Performance Analysis & Enhancement of PV System using PSO & GA

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Abstract — This work presents the performance analysis of Particle Swarm Optimization (PSO) based Photovoltaic (PV) system with Genetic algorithm (GA) system. PV system is widely used in domestic applications as well as grid based applications. They are meeting with lot of challenges but still they provide low pollution. This system uses a boost converter; (MPPT) to be applied to the system to obtain a maximum output power of the PV system. This work provides comparative analysis of PV system using two optimization techniques in terms of their performance parameters. The results are compared with PSO and GA in terms of their performance characteristics. Simulation results are presented using MATLAB/Simulink Tool.

Keywords—PV system, Efficiency, MPTT Controller, PSO Optimization etc.

I. INTRODUCTION

To meet the continuously increasing energy demand and to combat the global warming, green energy which is a clean energy has been given the top priority in energy sector in recent years. Also due to exhaust of non-renewable resources and thereby rise in oil and coal price have propelled scientists, researchers and engineers around the world, to innovate technology to extract maximum energy from renewable resources like solar, wind, tidal and geothermal, which are cleanest form of energy. Among all the renewable resources, solar energy is most reliable energy because it is available throughout the day time and also Silicon which is the fundamental element used in large scale in each PV module is second abundant element in the earth's crust after oxygen.

There are different types of PV model for different users depending upon their energy consumption. A standalone PV system is modelled for domestic purpose only whereas a grid connected PV system is modelled to cater large number of industrial and domestic users. A typical PV system consists of PV arrays, DC/AC converters, dc loads, ac loads and battery. A large number of series and parallel combination of PV modules are connected to inverters to increase the PV systems voltage and current rating. The battery is generally provided to store excess energy during day time and deliver the same during peak hour inverter are used to interface the DC output voltage of PV systems to the AC loads or to the grid. Inverters exploit maximum power point tracker (MPPT) to obtain maximum power from the PV modules.

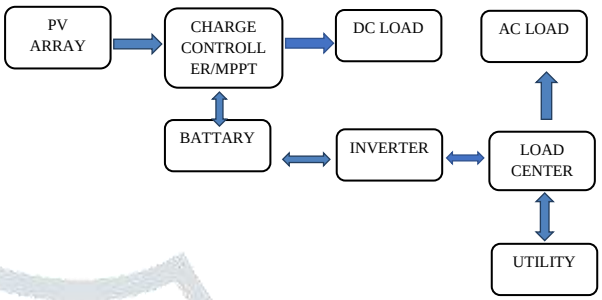

Fig 1: Block Diagram of PV System [1]

Voltage and Current yields of the PV modules is influenced by temperature and irradiance. Force gadgets segments of a photovoltaic framework, for example, network direct inverters have greatest and least voltage inputs. During rating of intensity hardware gear, these varieties ought to be considered particularly for the MPPT scope of inverters.

The remainder of paper is requested as follows. In segment II, it provides the recent trends related with PV system. In Section III, It explains the concept of designing of PV System. Performance analysis model is presented in Section IV. Results are presented in Section V. At last, conclusion is clarified in Section VI.

II. RECENT TRENDS RELATED TO PV SYSTEM

Plant-oriented configuration has observed to be one of the most popular PV grid-connected system's architectures due to its simplicity and low cost per peak kilowatt, and assumes a single PV array formed by parallel connection of strings which is linked to the grid through a single central inverter. The DC power extraction is carried out by the inverter input stage which is generally driven by a maximum power point tracking (MPPT) algorithm in charge to ensure the PV array operates at its maximum power point regardless of the environmental (irradiance and temperature) conditions. Partially shaded of the PV array by clouds or by surrounding obstacles such as nearby buildings and trees, has been the major source of power losses in such architecture. These losses are mainly due to PV module failure or the electrical configuration of the PV array, in particular to the hardwired series connection of PV modules in each string since a partially shaded module limits the string current where it is connected, thus reducing the maximum available dc power of the PV array . one of the strategies to improve DC power from a partially shaded solar array is to modify the power processing architecture. This approach improves the energy efficiency and the reliability of the PV system.

A. Muhtar et al. [2017] [1] presented that the P-V bend of photovoltaic framework shows different tops under different states of capacity and changes in meteorological

conditions which diminished the adequacy of regular greatest force point following strategies. Counterfeit Neural Network (ANN) was one of delicate registering utilized for getting the hang of, demonstrating, and examining an extremely convoluted wonder. Besides, there was a calculation dependent on meta-heuristic, which is normally utilized for some improvement issues. One of meta-heuristic calculations utilized in this paper was Particle Swarm Optimization (PSO) calculation. In this work, an examination between ANN utilizing PSO and ANN utilized back proliferation as a learning calculation to follow MPP in photovoltaic framework. Each preparation model was directed with various learning rate, however the quantity of neurons and enactment capacities utilized was comparable in each preparation model. To assess both preparing models of ANN, Mean Square Error (MSE) was utilized.

R. Min Chao et al. [2017] [2] presented that Photovoltaic (PV) framework under incomplete concealing condition has been talked about by numerous analysts. By utilizing the dispersed PV framework, one can handle each PV board freely all together least impact brought about by board concealing and befuddling. To most extreme the utilization of microcontroller and further to decrease the expense for the conveyed PV framework, research work changes to the advancement of multivariable MPPT procedure. This paper reported the plan of the force enhancer and the focal MPPT regulator related with the conveyed PV framework. Execution test by a few MPPT strategies including the multi-variable molecule swarm improvement and the steepest nice technique was introduced.

S. Sisodiya et al. [2018] [3] presented that a sunlight based photovoltaic (PV) framework is the most helpful sustainable power source (RES) for home energy the executives (HEM). A calculation was intended for planning of a house loads as warming ventilating and cooling (HVAC), electric water siphon (EWP), and electric water radiator (EWH) with the provisions of PV framework and utility under interest reaction (DR) with the assistance of molecule swarm advancement (PSO) technique in MATLAB climate. There was additionally viewed as a break in the calculation. This calculation is proficient to lessen power bill of a house, pinnacles of the utility loads just as carbon in the climate. Hence, it is useful for customers, providers, and climate.

S. Murali [2018] [4] presented that the expanded significance of sustainable sources in the field of car area involves the utilization of sun oriented photovoltaic (PV)-took care of water siphoning framework driven by a brushless DC (BLDC) engine drive. To beat the disadvantage related with the customary DC-DC converters, a zeta converter is utilized to improve the force preparing. The greatest force is removed from the sun-based cluster by controlling the obligation pattern of zeta converter through molecule swam enhancement (PSO) based most extreme force point following (MPPT) calculation. To moderate the PV yield variety, cross breed energy stockpiling framework (HESS) is incorporated to the PV framework which thus keeps up the consistent voltage at the contribution of BLDC engine drive. A vigorous force the board calculation is utilized for appropriate control of PV-HESS framework.

M. Osama et al. [2018] [5] proposed Maximum force point following (MPPT) of PV-wind-FC crossover framework taking care of another network in Egypt-New El-Farafra Oasis as a Case Study. The proposed framework incorporates PV framework, lasting magnet simultaneous generator-based breeze turbine and power module with an energy stockpiling framework. MPPT applied to PV, wind and power device utilizing Cuckoo search (CS) man-made brainpower method independently through three DC-DC help converters. These converters were additionally used to increment and bind together the yield voltage of the three sources after MPPT method proposed to a typical DC transport. DC/AC inverter is used to associate the half breed power framework into AC heaps of proposed network. The three believers and the inverter are constrained by PI regulator tuned by Particle Swarm Optimization (PSO). The outcomes show that the capacity of Cuckoo Search control procedure to accomplish MPPT for every age source.

M.N. Dehedkar et al. [2018] [6] This work was about the job and probability of greatest extraction of intensity with regulator in Solar Photovoltaic framework to present reproduction and displaying with enhancement and investigation. Reproduction of environmentally friendly power framework assists with getting lattice computations for matrix inverter with information plotting, their capacities, MPPT calculation executions, UI creation for observing PV modules, interface with converter and inverter. It looked at their propriety in single stage lattice connected with PV framework. Model of Simulink for sun-based force transformation frameworks gives technique to break down the presentation of PV cells, clusters, modules, inverters and Maximum Power Point Tracking regulators under climate and actual elements changes. Simulink arrangement of various control techniques of intensity modules are talked about and Features, Simulink arrangement of Solar PV power modules are contemplated dependent on sun-based radiations and distinctive temperature levels.

R. Rajendra Bholane et al. [2018] [7] presented a MPPT (greatest force point following) plan for a Grid associated PV (Photo-voltaic) framework utilizing FB-PSO (Forward Backward molecule swarm advancement) Technique. The FB-PSO was another improved strategy which brings about most extreme effectiveness, optimizing of greatest force point, less consistent state motions contrast with PO (Perturb and Observe) and CPSO (Conventional PSO) techniques. The proposed plot was look at under PSC (incomplete concealing conditions) and its outcomes are contrast and other two techniques. The FB-PSO calculation is actualized in MATLAB/SIMULINK and it is seen that proposed technique is best contrast with PO and CPSO MPPTs.

S. Kamalsakthi et al. [2019] [8] presented a three-stage framework took care of photovoltaic framework dependent on a most extreme force point following, which go about as the greatest molecule swarm advancement. The nearby planetary group took care of to the network needs extra conditions to get from an enormous quality electric framework. The work presented association of three stage took care of nearby planetary group. Subsequently, the lift converter framework with most extreme force point (MPSO, MPPT) was applied to use the greatest force get from the sun oriented and adjust them to the utility matrix.

R. Arora et al. [2020] [9] had offered ascend to put resources into environmentally friendly power sources which are obviously superior to ordinary wellsprings of intensity. However, the sustainable force sources, for example, wind, PV are variable in nature which influences the force nature of network. Subsequently, the force framework is needed to make balance between power interest and age. To improve the steadiness, the PID regulators are utilized. However, these are fixed increase regulators. Along these lines, to defeat this issue, AI strategies should be utilized. This work gave the crossover sustainable power framework wind, PV and Fuel cell associated with the network. The PID regulator was utilized

with the framework whose boundaries are tuned with Particle Swarm Optimization strategy. This enhancement improves the soundness of the framework. The demonstrating and re-enactments were done in MATLAB and results are noticed for better execution under factor stacking conditions.

L. Xu et al. [2020] [10] presented an improved molecule swarm advancement (PSO) strategy to follow the worldwide pinnacle (GP) under mostly concealing condition (PSC) and uniform irradiance condition (UIC). In this strategy, the underlying situation of particles can be dictated by a procedure, not irregular. When the photovoltaic (PV) string works under PSC, the underlying particles can guarantee that the relating working focuses work in the region of the pinnacles. Furthermore, under UIC, the underlying position is near the GP obligation cycle by utilizing the attribute of DC-DC converter. Subsequently, the improved PSO most extreme force point following (MPPT) strategy can arrive at the GP quick. In MATLAB/Simulink, the examinations between the proposed technique and different strategies, including regular steady conductance (INC) and PSO strategy, are made under different plans.

III. DESIGN OF PV SYSTEM

In the standalone PV system, the PV module technical specification must satisfy the distribution of PV modules among the inverters and also the dimension limitation of available installation area. The assumption taken in this present work is the annual energy generated by PV modules is constant during total operational period of the SPV system. In designing the power stage of the inverter there are important parameters needed to be considered in the design process. In the input stage, the input voltage range, nominal output voltage and maximum output current. In the output stage the filter is essential. In the design some of the assumptions are needed to compromise the design. This work discusses the important parameters for the power stage of the inverter with PV design.

1. Input and DC-link Capacitors

The DC link capacitor sometimes called power decoupling is normally achieved by means of electrolytic capacitor. For years design engineers have chosen electrolytic capacitor technology for use as the bus link capacitor on inverter designs. Electrolytic capacitors have been the workhorse technology for hard switched inverter bus link capacitors for many years. Electrolytic capacitor technology has also remained virtually unchanged over the years. The main attraction has always been the low cost per farad associated with electrolytic capacitors. The DC link capacitor is very important in the life time of the converter, and it should be kept as small as possible and preferably substituted with film capacitors.

2. Input Inductance and Capacitance

The necessity and importance of the input parameters as applied to the input voltage from the PV array have been explain in previous sections. These parameters are boost inductor or DC inductor L_{pv} and input capacitor C_{pv}. The system has two strings which are connected in series to have a nominal voltage of 420 V. The two series combination is then connected in parallel to give a current of 10A. It is very difficult to achieve nominal voltage of 420V from the available PV array. the PV cells convert about 15% of the solar radiation to electricity. Due to this reason and for the benefit of this work the minimum worst case of voltage that is assumed to be available all the time shall be taken as 100V. The minimum voltage is used to estimate the duty ratio, D of the boost converter. The minimum voltage is used because it gives the maximum switching current. The duty ratio is calculated as:

$$D = 1 - \frac{Vin*\eta}{Vout} \quad (1)$$

3. DC- Link Design

The output AC voltage of the inverter is specified to 230 V as VSI single phase. This value will give the estimated voltage value of 400 V at the DC bus. This voltage is seen at the DC link capacitance which sometimes is called power coupling capacitor. The DC link voltage is estimated as the bus voltage, V_{bus}. In this design the ripple voltage is taken as 10% of the specified bus voltage or link voltage. It is difficult to control the grid current if the DC link voltage is lower than the peak grid voltage plus the voltage drop across the semiconductor devices and filter voltage. This is the reason to which the 10% is added and gives an approximated DC bus voltage of 400V.

IV. PROPOSED WORK OF SYSTEM

This work presents a PV system with optimization with GA & PSO method. The main key of this method is choosing a reference voltage, and keep changing the output PV voltage signal to decrees the power variation. (MPPT) is applied between the energy source and load, due to utilizing the available maximum power output of the PV. In the current work, a hybrid system is actualized for effortlessness. After determination and hybrid, presently we have another age, some are straightforwardly duplicated, and others are created by hybrid.

This work uses GA & PSO algorithm for improving efficiency of PV system. This present reality issue which are non-differentiable, non-direct, constant and genuine esteemed can be tackled to get worldwide ideal arrangements by these (GA,PSO) current stochastic calculation. Consequently in this work, every one of this calculation is mimicked and thought about for the plan advancement of independent PV framework.

1. Genetic Algorithm

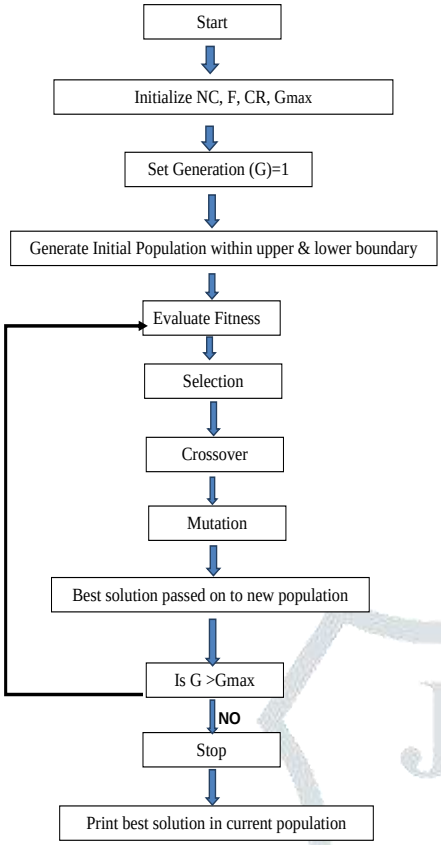

Fig 2: Flowchart of PSO Algorithm

Hereditary Algorithm mirrors the normal determination and natural selection. GAs is a specific class of advancement calculations that utilization strategies enlivened by science, for example, choice, hybrid (additionally called recombination) and change. It is a pursuit technique utilized in registering to discover rough answers for streamlining issues. A bunch of boundaries to be enhanced characterizes the individual and set of people contain populace which with time advance by the cycle of determination, hybrid and change. In this calculation, at first an arbitrary populace or arrangements are produced and afterward its wellness is assessed. At that point dependent on the wellness, determination is done on the people for proliferation.

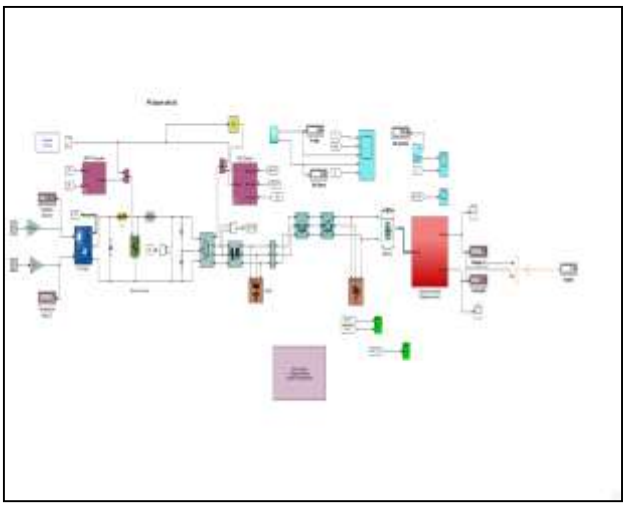

Fig 3:Proposed System Model using GA

The combination speed of the calculation relies upon numerous variables like populace size, hybrid likelihood, change likelihood and elitism. The essential GA calculation is appeared in Figure 4.1. Each chromosome portray a potential arrangement of the improvement issue and numerous boundaries. In the current work, it contains three boundaries, for example, $x = [NPV|N|\beta]$. Prior to beginning GA streamlining measure, initial an underlying populace of 20 chromosomes or people is haphazardly created. Also dependent on the wellness esteem determination is accomplished for propagation of best people. The better the wellness esteem, more is the odds of determination.

2. Use of Particle Swarm Optimization

PSO mimics the social behaviour of a swarm of bees or flock of birds. In swarm intelligence, each particle moves to a new position using the velocity. Then the best position of each particle p_{best} and the best position of the swarm of particles best is updated. The velocity of each particle is then updated based on the experiences of the particle. The population initialization is done with a random velocity and position. Then fitness of the population is evaluated and compared with previous $pbest$ and $gbest$. Their positions are updated where needed. Hence a new swarm or population is created. The velocity and position is updated till maximum generations or convergence is reached. Some of the main advantages of PSO algorithm compared to other methods are that no calculation of derivative is required, the information of best solution is held by all particles and those particles offer data among them.

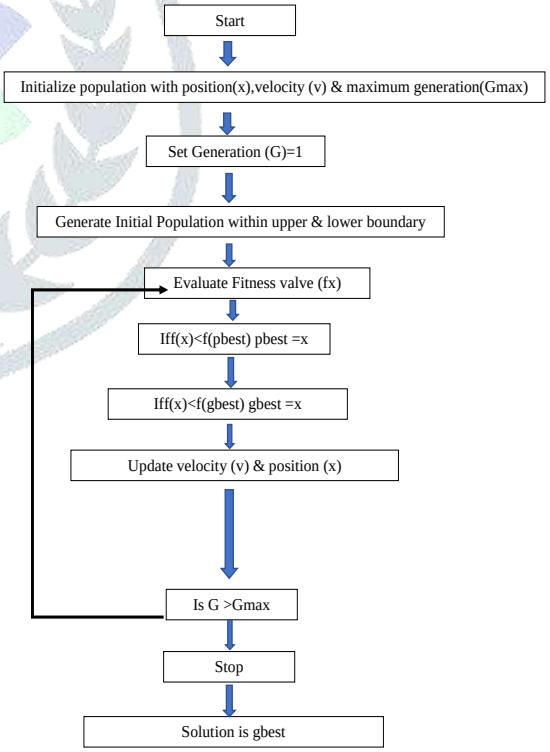

Fig 4: Flowchart of PSO Algorithm

Since output voltage is nearly constant (as defined by battery voltage), the variations in the duty cycle balance the changes in the input voltage. As such, this maintains the current. The DC link capacitor sometimes called power decoupling is normally achieved by means of electrolytic capacitor. For years design engineers have chosen electrolytic capacitor technology for use as the bus link capacitor on inverter designs. The DC link capacitor is

very important in the life time of the converter, and it should be kept as small as possible and preferably substituted with film capacitors. Unfortunately, film capacitors are far more expensive than the electrolytic ones in term of cost per farad and hence the size of the capacitance has to be smaller to keep the price of the capacitor acceptable. However, smaller capacitance would weaken the power decoupling ability of the DC-link capacitor which may cause DC-link voltage fluctuations that lead to distortion of the inverter output current to the grid. On the other hand, since the PV modules are current sources, a capacitor has to be added in parallel when using a voltage source inverter (VSI), in this way the inverter sees a voltage source.

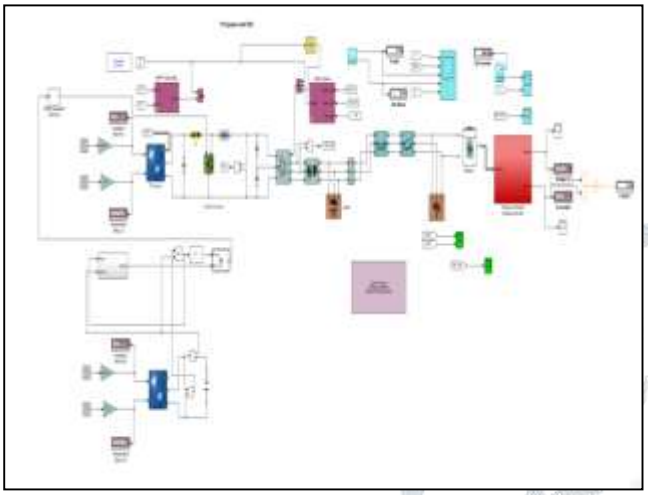

Fig 5: Proposed System Model using PSO

V. RESULTS & DISCUSSION

This work explains the details of the PV system with optimization by PSO & GA method to boost power stage designed in this work. The circuit is designed using MATLAB R2019a.

1. Results using GA Algorithm

Genetic Algorithm mimics the natural selection and survival of the fittest. GAs are a particular class of optimization algorithms that use methods inspired by biology such as selection, crossover (also called recombination) and mutation. After selection and crossover, now we have a new generation, some are directly copied, and others are produced by crossover. In order to ensure that the individuals are not all exactly the same, the next step is to allow for a small chance of mutation. In this step only a few individuals are chosen randomly from the new generation. The results with PV system is shown below:

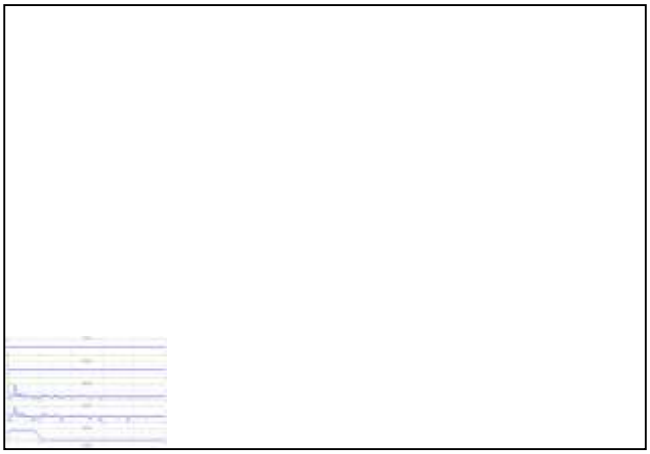

Fig 6: Performance Parameters of PV system using GA

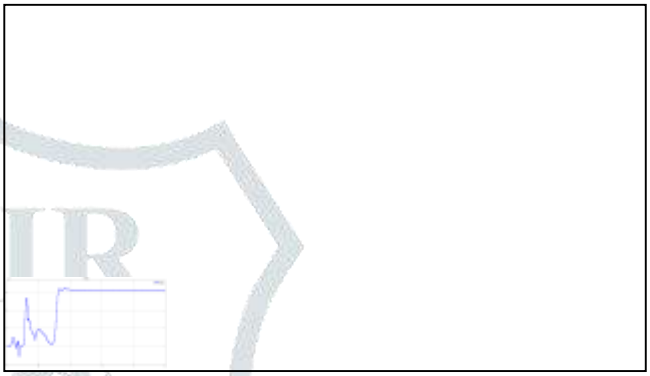

Fig 7: Power Display of Battery using GA

Fig 8: Voltage & Current Display of PV using GA

2. Results using PSO Algorithm

In PSO algorithm, each particle is represented as solution and a swarm of particles is collectively known as population. The population initialization is done with a random velocity and position. Their positions are updated where needed. Hence a new swarm or population is created. The velocity and position is updated till maximum generations or convergence is reached. Some of the main advantages of PSO algorithm compared to other methods are that no calculation of derivative is required, the information of best solution is held by all particles and those particles offer data among them.

Fig 9: Performance Parameters of PV system using PSO

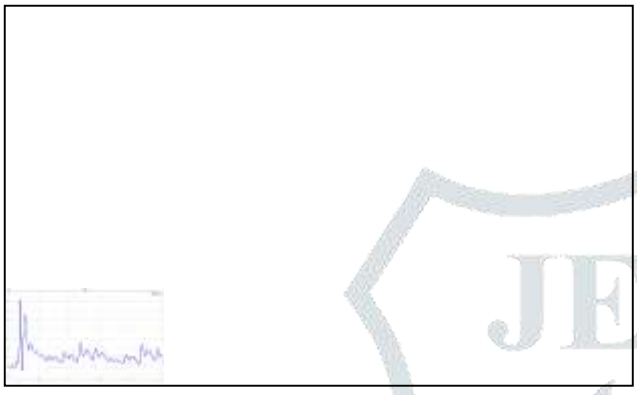

Fig 10: Power Display of Battery using PSO

Fig 11: Voltage & Current Display of PV using PSO

Table 1 shows the performance comparison of PV system with GA & PSO algorithm and results show that PSO is better than GA in terms of Voltage booster output.

Table 1: Performance Comparison of System

Parameters	**Results using GA**	**Results using PSO**
Vdc Boost (%)	0.30	0.91
Vdc Output (V)	276.3	684.8
Output Factor D	Fluctuating	Constant Stable

VI. CONCLUSIONS

This work provides the concept of performance analysis of PV system with PSO and GA based techniques. Though the PV systems have some challenges, they meet continuously increasing energy demands and also reduce pollution which are caused by thermal, diesel, nuclear power plant. In this work, a methodology for design optimization and economic analysis of PV system. The main objective of this work is to maximize the efficiency of system. And it is done by optimization of system by selecting suitable technique. Also the proposed optimization algorithms (GA, PSO) have the capability to find global optimum solution in case of complex problems with non-linear objective function and non-linear constraints. Both methods compared with their performance parameters and PSO shown better as compared to GA.

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