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Designing of Hybrid Integrated Constrained PSO Algorithm for Two Converters in Solar PV System

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Abstract: The use of renewable energy sources such as solar and wind energy can be extended to include residential and transportation applications due to environmental benefits. The main objective of this paper the solar energy system will be equipped with two type of converters DC/DC and DC/AC. The DC/DC boost converter is generally driven by the MPPT technique. We need to design a single controller for both the converters that would meet the power requirements and enhance its efficiency. To enhance the active power output by utilizing the designed controller for both the converters. The power enhancement would be done by utilizing a hybrid integrated constrained particle swarm optimization technique that is also modified to meet the MPPT requirements of the solar energy system. the result of The single controller has resulted in the following key improvements. The algorithm was first incorporated with the MPPT algorithm for the boost converter which has improved the DC voltage profile from 500 V to 595 V. The active power output from the system has enhanced to 113KW from 100Kw which is also stable as compared to the system having dual controllers for the converters. The PSO algorithm is so constrained in a manner such that the output voltage and current distortion has also reduced. The voltage output distortion level from the hybrid constrained PSO controllers was found to be 0.20% which is less than 0.26% of the system having dual controllers Also the THD level in the current output from the hybrid PSO integrated algorithm was reduced to 0.16% from 3.36% in the solar PV system modeled with dual controllers.

Keyword: THD, PSO, DC, MPPT.

I. Introduction

The use of renewable energy sources such as solar and wind power can be extended to residential and transportation applications due to the environmental benefits. For high voltage applications, the type of solar cell must be considered, which is divided into three main groups: monocrystalline (monocrystalline structure), polycrystalline (partially crystalline) and thin film of amorphous silicon [1].

Solar energy systems can be divided into two types: off-grid and off-grid. With off-grid solar systems, the main energy is supplied only by photovoltaic modules and batteries. These systems are suitable for remote areas normally isolated from the local network. To maximize the power consumed by the photovoltaic modules, the MPPT (Maximum Power Point Tracking) charge controller is used by converting the variable DC voltage into the maximum voltage of the power point. The important device in off-grid solar systems is the line inverter, which converts the direct current of the photovoltaic modules and batteries into alternating current to directly power the building with electricity. Inverters are divided into two types: line inverters and normal inverters. The former directly converts solar energy into main energy. While the latter convert the direct current of the photovoltaic modules and batteries into a local network. The latter is also used to charge the batteries [2].

II. Literature Review

S. Lenin Prakash's research et al [3] this document provides a comprehensive overview of Maximum Power Point Tracking (MPPT) techniques used in these grid-connected photovoltaic systems. A classification of the different MPPT techniques based on the topology of the network interface is presented. In addition, the simulation and detailed performance analysis of the incremental conductivity (INC) method with d (delta) control was presented. The simulation results have been presented in detail and the results show that the modified conductivity in MPPT increments works for different values of irradiation, temperature and variation of the network parameters and is presented in this work.

M. Madsen, A. Knott et al [4] This article presents the structure of a resonant converter with a switching frequency in the very high-frequency range (30-300 MHz), a large reduction ratio (ten times), and a low output power (1 W). Different inverters and rectifiers are analyzed and compared. Class E inverters and rectifiers are selected based on complexity and efficiency estimates. Three different levels of performance are implemented. One with a large input inductance, one with a low-capacitance switch, and one with a low-resistance switch. Performance levels are designed to the same specifications and efficiencies of 60.7-82.9% are achieved.

A.J. Mahdi et al. [5] the amount of electricity produced by a photovoltaic (PV) system mainly depends on the following factors, such as: B. temperatures and sunlight. Depending on the high costs and low efficiency of a photovoltaic system, it should work with the maximum power point (MPP), which changes with solar radiation or load fluctuations. The proposed MPPT algorithm was implemented by a dSPACE DSP controller. Experimental results show that the photovoltaic energy system, using the proposed MPPT algorithm, is able to closely follow the maximum power points (with minimal stationary power oscillations) with rapid fluctuations in irradiation.

M. S. Benghanem et al. [6] the production of electricity from fossil fuels for general use is associated with problems such as greenhouse gas emissions, environmental threats and energy crises. In this article, we present an optimization model to ensure efficient use of photovoltaic modules. We build a one-diode model with blocks from the MATLAB / Simulink library. Simulations were performed to vary the irradiation from 400 Wm-2 to 1000 Wm-2.

III. OBJECTIVE

- Design a Solar Wind Energy System using MALAB/SIMULINK environment
- The solar energy system will be equipped with two type of converters DC/DC and DC/AC. The DC/DC boost converter is generally driven by MPPT technique. We need to design a single controller for both the converters that would meet the power requirements and enhance its efficiency.
- To enhance the active power output by utilizing the designed controller for both the converters.
- The power enhancement would be done by utilizing hybrid integrated constrained particle swarm optimization technique that is also modified to meet the MPPT requirements of the solar energy system.
- The control is designed to incorporate variation in the input irradiation levels of the solar panel system.

IV. METHODOLOGY

The power conditioning unit (PCU) or the inverter is the main component of the photovoltaic systems connected to the network that convert the direct current generated by the photovoltaic generator into alternating current that meets the voltage and quality requirements of the supply network for direct purposes to devices or transmission. To the supply network to obtain tariff compensation. If the network is not powered, the PCU automatically cuts off the power to the network.

A two-way interface, located on a local distributor or at the entrance of a service, allows the alternating current generated by the photovoltaic system to feed the electrical loads on the site or to reintegrate into the network if the power of the photovoltaic system is greater than that Local performance is a load requirement. If the electrical loads are higher than the power of the photovoltaic system, especially at night and in cloudy weather, the power balance required by the loads is received by the electricity supplier. This is a safety function in case of network failure for maintenance or repair to ensure that the photovoltaic system is no longer in use and is reintegrated into the electricity grid.

A. *PV Module modeling*

PV cells have single operating point where the values of the current (I) and voltage (V) of the cell result in a maximum power output. These values correspond to a particular resistance, which is equal to V/I. A simple equivalent circuit of PV cell is shown in Fig.1.

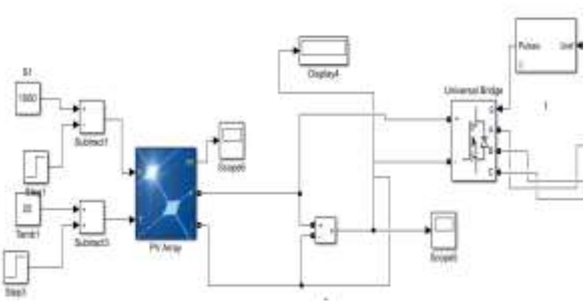

Fig. 1 Modeled solar system

A cell series resistance (Rs) is connected in series with parallel combination of cell photocurrent (I_{ph}),exponential diode (D), and shunt resistance (R_{sh}) , I pv and Vpv are the cells current and voltage respectively. It can be expressed as

$$I_{pv} = I_{ph} - I_s\left(e^{q(V_{pv}+I_{pv}*R_s)/nKT} - 1\right) - (V_{pv} + I_{pv} * R_s)/R_{sh}$$

Where:

I_{ph} - Solar-induced current

I_S - Diode saturation current

q - Electron charge (l.6e^{-l9}C)

K - Boltzmann constant (l.38e^{-23}J/K)

n - Ideality factor (l~2)

T - Temperature ^{0}K

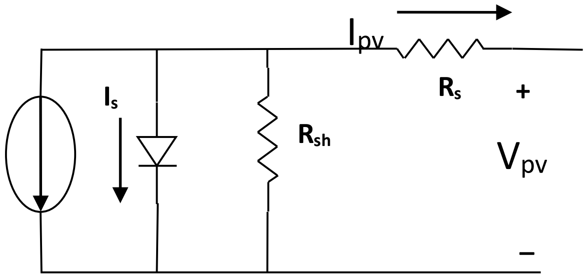

Fig. 2 Equivalent circuit of solar pv cell

The solar induced current of the solar PV cell depends on the solar irradiation level and the working temperature can be expressed as:

$$I_{ph} = I_{sc} - k_i(T_c - T_r) * \frac{I_r}{1000}$$

Where:

I_{SC} Short-circuit current of cell at STC

K_i Cell short-circuit current / temperature coefficient (A/K)

I_r Irradiance in w/m

T_C ,T_r Cell working and reference temperature at STC

A PV cell has an exponential relationship between current and voltage and the maximum power point (MPP) occur at the knee of the curve as shown in the Fig 3.

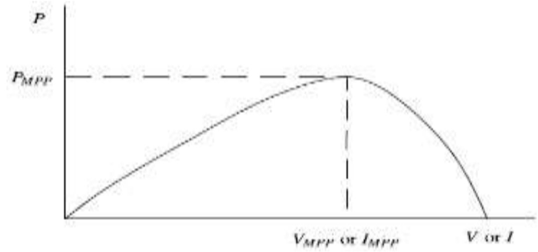

Fig. 3 Characteristic PV array power curve

Table 1 : PV module Parameters

Maximum Power	213.5 Watts
Number of parallel strings	40
Number series modules	10
Open circuit voltage	36.3 Volts
Shot circuit current	7.84 Ampere
Irradiation	500 to 1000 wb/m^2
Temperature	25^{0}C

B. Inverter modeling

The UPS system described in this document is a three-phase VSI (Voltage Source Inverter) configuration that is commonly used in distributed generation interfaces. A PI current controller with synchronous frame was selected to control the inverter.

If the electricity generated is transferred to the grid or used by AC loads, DC converters (inverters) must be used. The inverters can be single-phase or three-phase. There are four common inverters integrated into the grid for photovoltaic systems: the central system inverter system, the string inverter system, the strand inverter system and the micro-grid inverter system (AC modules).

The central inverter is the previous technology and is based on central inverters which have a large number of photovoltaic modules connected to the grid. The photovoltaic modules are connected in series (called chain). These strings are connected in parallel with string diodes to achieve high power levels. String inverters are the current technology and are the small type of central inverter that each string connects to the inverter. Multi-string inverters have multiple strings and are connected to a common DC-AC inverter with their own DC-DC converter. Thanks to their individual controllability, string inverters are better than central system inverters. The block diagram of the grid-connected three-phase DC-AC inverter is shown in Fig. 4.

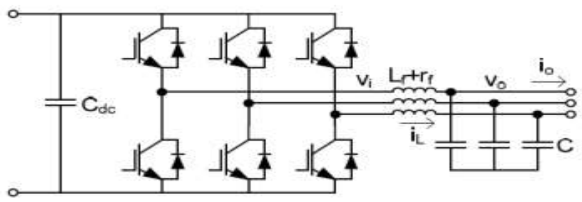

Fig. 4 Block diagram of three phase inverter.

Table 2 : Inverter Parameters

Power electronic device	IGBT/Diodes
Snubber resistance	5000 ohms
Forward voltages	0
Ron	1x10^{-3} ohms

C. Hybrid Controller

Particle swarm optimization PSO is a novel swarm optimization algorithm that is firstly proposed by Kennedy as an evolutionary algorithm based on behavior of birds. PSO uses a set of particles that each one suggests a solution to the optimization problem [10]. It is based on the success of all particles that emulates a population where the position of each particle depends to the agent position to detect the best solution P_{best} by using current particles in the population G. The position of any particle xi is adjusted by

$$x_i^{k=1} = x_i^k + v_i \quad (3.1)$$

where the velocity component vi represents the step size and is calculated by:

$$v_i^k = wv_i^k + c_1 r_1 (P_{best_i} - x_i^k) + c_2 r_2 (G - x_i^k) \quad (3.2)$$

where x is the inertial weight, c_1 and c_2 are the acceleration coefficients, r_1 and r_2 are random values that belong to the interval of [0, 1], $P_{best_i}$is the best position of particle i, and G is the best position in the entire population.

The operation shown in the flowchart can be analyzed in five phases: initialization, evaluation of physical conditions, updating of the best individual and overall value, updating of the speed and position of each particle and determination of convergence. In the first step, the particles of the distribution space are randomly initialized or initialized on the described grid nodes that embrace the search space.

Likewise, the initial speed values are set randomly. The fitness value of each particle is evaluated in the second phase, the fitness evaluation is performed in order to provide a possible solution for the objective function. The best individual and overall fitness values are determined in the third step, p_{best}_i and g_{best} are determined in each case.

Then the positions are updated and replaced with better fitness values if they are found. The velocity and position of each particle are updated in the fourth step The last step of the flowchart checks the convergence criterion. If the criterion is met, the process is finished. Otherwise, the iteration number is increased and procedure returns to step 2.

V. RESULTS

This chapter comprises with an analytical and numerical description of proposed algorithm for sentiment analysis of a power buffer which is simulated to obtain the performance of the proposed algorithm.

In order to evaluate the performance of proposed algorithm scheme, the proposed algorithm is simulated in following configuration:

Pentium Core I5-2430M CPU @ 2.40 GHz
4GB RAM
64-bit Operating System
Matlab Platform

A. *Simulation Environment*

MATLAB stands for MATrix LABoratory, which is a programming package exclusively designed for speedy and effortless logical calculations and Input/output. It has factually hundreds of inbuilt functions for a large form of computations and plenty of toolboxes designed for specific analysis disciplines, as well as statistics, optimization, solution of partial differential equations, information analysis.

In this research work MATLAB platform is used to show the implementation or simulation of implemented algorithm performance. Measurement toolboxes are used and some inbuilt functions for generating graphs are used. Simulation results and comparison of the performance of implemented model with some existing ones are calculated by MATLAB functions.

B. *Modelling of Solar System*

The solar panel has been modelled with PV arrays having 5 cells connected in each series with 66 parallel branches that together give out the DC output from the system. The variable illumination of 1000 lux is provided along with varying temperature of 25^0 C .This output is further sent to the inverter for its AC conversion. MATLAB/SIMULINK model of the system is shown in the figure below.

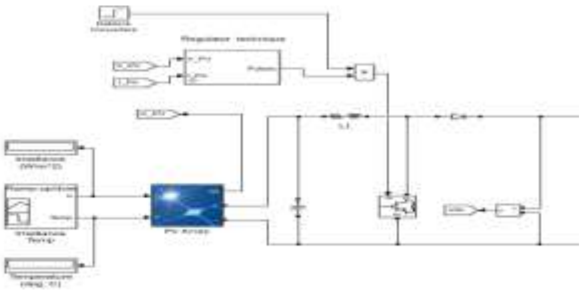

Fig. 5 Modelled Solar System in MATLAB/SIMULINK

C. *CASE 1: Solar system modeled with dual controllers for converters*

In this system the MATLAB/SIMULINK modelhas been created for the dolar energy system that is employing two controllers. The first controller is the IGBT based controller that receives the pulse from the MPPT based controlling technique. After this the DC/AC converter is designed with a voltage source controller for obtaining the required output. The two controllers work independently for achieveing the respective outcomes.

The output waveforms of the DC voltage, Ac voltage, current and active power from this sytem has been described in the figures below. The chapter also measures the dictortion level in the voltage and current waveforms to measure their effectiveness and after that compare it with the proposed controller.

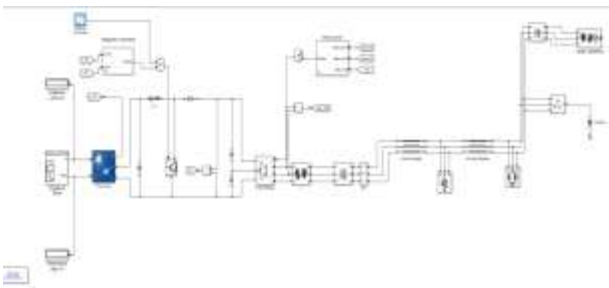

Fig. 6 MATLAB/SIMULINK model of solar system modeled with dual controllers for converters

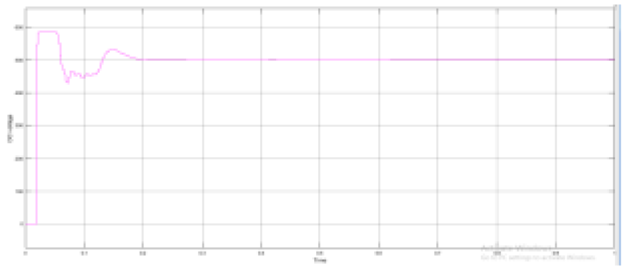

Fig. 7 DC Voltage output from the system with dual controllers for converters

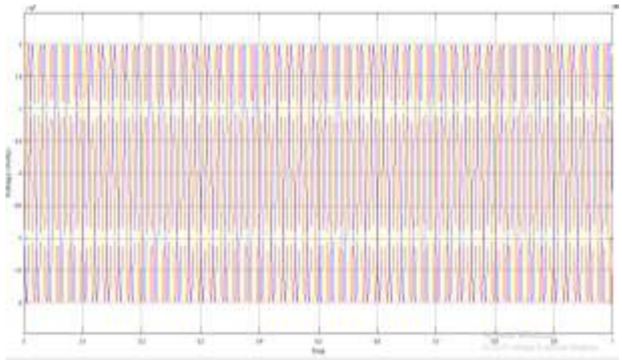

Fig. 8 Voltage output from the system with dual controllers for converters

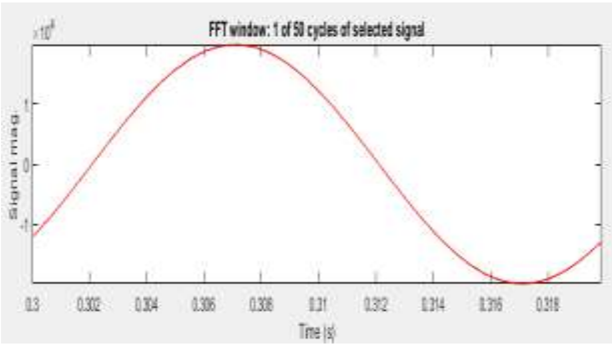

Fig. 9 FFT window of Voltage output from the system with dual controllers for converters

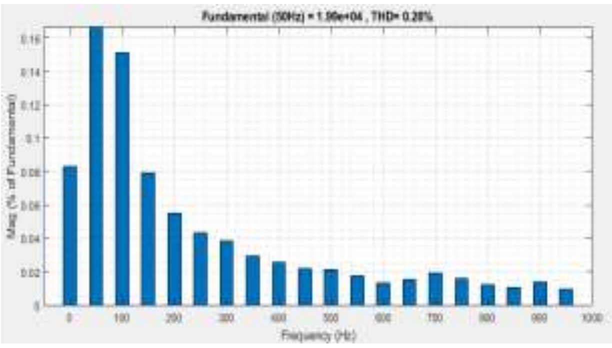

Fig. 10 THD% in Voltage output from the system with dual controllers for converters

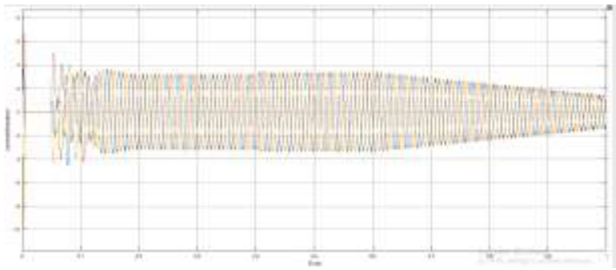

Fig. 11 Current output from the system with dual controllers for converters

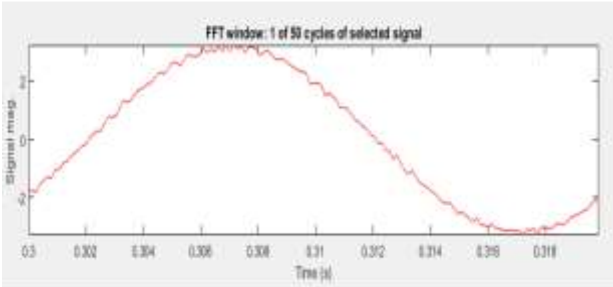

Fig. 12 FFT window of current output from the system with dual controllers for converters

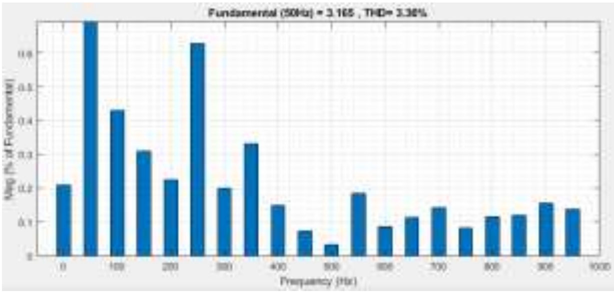

Fig. 13 THD % in current output from the system with dual controllers for converters

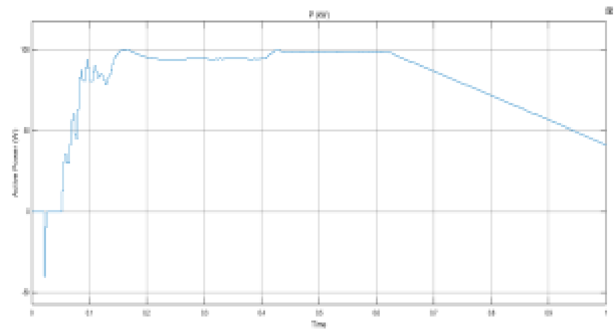

Fig. 14 Active power output from the system with dual controllers for converters

D. CASE 2: Solar system modeled with hybrid PSO integrated controller for converters

This case discusses the solar energy system modeled with proposed hybrid controlling technique. Modeling a solar PV DC network system takes place, with the possibility of using solar resources based on availability, which makes the system more reliable.

The system is being connected to the DC/AC inverter via DC/DC before its integration with the grid system. The controllers for the two converters has been designed in a hybrid integrating technique of PSO.

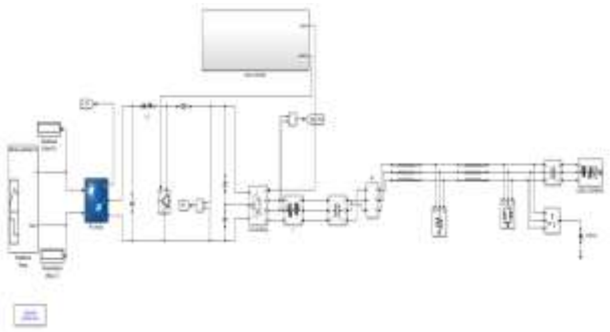

Fig. 15 MATLAB/SIMULINK model of Solar system modeled with hybrid PSO integrated controller for converters

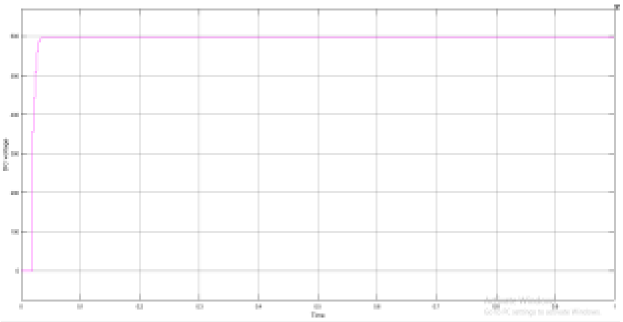

Fig. 16 DC Voltage output from the system having hybrid constrained PSO controller

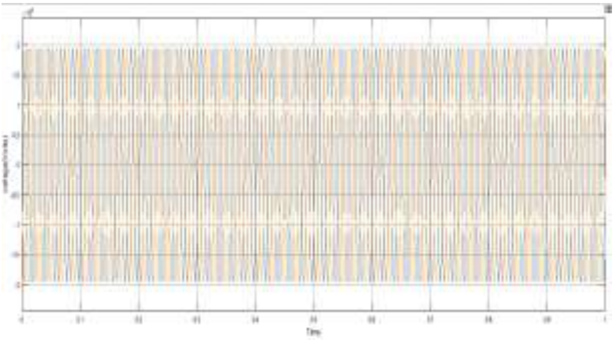

Fig. 17 Voltage output from the system having hybrid constrained PSO controller

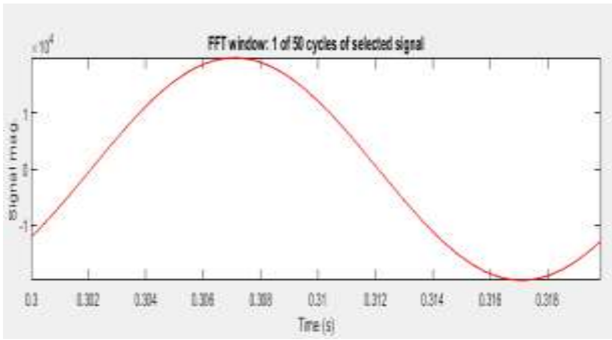

Fig. 18 FFT Window of Voltage output from the system having hybrid constrained PSO controller

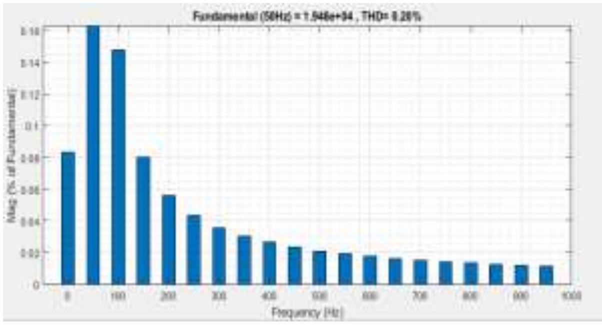

Fig. 19 THD % in Voltage output from the system having hybrid constrained PSO controller

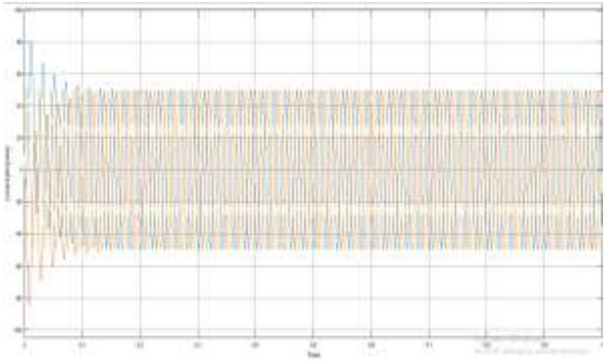

Fig. 20 Current output from the system having hybrid constrained PSO controller

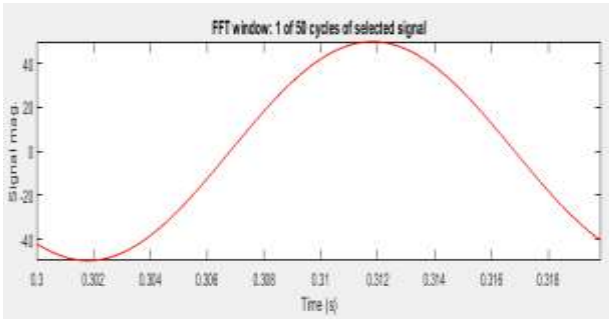

Fig. 21 FFT window of current output from the system having hybrid constrained PSO controller

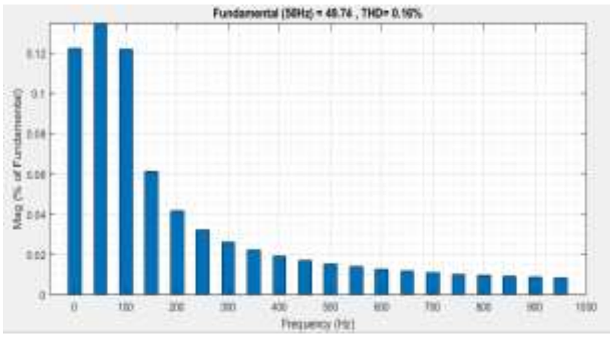

Fig. 22 THD % in current output from the system having hybrid constrained PSO controller

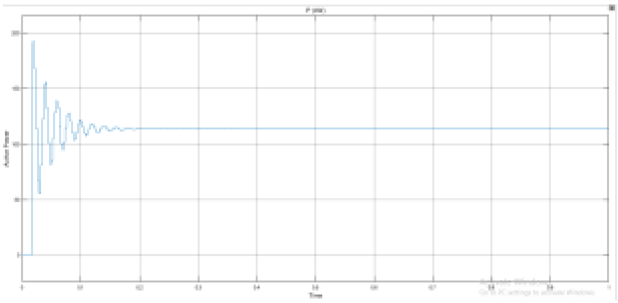

Fig. 23 Active Power output from the system having hybrid constrained PSO controller

E. Validation

The work has focused on developing a controller that can drive the two converters i.e DC/DC and DC/AC converters that are being employed in any solar energy system before its integration with the grid. This chapter emphasizes on the comparative values of various outcomes that has been derived from the solar energy system in the two cases. The chapter also discusses the variation and changes in the output when the variable radiation is taken as input to the solar system. The system response towards varying irradiation is expected to be stable when a proposed hybrid controller is designed in our work and its effect is studied.

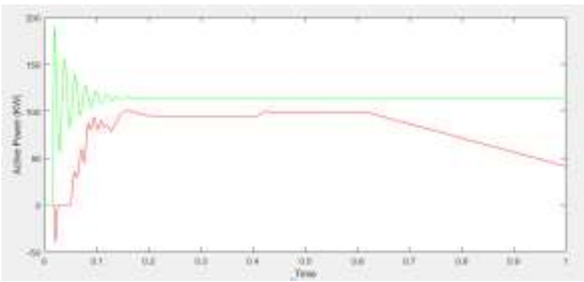

Fig. 24 Comparative analysis of Active Power output from the two system with solar PV generation

The figure depicts the graph of active power output from the solar energy systems having dual controllers for converters and that from the system having hybrid PSO integrated controller for converters. The red waveform shows the active power output from the system having dual controller for converters and is found to be approximately 100 KW varying with the changes in the input irradiation level.

The green waveform is of the active power output from the solar energy system driven by proposed hybrid PSO integrated controller for converters. The magnitude of the power was found to be slightly improved to 113KW. Not only this the power is maintained stable with the variation in input irradiation levels to the panels by the PSO based hybrid controlling technique for the converters.

The table shows the comparative values of the power output and distortion level in the voltage and current waveforms from the system having dual controllers for converters and that from the system having hybrid PSO integrated controller for converters.

Parameters	System with separate controllers for converters	System having hybrid constrained PSO controller for converters
Active Power Output (KW)	100 to 45	113
Nature of power	Varying with radiation	Stable
THD % in voltage output	0.26 %	0.20 %
THD % in current output	3.36 %	0.16 %

The table concludes that the distortion level in the voltage output and current output from the inverter is reduced by the designed hybrid PSO integrated controller for converters.

VI. Conclusion And Future Scope

The hybrid integrated constrained PSO based controller for the DC/DC and DC/AC converters was being designed for the solar PV system. The single controller has resulted in following key improvements.

- The algorithm was first incorporated with the MPPT algorithm for the boost converter which has improved the DC voltage profile from 500 V to 595 V.
- The active power output from the system has enhanced to 113KW from 100Kw which is also stable as compared to the system having dual controllers for the converters.
- The PSO algorithm is so constrained in a manner such that the output voltage and current distortion has also reduced. The voltage output distortion level from the hybrid constrained PSO controllers was found to be 0.20% which is less than 0.26% of the system having dual controllers
- Also the THD level in the current output from the hybrid PSO integrated algorithm was reduced to 0.16% from 3.36% in the solar PV system modeled with dual controllers.
- Development of the hybrid controlling technique for both the DC/DC and DC/AC converters has reduced the hardware cost of the system and two controlling techniques complications.

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