11. Dc-Dc Converter Output Current Waveform

Figures 10 and 11 respectively represent the voltage and current waveforms of the Landsman converter's output.

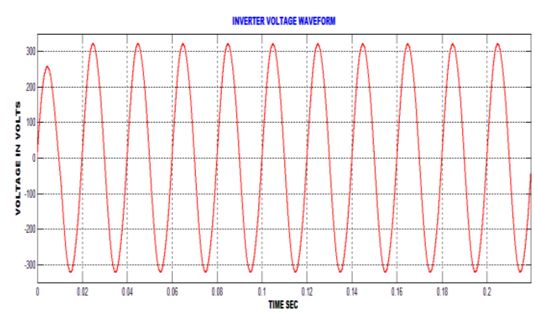

Figure 12. Waveform of a Single Phase Voltage Source Inverter

A waveform of single phase bidirectional inverter output voltage is presented in Figure 12. Reactive power compensation is achieved by using PI controller based grid synchronization.

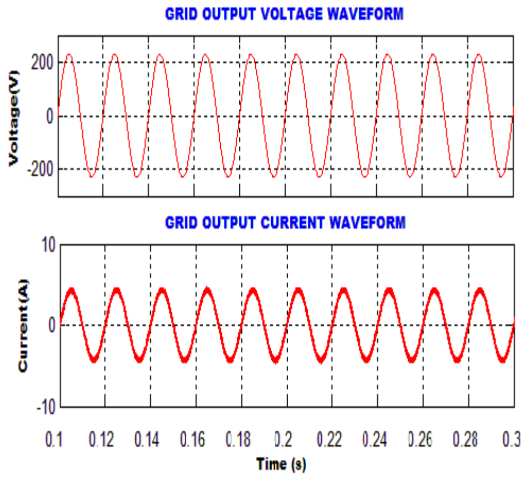

Figure 13. Single Phase Grid Output Waveform

For a single phase PV inverter functioning in both grid connected systems, a complete control method has been described in this section. Figure 13 presents the voltage and current waveform of single phase NP grid. Under various frequency settings, the performance of the proposed PLL controller is validated.

IV. CONCLUSION

A highly capable LANDSMAN converter is used in the proposed system to increase PV array usage and maintain steady current flow. By analyzing maximum power with the aid of a LANDSMAN converters, the Grey Wolf Optimizer maximizes the effectiveness of the photovoltaic panel. To enhance the proposed converter's dynamic characteristics and extract a steady state DC link voltage from the converter's output, the grey wolf optimization (GWO) method varies the variables of the PI controller. P&O, Fuzzy, IC, and Firefly techniques are compared to various optimization methods, and the results are examined and acquired. The proposed GWO algorithm's efficiency was increased. For single phase grids connected via inverters, grid synchronization is carried out. An LC filter serves the purpose of eliminating the harmonics from the VSI outputs, allowing the current to be safely fed into the grid.

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