Research Journal of Engineering Technology and Medical Sciences (ISSN: 2582-6212), Volume 05, Issue 01, March-2022
Available at www.rjetm.in/

Design of a Standalone PV System with Investigating the Quality Variables at the Load Side

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Abstract: *Combining solar panels and batteries is not a new concept. In this research paper we are presenting solar energy system with battery storage system and investigating its performance in two different cases. In first case we connected solar energy system with battery controller driven by standard voltage control and in Case 2 Solar system model using Artificial bee colony optimization method for battery control and parameters regulation. The comparative analysis with respect to total harmonic distortion in current and voltage is also discussed.*

Keywords: Renewable Energy, Solar Energy System, Energy Storage system, Battery storage system

I. Introduction

Renewable energy is expanding at all scales, from rooftop solar panels on residences that really can sell electricity back to the grid to massive offshore wind turbines. For heating systems, several rural areas rely entirely on renewable energy.

Solar, windy, hydropower, biomass, geological, and oceanic renewable energy systems are divided into five groups. Various energy conversion devices exist to convert renewable energy sources into valuable products.

Solar energy can be used in both thermal and electrical applications. Traditional solar energy methods are great for providing electricity, heating, chilling, and fresh water in residential settings. Concentrating solar energy collectors can power a variety of industrial activities that require medium-high temperature. In addition, concentrating photovoltaic (PV) systems have far better solar-to-electricity conversion efficiency. The extra heat can be used for various purposes such as chilling, distillation, and so on.

Solar photovoltaic module creates power, and they're only one of several components in a comprehensive photovoltaic (PV) system. A number of different technologies must be in place before the electricity produced may be used in a home or company.

PV arrays must be supported by a robust, long-lasting framework that can endure winds, rain, hail, and corrosion for decades. The PV array is tilted at a fixed angle defined by the local latitudes, structural orientations, and load power needs. Modules in the northern latitudes are aimed due south and slanted at an inclination equivalent to the local latitude to get the highest annual power generation. Rack mount has been the most popular approach due to its durability, versatility, and ease of construction and installation. Methods that are more complex and less expensive are still being developed.

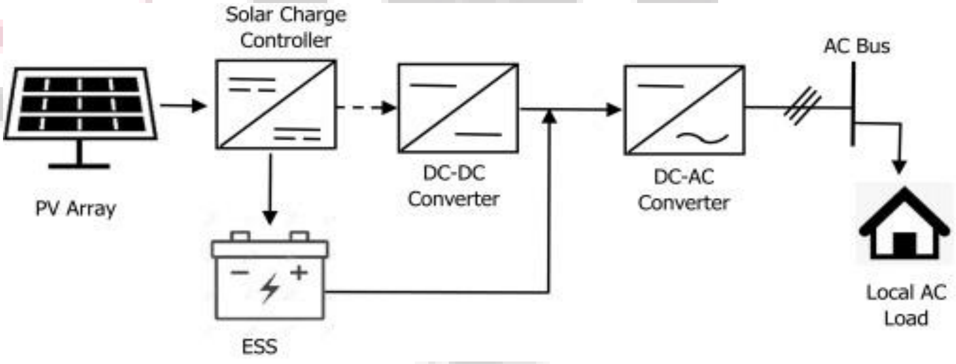

Figure 1: Solar PV system connected to load.

Photovoltaic systems have exploded in popularity as a result of the global shift to renewable energy and reductions in carbon emissions, and have proved them as a proven technology for generating electricity.

The irradiance, temperatures, and present pulled from photovoltaic panels determine the amount of energy provided by a PV system with one or more cells. To get the most power out of these technologies, Maximum Power Point Tracking (MPPT) is used. MPPT is useful in applications including putting power on the network, charging battery, and powering an electric generator..

Combining solar panels and batteries is not a new concept. Early solar pioneers frequently connected the solar panels to a series of marine energy storage systems. That would be the only option to consume stored solar electricity at night before smart metering became popular. The premise of modern battery energy storage is same, but they are far more complicated and efficient. If ancient batteries array were just like flip phone, new battery energy storage systems are like the newest smartphones - they both do the same things, and everything else is different.

A built-in inverter and computerized management systems are common features of modern battery energy storage systems. This implies they're all-in-one, turnkey solutions that are straightforward to install, mostly maintenance-free, and don't require the owner's time or knowledge.

The uses of battery energy storage systems are numerous. Peak shaving, load shifting, emergency backups, and dataset includes services are examples of business application. Self-consumption, off-grid houses, and emergency backup are examples of residential applications.

II. Literature Review

Grasshopper Optimization Algorithm (GOA)[1] tuned MPPT technique for controlling a DC–DC boost converter with the goal of getting the optimum duty cycle, D. Using the MATLAB Simulink framework, the present scheme is analyzed and compared to the traditional Perturb and Observe (P&O) based MPPT and the well-known Particle Swarm Optimization (PSO) based MPPT automated system under start-up transients, line disruptions, load variations, servo circumstances, and partially shaded situations. In comparison to P&O and PSO based MPPT algorithms, the suggested GOA adjusted MPPT technique provides good steady state and dynamics responsiveness, as measured by rising time, small steady state, percentages maximum overshoot, Integrated Squared Error, and Leading To structural Error.

(Saidi, 2021) [2] The influence of the STATCOM control system on avoiding pure voltage compensation while injecting voltage STATCOM with harmonics is also investigated. The 53-Bus Tunisian distributing electric grid with a 12 MW solar PV facility is the planned testing method under consideration. The proposed control strategy for improving power distribution quality is dependent on the Tunisian grid code is shown to be effective using simulation data. The dynamic response of the voltage is highly influenced by the electrical program's fault current capability at the site of PV integration, according to a study on voltage control.

(D. Verma et al., 2022) [3] introduces a maximum power point tracking (MPPT) method for solar photovoltaic (SPV) systems that uses fewer sensor, is simple to install, and provides good tracker performance and effectiveness. The perturb and observe (P&O) algorithm is perhaps the most popular MPPT algorithm in the literature because it requires less provided an extensive and is simple to implement. However, it suffers from fast-changing environmental circumstances, especially in shading conditions, and it takes two detectors, namely voltage and current. This research describes a sensor-based technique based on a redesigned conversion design that avoids the effects of partial shading and rapidly changing environments.. Using an FPGA-based NI-sbRIO card and Labview software, the given MPPT algorithm was developed and evaluated.

(Taghavifar & Taghavifar, n.d.)[4] We offer a unique adaptive resilient control framework for PV-battery system energy management under a variety of operating situations and unmodeled dynamical. Using a multi-rate converging adjusting mechanism for the sliding surface, an enhanced exponential-like adaptive integral sliding mode (EISM) controller linked to neural net approximator is developed to improve the closed-loop program's transient response. Moreover, unlike prior studies that merely considered parameter uncertainty, the full dynamics of the hybrid power system is deemed uncertain. The program's global asymptotic stability is ensured, and the efficacy of this unique framework is evaluated against benchmarking studies.

(P. Verma et al., 2021)[5] The MPP is maintained by a deep neural network based estimate, and reserves is adjusted to use a fuzzy reserve controllers in a novel deloading based energy regulation approach for dc/dc converter. When comparing the suggested control to the mainstream resource methods, the adequacy of the accepted reserve control method is demonstrated. Simulations and experimental findings are used to verify the functionality of the created controllers.

(Oliveira et al., 2021)[6] compares four multipurpose grid-tied photovoltaic (MPV) systems, split into single-stage and double-stage topologies. The features include active electricity production and injections into the power system, and also active power conditioner, which includes power factor and loading unbalanced compensation, and also suppressing of activity that contributes current flow. Beyond the traditional purposes of photovoltaic (pv) systems, MPV systems also contribute to enhance energy quality metrics. Two energy inverter setups are built using single complete (1-FB) inverters.Three 1-FB inverters share a DC-bus in the first, known as MPV-FB, while each of the three 1-FB inverters has its own DC-bus in the second, known as MPV-3FB. Each inverter configuration incorporates solitary and the double MPV architectures, in which the photo - voltaic array has been directly connected to the inverter DC-bus in the single-stage configuration, and a step-up DC–DC converter is implanted between both the photovoltaic panels and the inverter DC-bus in the DS arrangement.

(Chtita et al., 2021)[7] provides a better balance of power control method based solely on two proportional and integral (PI) compensators, capable of properly balancing the PV power flow given to the DC load and the batteries, allowing the PV power to be effectively employed and the power supply to be properly charged. To make the building of the PI compensators easier, the complete system is first modeled using the linear PV array model. In additional, four working modes have been developed to address the aforementioned concerns with temperature and load requirement and expectation. Maximum Power Point Tracking (MPPT) mode, Non-MPPT mode, Night-mode, and Off-mode are the four options.Following that, a digitally anti-windup control scheme involving PI converters is created to enable a smooth transition from one operating mode to the next. Furthermore, to extract the most voltage of the Pv array, an enhanced Intermittent Conductance IC-MPPT method is used.

(Joshi et al., 2021)[8] Renewable energies are one of the most promising alternatives for meeting the world's constantly rising electricity demand. Because solar and wind are complementary in nature, a hybrid model combining the two provides a viable solutions for independent applications. The addition of a battery energy storage system boosts the overall program's reliability and quality. When power generation is less than load required, the battery is utilized to store additional electricity and return it to the network. This paper proposes control strategies for improving voltage stability in a standalone hybrid system during transients, which have been evaluated using MATLAB/SIMULINK software.

(Yan et al., 2021)[9] This research proposes a hybrid control technique for a PV and battery energy storage system (BESS) in a stand-alone dcMG. Unlike traditional control methods that solely use the BESS to manage the dc-link voltage, the suggested control approach uses both the Photovoltaic systems and the BESS to regulate the dc-link amperage. The PV serves as a primary dc voltage regulation, allows the batteries to function as a secondary dc voltage supervisory authority. As a consequence, the proposed control method reduces the BESS's use in order to extend its lifetime while keeping the current battery state of charge (SoC) within a targeted range.To do this, the PV system uses the flexible power point tracking (FPPT) idea to improve the dcMG's dynamic response by adaptively altering the Maximum power point according to the load curve.

(Abianeh & Ferdowsi, 2021)[10] intends to improve the regulation of HESS in an islanded DC microgrid with pulsating power demands. Whereas the Power generating unit is the primary source of energy, a batteries and super - capacitors combo is used to effectively meet the extra power demands under various loading situations. The traditional low pass filtration strategy for isolating the averaged and transitory HESS current components is substituted with a flat rate limitation to determine the correct batteries flow velocity. The issues of non-systematic cut-off frequency selection are alleviated by eliminating the low pass filter (LPF), as more concrete elements, such as batteries flow velocity, can be used for decoupled purpose.

II. Methodology Used

This section contains an analytical and numerical explanation of the proposed algorithm for UPFC sentiment classification, which is modeled to determine its effectiveness.
A converters and transformers connects the large-scale solar power system. The power factor correction device UPFC is linked to the grid to improve the transitory voltage regulation of the massive solar systems. The compensation is offered for improving output parameters such as THD in voltages, THD in flow, and reactive output power.

PV cells have a single operational point when the cell's current (I) and voltage (V) produce the maximum amount of electricity. These numbers correspond to a certain resistance, which is V/I. Figure 6 depicts a simple PV cell equivalent resistance.

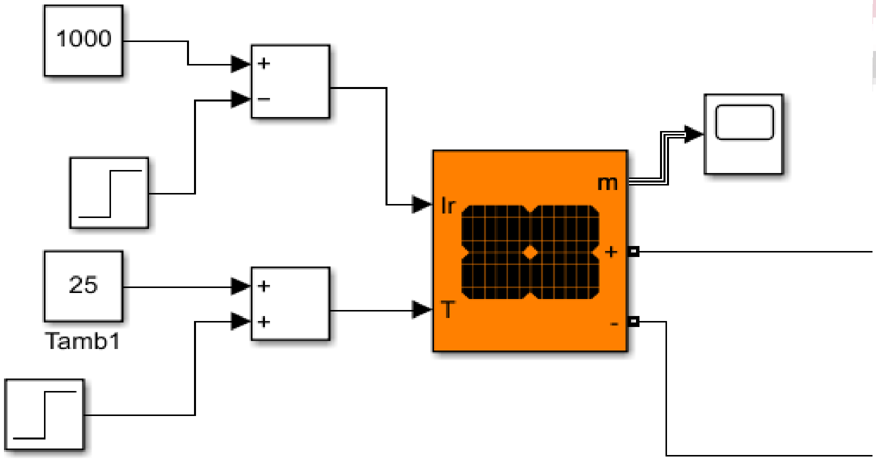

Figure 2: Modeled solar systems

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

BMS is defined differently depending on the specific application. BMS is a management scheme that monitors, manages, and optimizes the operation of an independent or many battery modules in an energy storage device. In the event of faulty condition, the BMS can command the module(s) to be disconnected from the system. It's being used to promote performance of the battery in systems with suitable safety measures. The BMS is used in an energy system is to monitor, regulate, and supply the current battery energy at maximum efficiency (battery life is also considered here).BMS is utilized for power management in various network equipment in car application and ensures the program's safety from possible threats. BMS is made up of different functional blocks. BMS functionality blocks are linked to battery and other organized system components such as controls, grids, and other available materials.

IV. Result

This chapter includes a numerical and analytical explanation of the suggested algorithm for sentiment classification of an energy buffers, which is simulated to determine its effectiveness.

PV arrays with 10 cells in each series and 40 parallel branches have been used to represent the solar panel, which together produce the DC output of the system. Variable illumination of 1000 lux is available, as well as a temperature range of 250 C. This output is then combined with the renewable power program's DC output and routed to the inverters for AC conversions. The DC output waveform is depicted in the diagram below.

The analysis was carried out in the MATLAB environment using the SIMULINK capability, and two models were created and produced, one of which included solar system modelling in autonomous mode with battery backups. The main goal is to create a control at the DC end of the system that is also effective at the load terminal for energy quality assurance. The goal is achieved by designing the model in the following two scenarios:

Case 1: Solar system model using battery controller driven by standard voltage control

Case 2: Solar system model using Artifical bee colonyoptimisation method for battery control and paramters regulation

Modelling of Solar power system in standalone mode in case 1

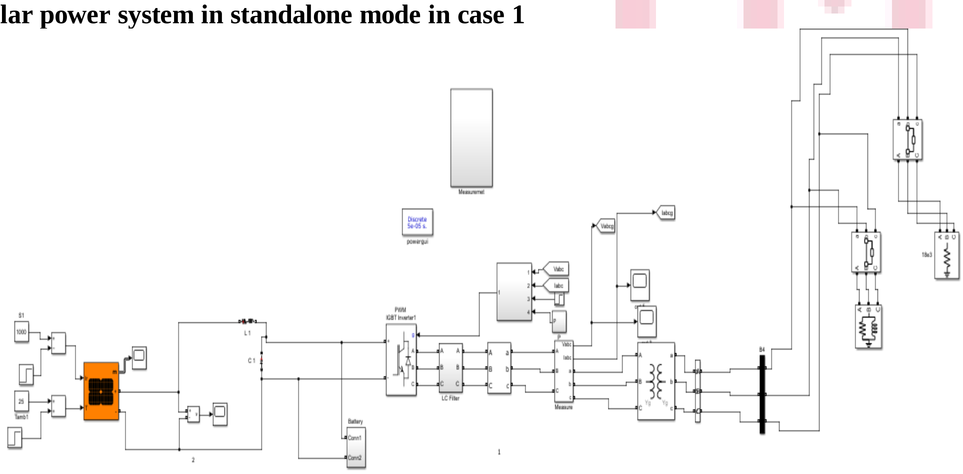

Figure 3: Solar power system modeling with battery controller driven by standard voltage control

The system was modeled utilizing a solar power system with a battery pack and a control well before converters, with the load being fed straight from the grid. This systems has photo voltaic electricity production, which is driven by an inverter for DC to AC conversions of the solar program's energy power.

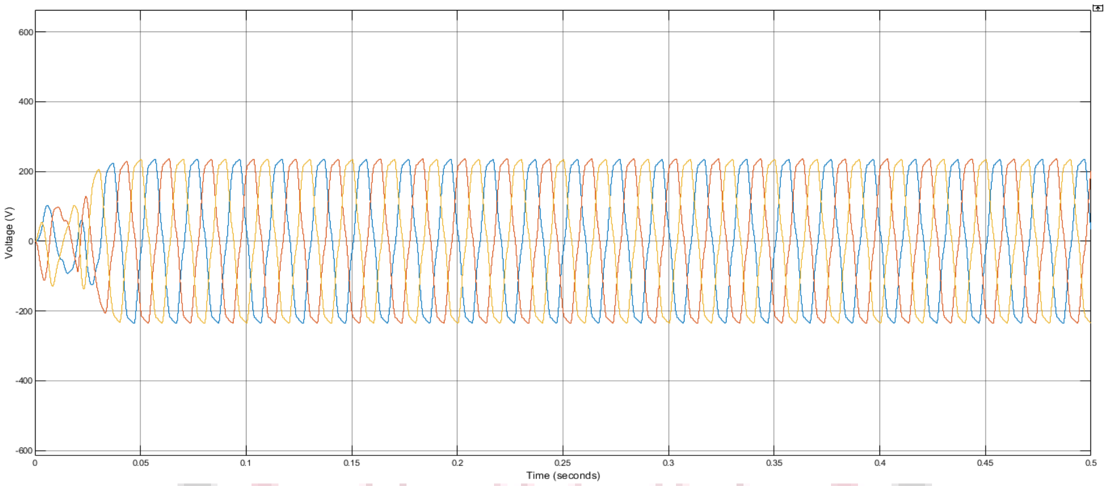

Figure 4: Voltage output available at the load bus in case 1

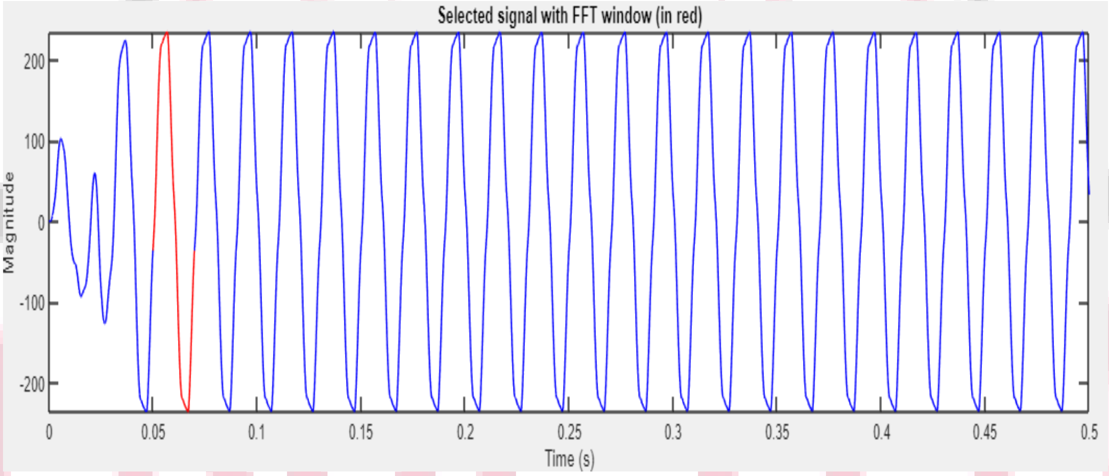

Figure 5: FFT analysis of load voltage in case 1 with battery controller driven by voltage regulation control

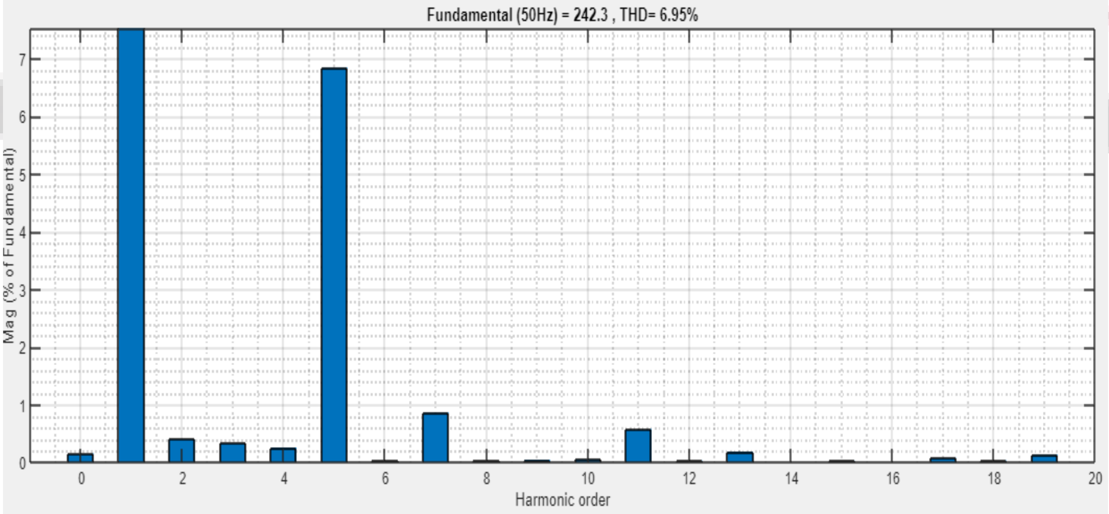

Figure 6: THD% of load voltage in case 1 with battery controller driven by voltage regulation control

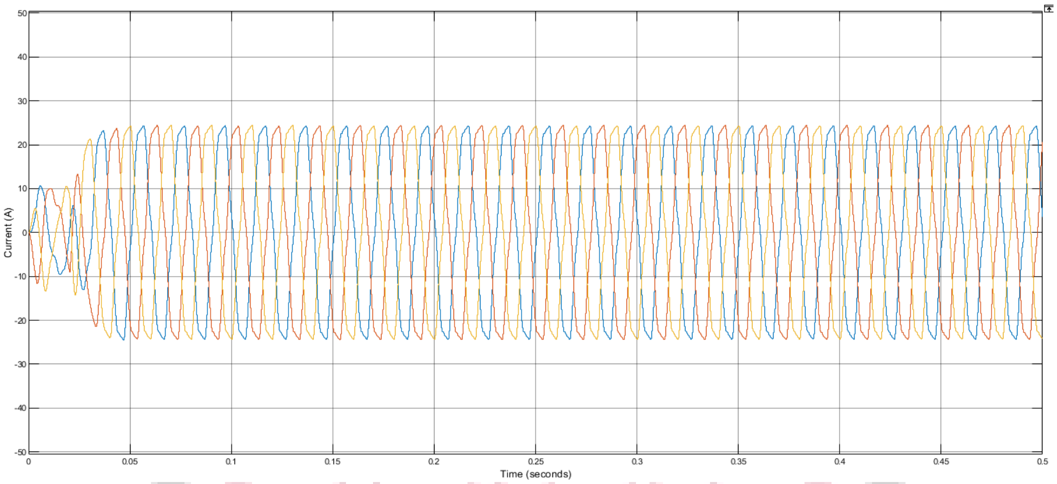

Figure 7: Current output available at the load bus in case 1

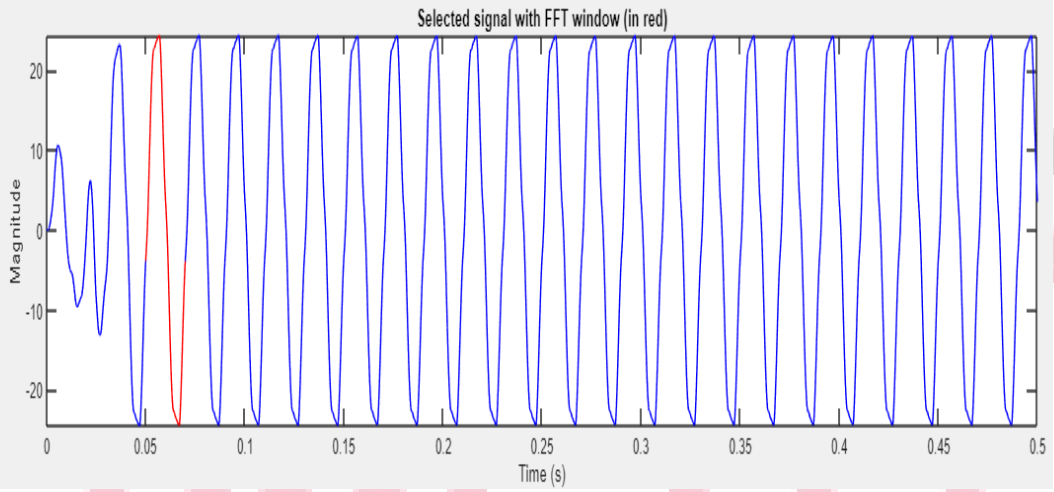

Figure 8: FFT analysis of load current in case 1 with battery controller driven by voltage regulation control

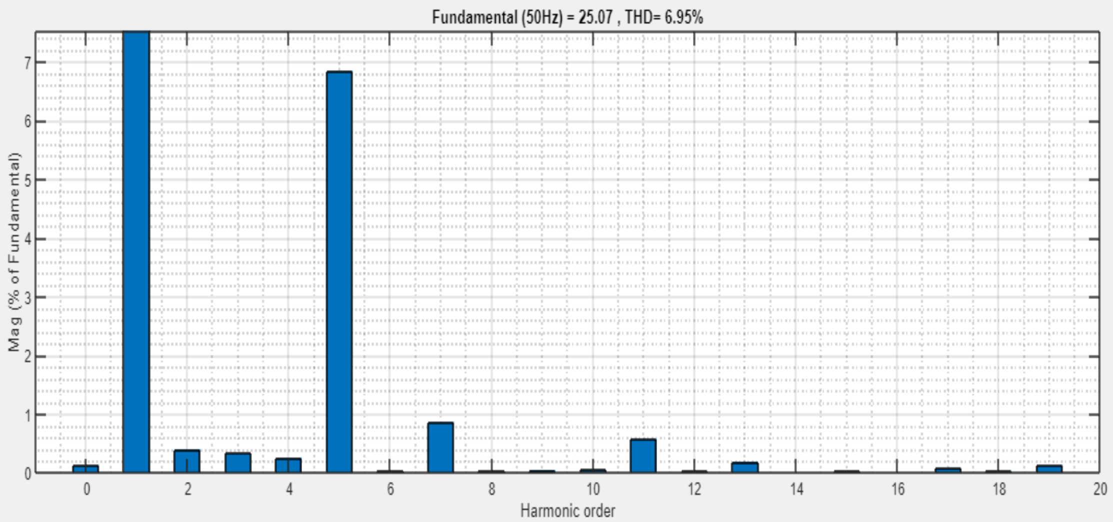

Figure 9: THD% of load current in case 1 with battery controller driven by voltage regulation control

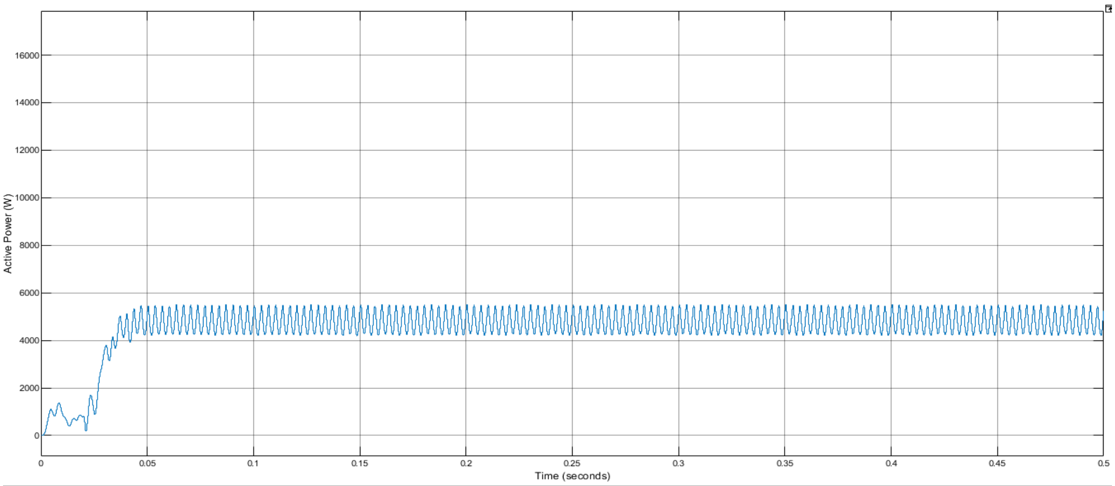

Figure 10: Active Power output available at the load bus in case 1 with standard voltage controller

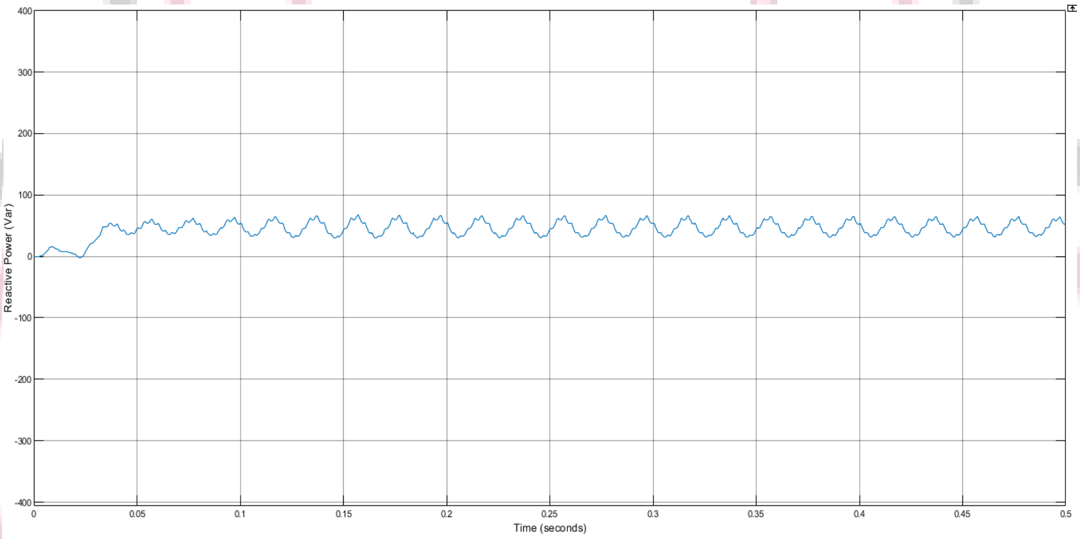

Figure 11: Reactive Power output available at the load bus in case 1

Modelling of Solar power system in standalone mode in case 2

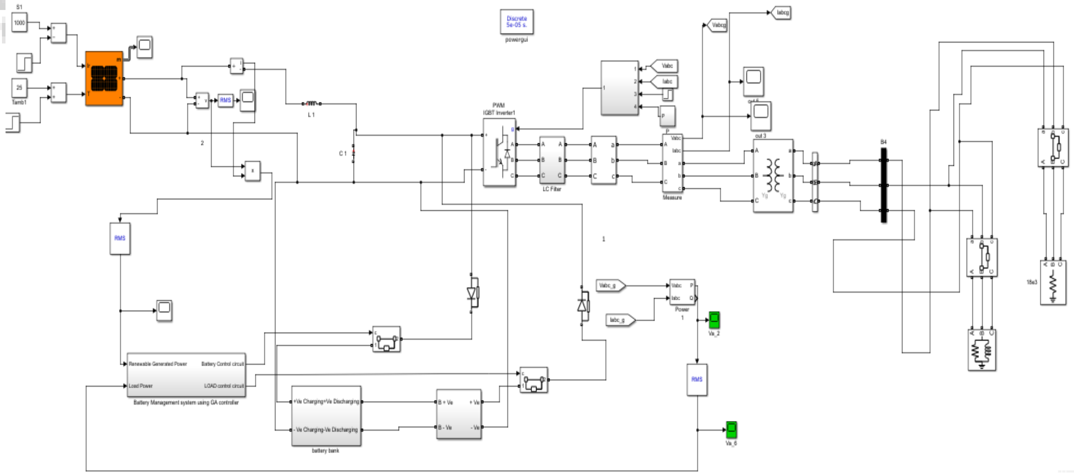

Figure 12: Solar system model using Artifical bee colonyoptimisation method for battery control and paramters regulation

In this scenario, the system is modeled with sun's electricity and a batteries controllers whose regulatory parameters are constantly evaluated and modified using an artificial bee colony optimization method that produces better loading bus results. The suggested controllers is intended to successfully handle power flow to the loads under both continuous and switching conditions. The optimization process used in the batteries controller records and corrects the AC power supply. The waveforms of voltages current, power factor, and reactive power were also examined.

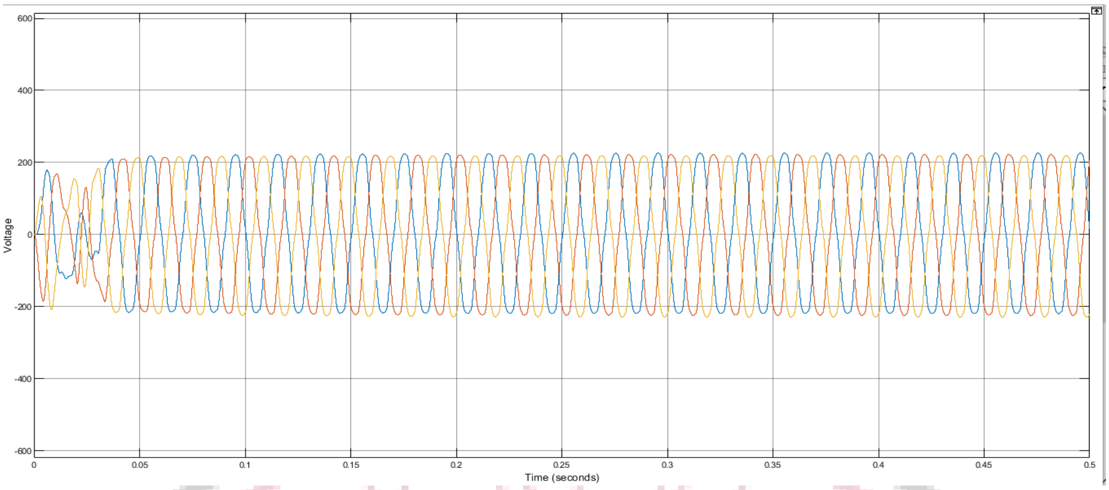

Figure 13: Voltage Output available at the load bus in case 2

The three phase AC voltage is represented by a set colours for every phase and has a magnitude of roughly 230 V for work in Figure 13. This power supply is examined in a PV system with a control that is driven by a suggested ABC-based battery optimisation controller.

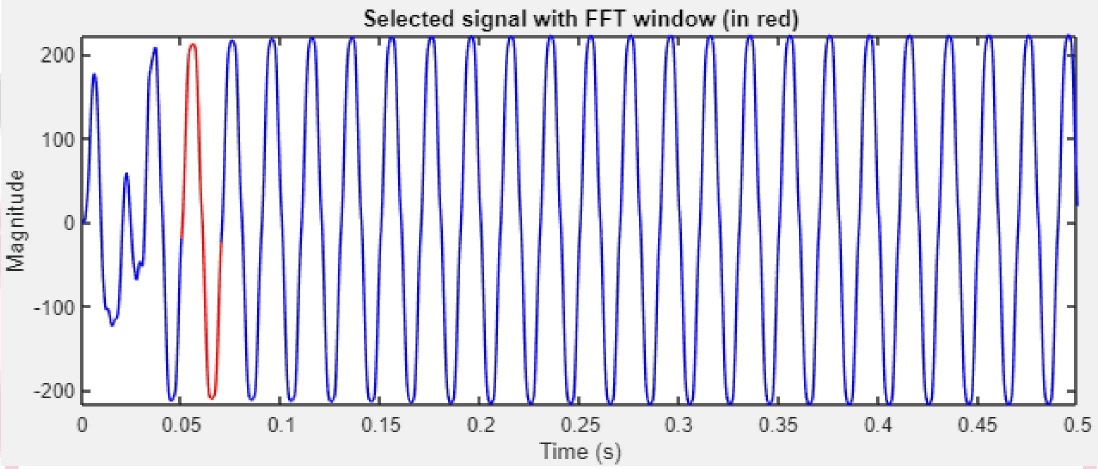

Figure 14: FFT analysis of load voltage in case 2 with battery controller driven by ABC algorithm

The FFT analysis of the three phase AC voltage for every cycle in the system is depicted in Figure 14, which is examined with a controllers powered by the suggested ABC algorithm and is then utilized to calculate the total harmonic current level in this systems.

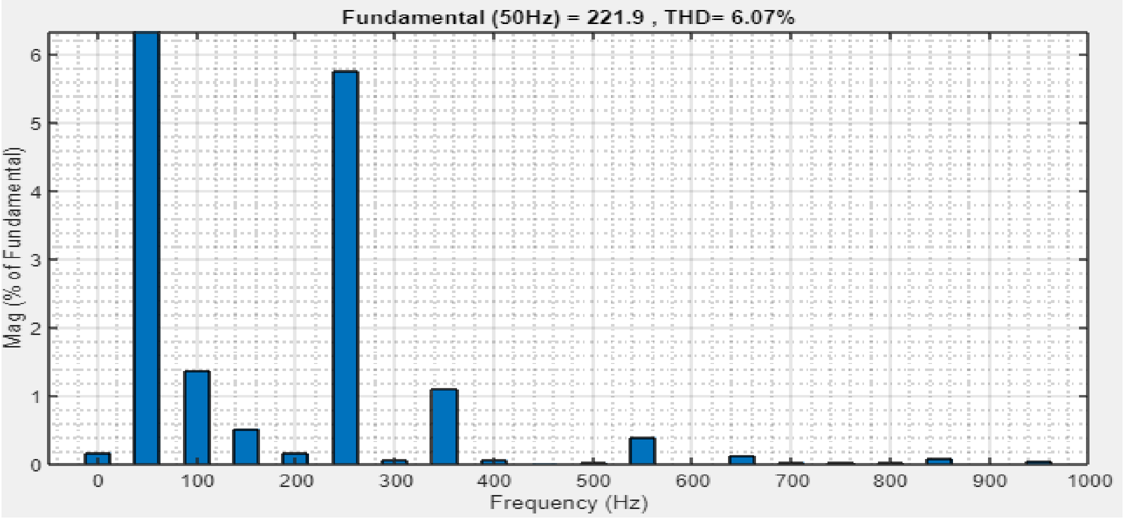

Figure 15: THD% in load voltage in case 2 with battery controller driven by ABC algorithm

The FFT analysis of the three phase AC voltage for every cycle in the system is depicted in Figure 15, which is examined with a controllers powered by the suggested ABC algorithm and is then utilized to calculate the total harmonic current level in this systems.

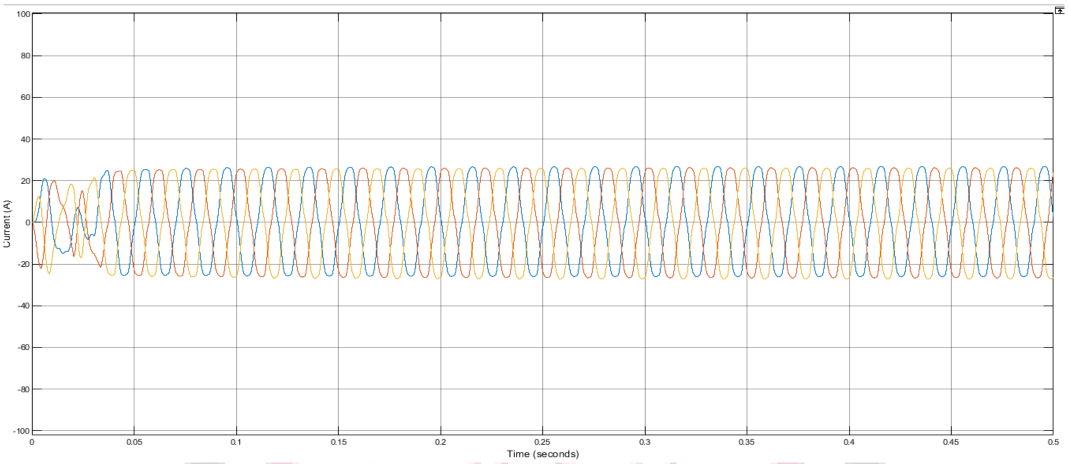

Figure 16: Current Output available at the load bus in case 2

Figure 16 depicts a three-phase AC current with three primary colors for each phase. In a PV system, the current output is assessed using a control driven by a suggested ABC-based batteries optimisation controller.

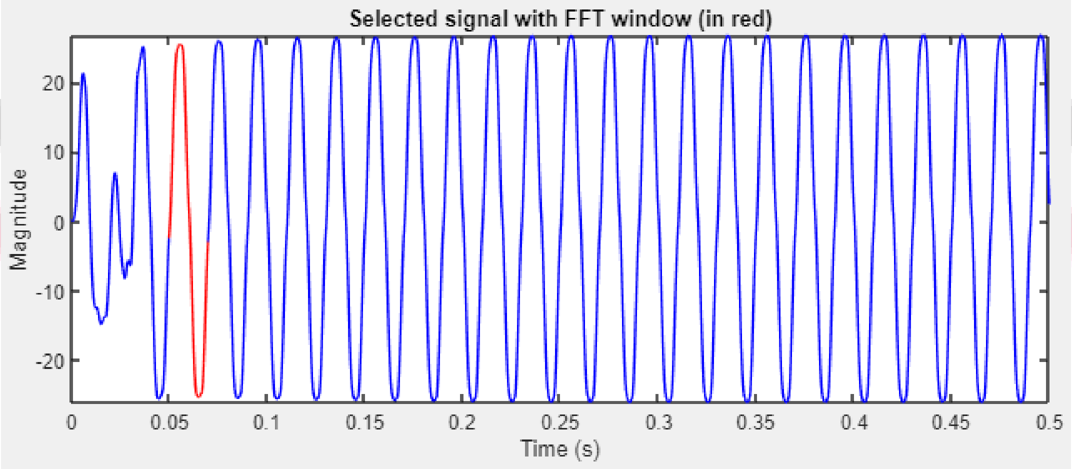

Figure 17: FFT analysis of loadcurrent in case 2 with battery controller driven by ABC algorithm

The FFT assessment of the three phase AC voltage for each cycle in the system is depicted in Figure 17, which is examined with a controllers powered by the proposed ABC algorithm and is then utilized to calculate the total harmonic distortion levels in this systems.

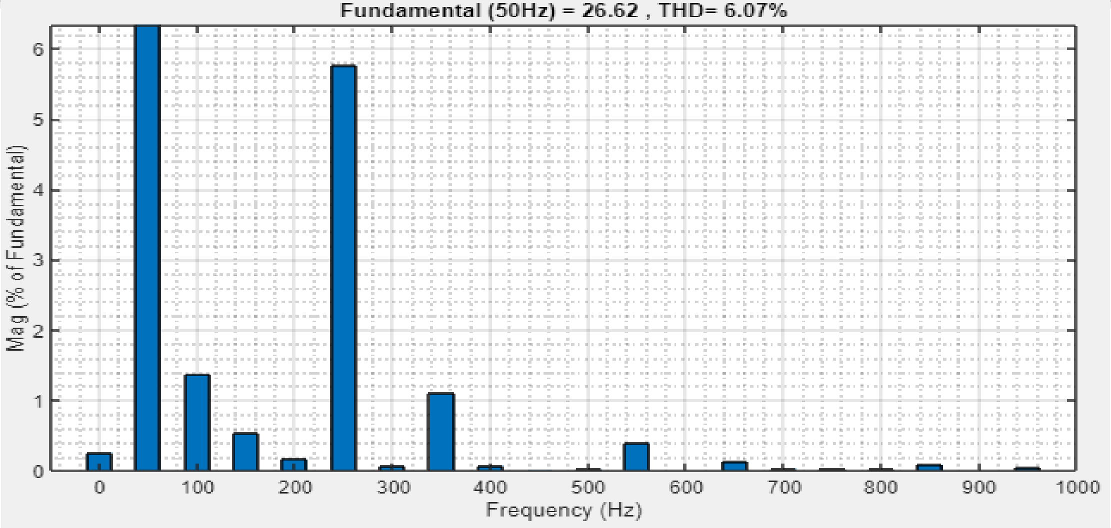

Figure 18: THD% in load current in case 2 with battery controller driven by ABC algorithm

The THD% is calculated in the software which comes to be 6.07% in current waveform in system having battery system with ABC algorithm for load management and higher order harmonics are reduced in them.

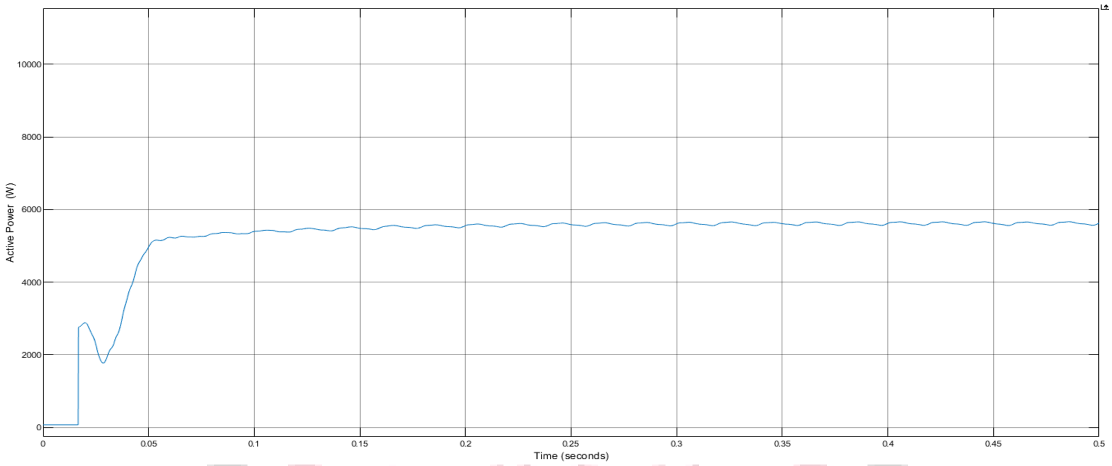

Figure 19: Active Power Output available at the load bus in case

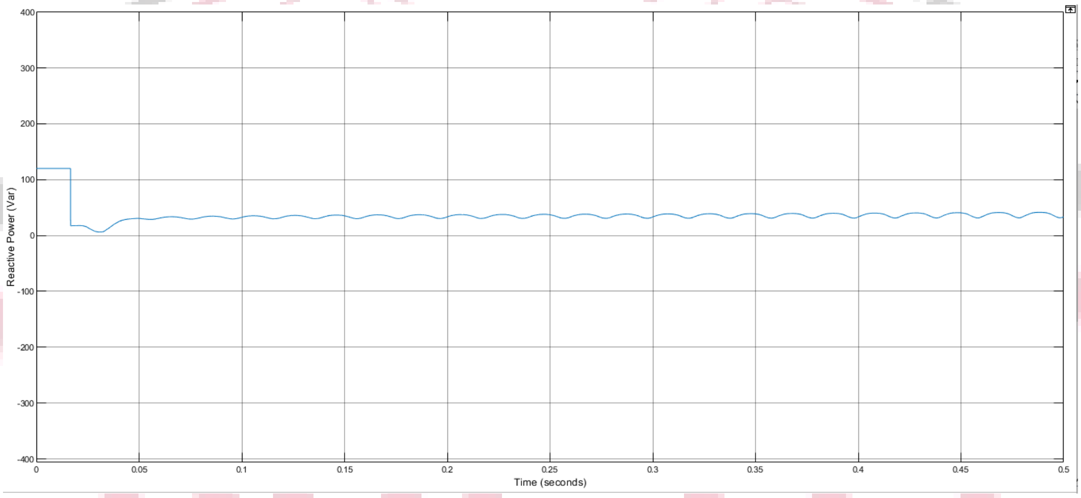

Figure 20: Reactive Power Output available at the load bus in case 2

Scenario 2: Analyzing the load swiching parameters effect in system with battery backup havaing different controls

The progressions in the current (I) waveform in the reach where the load was quickly moved to the lines were explored for this investigation. As a result, a three-phase breakers with a varying loads was used, with the continuity equation remaining in the off position. The breakers acts as a switch in seconds, as well as the load is moved to the solar PV system's line. At these switching points, the voltage remains constant at 230 volts. After 0.4 seconds, the load is abruptly withdrawn from of the line, and the present waveform show commensurate change.

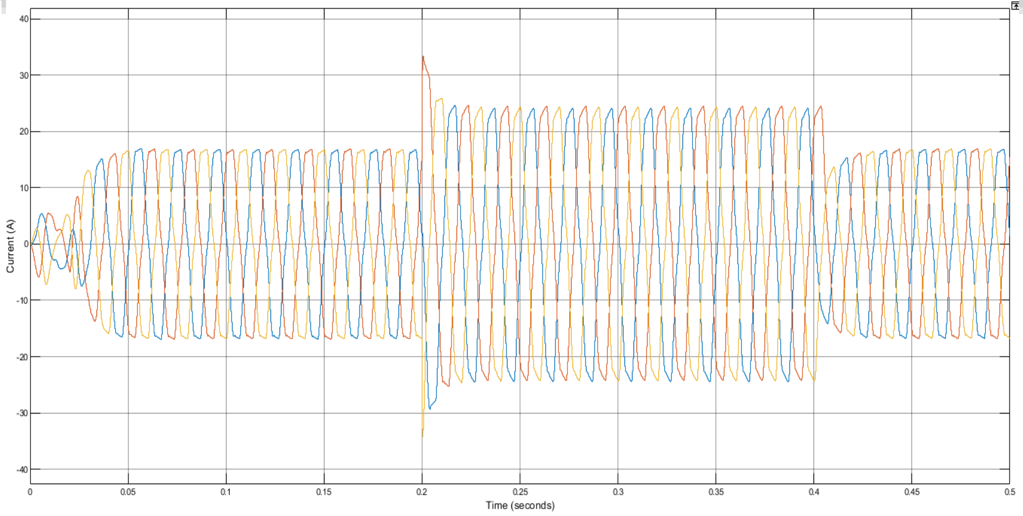

Figure 21: Current O/P from the PV system with battery controller driven by voltage regulation control during loading condition

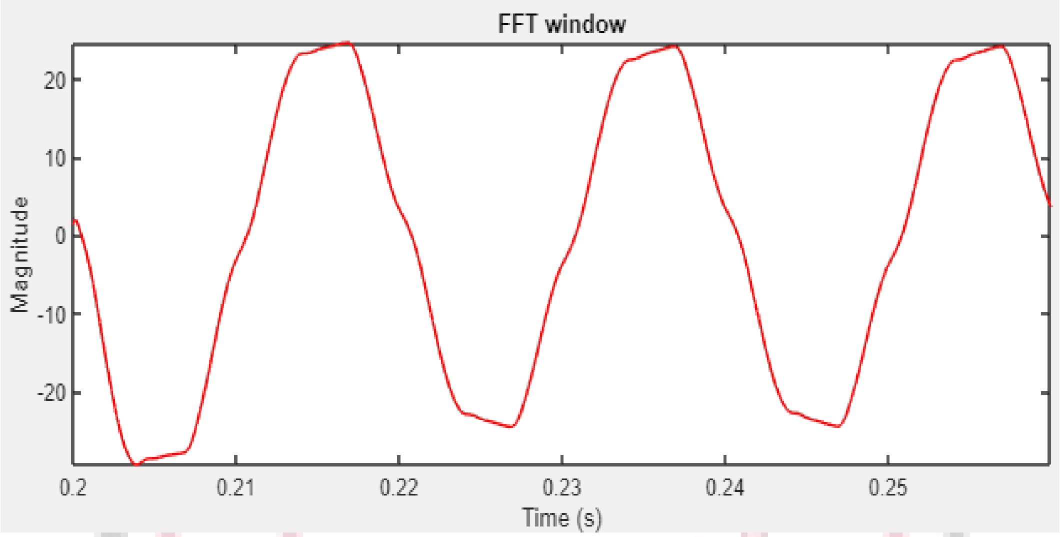

Figure 22: FFT analysis of Current O/P from the PV system in case 1 at 0.2 second loading point

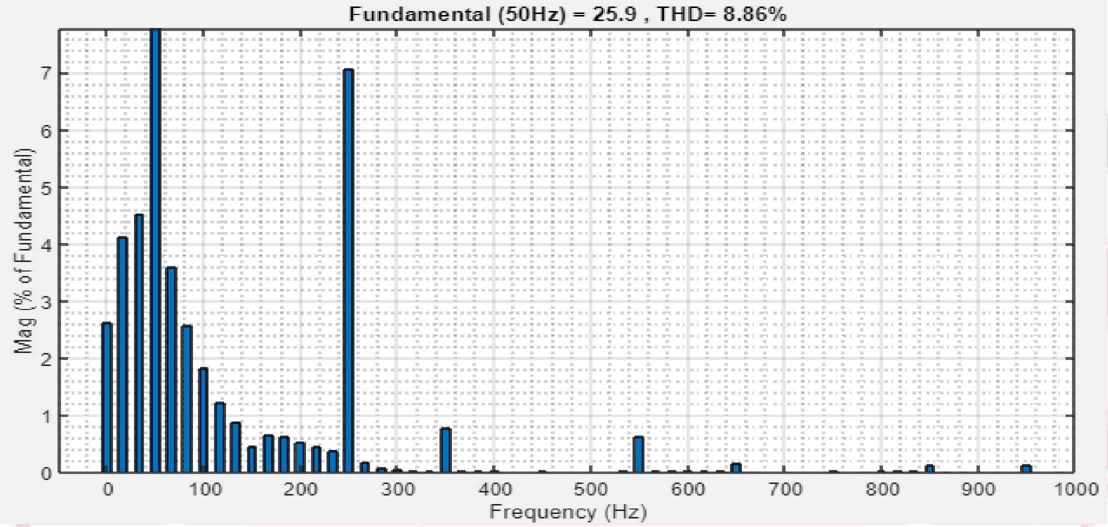

Figure 23: THD% in Current O/P from the PV system in case 1 at 0.2 second loading point

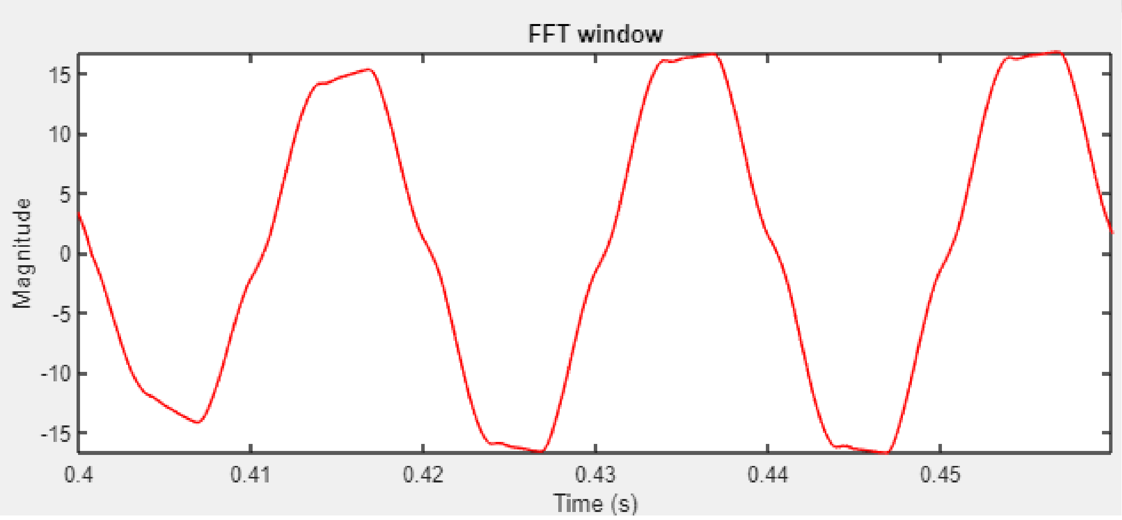

Figure 24: FFT analysis of Current O/P from the PV system in case 1 at 0.4 second off-loading point

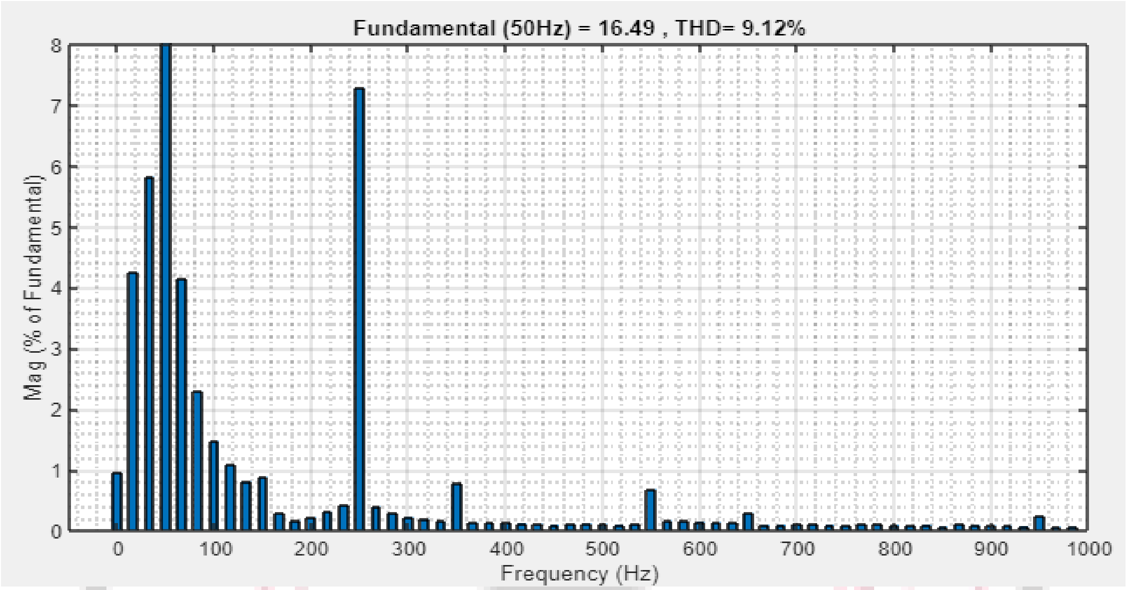

Figure 25: THD% in Current O/P from the PV system in case 1 at 0.4 second off-loading point

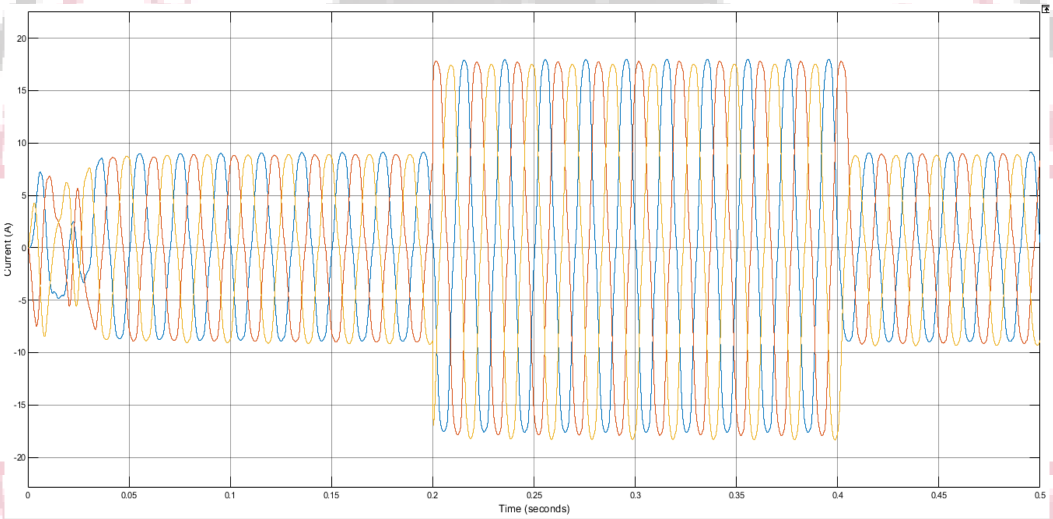

Figure 26: Current O/P from the PV system with battery controller driven by proposed ABC control during loading condition

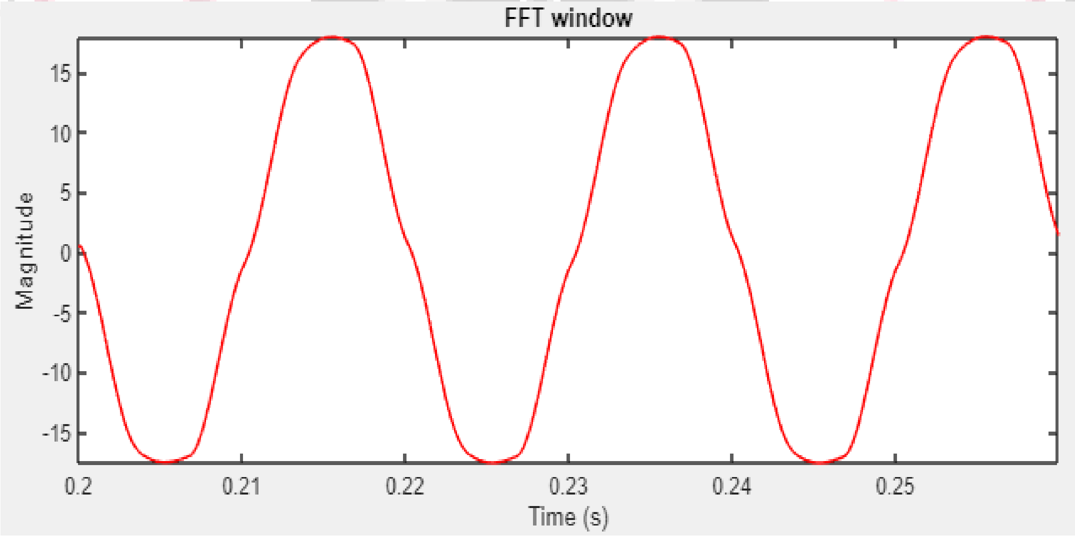

Figure 27: FFT analysis of Current O/P from the PV system in case 2 at 0.2 second loading point

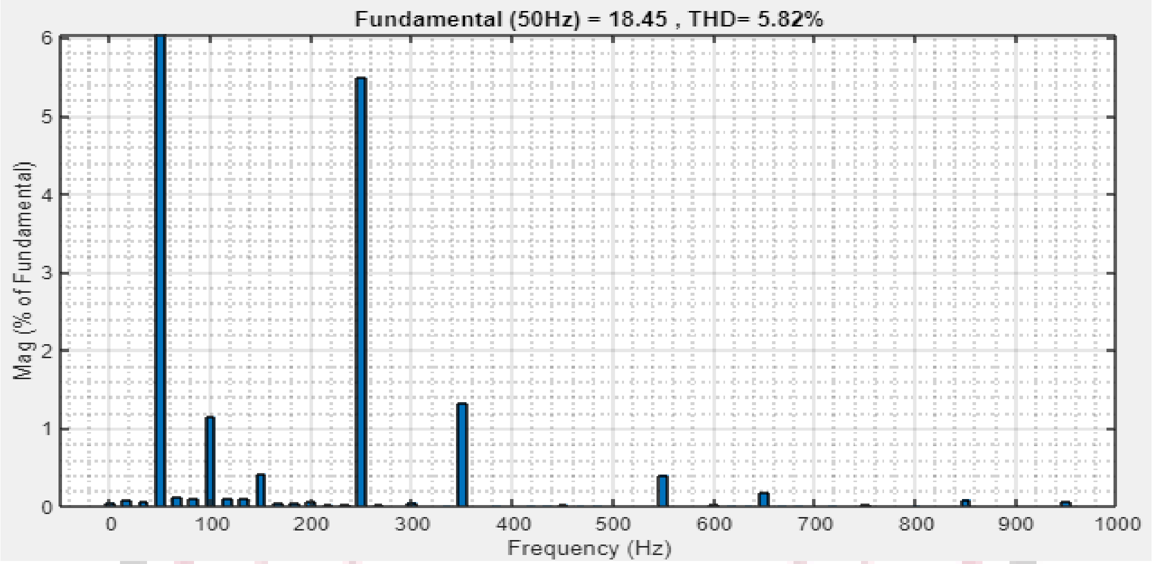

Figure 28: THD% in Current O/P from the PV system in case 2 at 0.2 second loading point

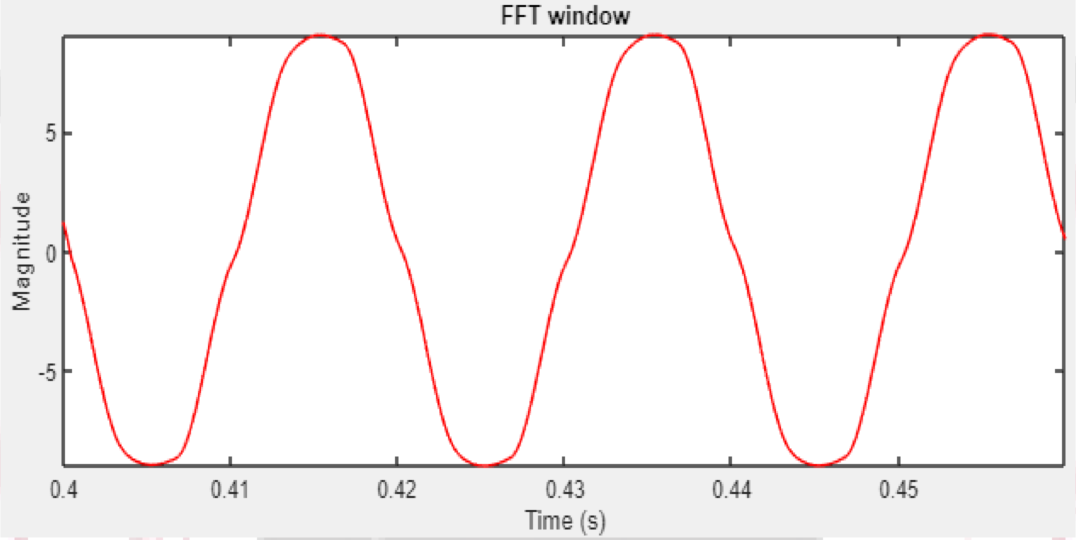

Figure 29: FFT analysis of Current O/P from the PV system in case 2 at 0.4 second off-loading point

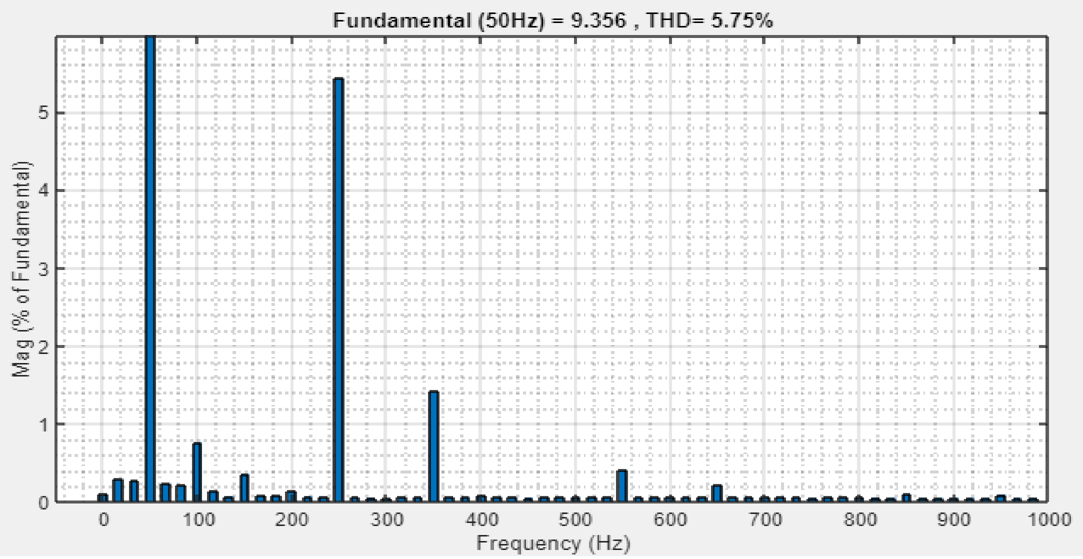

Figure 30: THD% in Current O/P from the PV system in case 2 at 0.4 second off-loading point

Comparative analysis of proposed controller table:2		
Parameters	**Case 1**	**Case 2**
Active power	77000 Watts	78780 Watts
Reactive power	11900Var	9200Var
THD% in voltage	1.08 %	0.08 %
THD% in current	1.11 %	0.53 %
Transient loading comparison		
THD% in current (loading point)	0.46 %	0.46%
THD% in current (off-loading point)	0.96%	0.93%

V. Conclusion

The analysis was carried out in the MATLAB environment using SIMULINK capability, and two models were created and produced, one of which included complete solar modelling in standalone mode with battery backup. The controllers in this model is developed at the DC point and is also efficient at the load end for energy quality assurance. In two circumstances, the research goal is addressed by designing the designs: Models of solar systems with battery controllers powered by conventional voltage control and models with artificial bee colony optimization methods for battery control and parameter regulating. This work added to the current body of work by suggesting an optimal design for energy PV systems using methodological approach and numeric values analysis, as discussed in previous chapters.

- When a solar PV system uses a batteries controllers with conventional voltage regulation, total harmonic distortion (THD) in the voltage is 1.08 percent. In the identical situation, Total Harmonic Distortion (THD) in current is 1.11 percent. THD is 0.46 percent in the loading situation and 0.96 percent in the unloading state.
- When a Solar PV system applies an artificial bee colony optimization approach for integrated control and parameter adjustment, total harmonic distortion (THD) in power is 0.08 percent. In the same condition, Total Harmonic Distortion (THD) in current is 0.53 percent. THD is 0.46 percent in the loading situation and 0.93 percent in the unloading state.

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