OPTIMAL SCHEDULING AND OPERATION OF ESS IN GRID CONNECTED INDUSTRIAL COMPLEX USING GENETIC ALGORITHM

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Abstract

Prosumer is the one who generates energy and consumes energy to meet the loads. Prosumer faces many problems during generation of energy because of using conventional sources such as coal, petroleum, gas etc. Use of conventional sources will increase in production cost, and also they are non-renewable. They can be replaced with non-conventional sources or renewable energy sources such as solar, wind, tidal etc, usage of these sources will reduce production cost. Even though they replace conventional sources, they are weather, climate dependent. To monitor these sources and to operate in a effective way, the quadratic programming is replace with GA. This GA is a real time monitor, and automatically operates the sources based on the climatic conditions. In this we are implementing GA to improve the prosumer profits by reducing production cost. It also minimizes the operation costs and prevents the deterioration of battery.

Keywords: Prosumer, quadratic programming, genetic algorithm, deterioration.

NOMENCLATURE

	Variables
F	Objective function
x	State variables
u	Control variables
P_t^S	Real power imported from utility (KW)
W	Weight factor
T	Hourly time interval
P_t^{PV}	Real power generations of PV (KW)
P_t^{FC}	Real power generations of FC (KW)
P_t^{ES}	Real power output of the ESS (KW)
P_t^D	Real power loads of prosumers (KW)
P_t^C	Real power loads of consumers contracted (KW)
SOC_t	SOC level of the ESS (%)
K	Electricity rate

Parameters

P_{max}^S	Maximum import power (kW)
P_{min}^S	Allowable export power (kW)
SOC_0	Initial level of SOC (%)
SOC_{max}	Maximum level of SOC (%)
SOC_{min}	Minimum level of SOC (%)

Acronyms

ESS	Energy storage system
PV	Photovoltaic
FC	Fuel cell
SOC	State of charge
GA	Genetic algorithm

INTRODUCTION

In recent past, Now a days the generation cost of the energy is been increasing drastically but it is essential to generate the power because it is the main and basic component in our daily life whether it is household purpose or industry purpose or agriculture purpose anything the power is required and it is essential. Without power we cannot do anything in our day to day. So, to reduce the cost of production of power a few years ago quadratic programming is used. By using this MATLAB quadratic programming, the production cost of the power is somewhat reduced.

To reduce more production cost the renewable energy sources such as solar power, wind energy etc are used to produce power. With these renewable energy sources, the power generation is reduced although the installation is high. This type of production requires continuous monitoring because of quadratic programming usage for optimization. In this previous data is recorded for further usage. So, before starting the next day generation the prediction of the day is done based on previous historical data, which includes how the whole day will be, and how the weather conditions and how could the solar or wind generation. The historical data includes weather data (solar radiation, air conditions). Based on these data prediction of the next day will be done. Based on the prediction the energy sources are operated. If the next day generation is high than predicted then after all load demands are met, the surplus energy is sold to the contractors, consumers. If the energy is then surplus it is fed to the grid and stored in the battery for future use.

If the power generated is less than the predicted then the power is bought from the utility and from the battery is also used to meet the load demands and to supply the contractors or consumers. In some cases, the energy generated from solar is less than what expected in such a case the wind/fuel cell is operated for more time to generated required power to meet all the demands. So, to increase generation and to optimize the production cost of power better than the quadratic programming, Artificial Intelligence techniques are used. This AI is advanced technique which optimizes more than the previous technique[2]. GA a technique in AI, this combines the two best genes and produces a quality best gene. The two best genes are selected based the methods in GA. There are three methods in selection of two best genes. So, this GA is advanced technique which is implementing rapidly in recent years[11]-[13].

In our project instead of quadratic programming we are using GA that helps in optimization of production cost and the power generated is smoother [14]-[15]. As the generated power is smooth the converters required are less and the sizes of passive elements that are used in the converters are also less when

compared. The flowchart clearly explains the process of GA as shown in fig 1.

The renewable energy sources such as solar power and Fuel cells are used to generate the power. The renewable energy sources are to reduce the production of the power even though the installation cost is high. When coming to practical conditions the weather changes minute to minute in a day so, the power generated from solar panels may vary in such a way that sometimes it produces more power and sometimes it produces less. The two sources combined produces the power to meet the load demand[3].

The prosumer who produces and consumes power will produce power by using renewable energy sources and meet the load demand, and when the power generated is surplus, the prosumer makes the contract to some of the customers to sell the surplus power. This GA takes the previous data, load data, and power generation from each source data. By integrating all these data's, it instructs the energy sources to generate some amount of power that meets the all load demands. So, to collect the data, each device is equipped with each monitoring device, in which all the data is gathered by GA, and it operates all the power efficiently by using this data. Based on all these advantages the efficient controller GA isused.

DESIGN OF SYSTEMS
Genetic algorithm

GA is used for solving high quality problems and also optimization. The mutation, crossover, selection techniques are used to find the problems. It is based on the mechanics of natural genetics and natural selection and based on these selections the best gene or the fittest member has the highest probability of the survival. Relationists on occasion charge that improvement is inconsequential as a coherent speculation. Since, it conveys no realistic points of interest and has no congruity to step by step life. Regardless, the verification of science alone shows that this case is bogus. There are different regular wonders foe which improvement gives us a sound theoretical supporting[9].

To name just one, the watched improvement of impediments-to bug showers in crop bugs, to against contamination specialists in microorganisms, to chemotherapy in threatening development cells and to antagonistic to retroviral cures in diseases, for instance, HIV- is an immediate consequence of the laws of progress and decision, and understanding these measures has helped us to make techniques for dealing with these terrible living things[1].

Fig. 1: Flow chart of optimization of GA

Finally, the standard of explicit imitating has been used to exceptional effect by individuals to make revamp living creatures unlike anything found in nature for their own preferred position. This GA is a programming technique that solves many critical problems and give most optimized solutions. Every individual is encoded with a fitness function. So, each individual is evaluated based on this fitness function in a group of individuals. In this evaluation most of the individuals will not work at all and those will be deleted. So, a few individuals are left back and they are used for reproduction. These propelled successors will go to the individuals to come and structures another combination of individual and they are presented to a second round of well being evaluation.[10].

Methods of Representation: A method is needed to encode potential solutions before the GA is directly applied to the problem. That method encoded potential solutions should be in a form that computer can process. The other approaches have a need of decimal numbers or as a array of integers, this will represent the solution in each position. The basic flowchart of GA shown in fig 2. This will allow a greater precision and complexity when compared with the method of binary numbers, and this is very close to the problem space. The other way of approach is to represent the individuals in strings of letters in GA, in which each letter will again represent each solution. So, all these methods will provide us high optimization in problem solving.
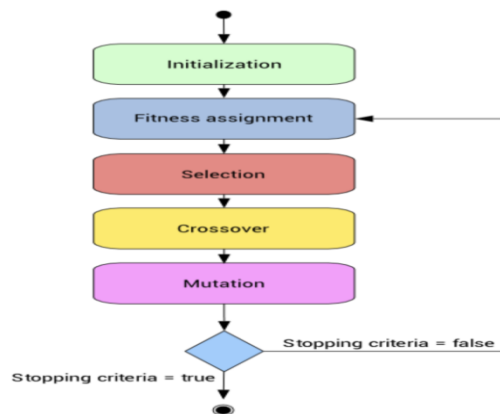
Fig. 2: Flow chart for GA

Method of Selection: In GA the selections of genes or individuals or members based on fitness function is very essential. To select the best genes different techniques or methods are available in GA. These techniques will help in selecting best individuals or genes that are suitable to generate new individuals for the next generation.

Mutation: This is the first and simplest method to change the individual or to improve the fitness of gene. As in living things, the
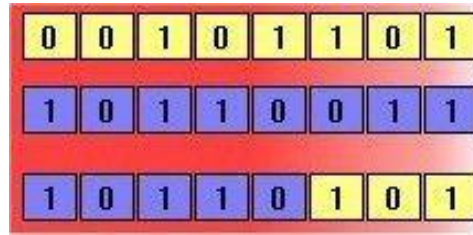

Fig 3: Crossover mutation in the GA is also same and alterations are caused in the genes or individuals.

Crossover: This is the second method to change or to improve the fitness of the individual. This method chooses two individuals and swaps their genetic code in producing artificial offspring of new individual that are combinations of their old parents as shown in fig 3.
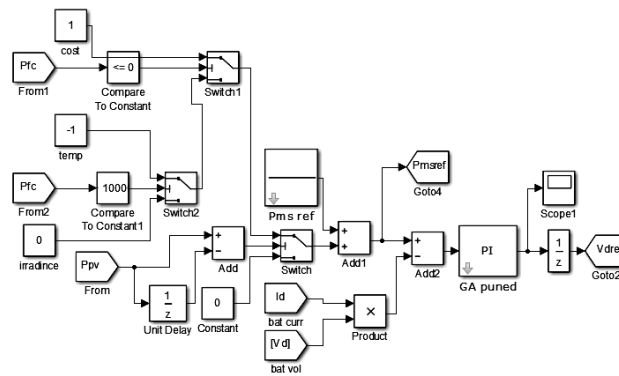

Fig. 4: Matlab model of GA for PV, Fuel cells and Grid connected network system

The above fig 4 represents the application of GA for optimal scheduling using PV system, fuel cells and grid connected network system.

Photovoltaic System

A PV subsystem consists of irradiance, solar radiation with a timer, current source, voltage source, constants, ant parallel diode, voltage and current measurement. The irradiance measures the power per unit area falling on a given surface in the form of electromagnetic radiation and solar radiation is a form of energy which will converts the sun rays into useful forms of energy. The irradiance is given to a constant value 10 and solar radiation is given into a gain positive and gain negative (k+ and k-) and product of these two given to a current source and voltage source respectively shown in fig 5. And the output from the voltage source is observed din voltage measurement and current source is observed in current measurement block. The voltage and current from PV are integrated to obtain the power. Power from PV is then given to DC-DC converter to maintain the constant output voltage.
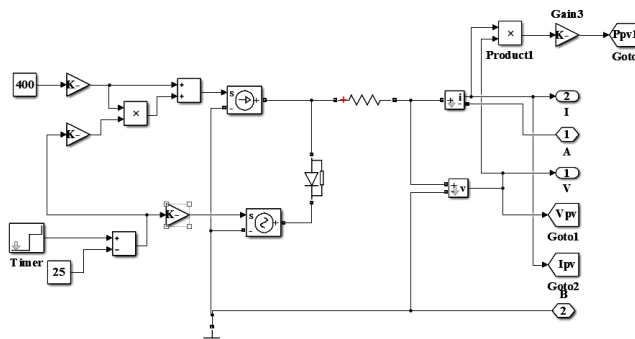

Fig. 5: Matlab model of Photovoltaic system

DC-DC converter

Boost DC-DC converter is used, so to maintain the constant output voltage from the PV module. Output power from PV is fed or given to this boost converter. By using MPPT technique maximum power is obtained from the PV module as shown in fig 6 and that voltage is used as reference and pulses are generated using pulse generator for the switch used in the boost converter.
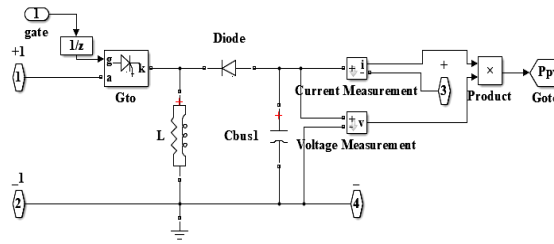
Fig. 6: Matlab model of DC-DC converter

Inverter

As we require AC, to transfer from one place to other or to meet the load demands. An inverter is used to convert the DC input to AC output. So, the output from the DC-DC converter is fed to the universal bridge inverter. By using reference voltage from the voltage regulator, the pulses are generated to the switches in the universal bridge to operate. Based on the pulses the switches will operate and the output from the inverter will vary as shown in fig 7.
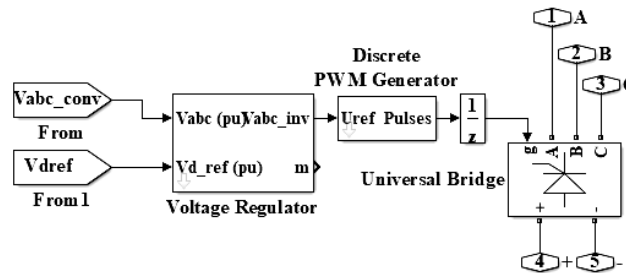

Fig. 7: Matlab model of Inverter

Thus, the obtained AC voltage is fed to the prosumer loads and contracted customers. In surplus the energy is sold to the utility and some amount is stored in batteries for future use.

Fuel Cell

From some Chemical reactions the Hydrogen Fuel Cell produces Electricity directly. Hydrogen ions are forced into the electrolyte and that electrolyte takes off protons from the hydrogen and leaves the electrons in the hydrogen. And those electrons are forced to pass through a electric circuit and thereby electricity is generated. Meanwhile the air forced from the cathode and at cathode these protons and electrons combined forms hydrogen and that hydrogen reacts with oxygen in air and forms water (H2O) as by product. The below fig 8 explains about matlab model of a fuel cell. This water can be recycled to produce hydrogen by electrolysis [8]. Although these Fuel Cells are mainly pollution free but the cost is expensive and also hydrogen is very dangerous as it is highly flammable. So still the research is going on and they are not in practical implementation[7].
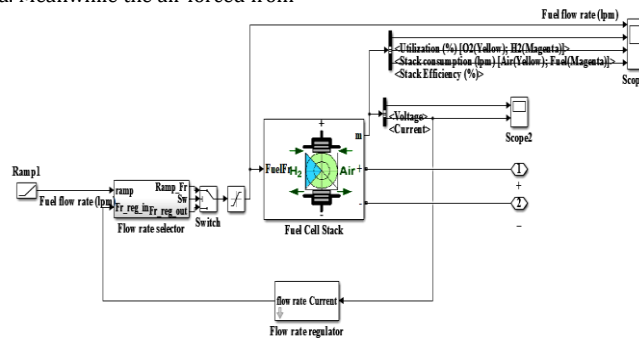

Fig. 8: Matlab model of Fuel Cell

At anode the oxidation (evacuation of electrons) happens and at cathode decrease (expansion of electrons) happens. In this way, at anode the hydrogen is part into protons (+) and electrons (e-) and the electrons are persuasively gone through a circuit which produces power. At cathode the protons, electrons are joined and shapes hydrogen and that responds with oxygen in air and structures water.

Energy storage system

Battery is the one which stores the energy in electrochemical form whenever requires it converts the electrochemical form in to electrical energy. So, this electrochemical form that battery stores are in fluid form. It takes the chemical energy which are composed of chemical reactions and by that reactions it converts the chemical energy into Electrical energy. A battery has two terminals one is positive which is widely known as anode and the other one is negative known as cathode. At anode oxidation takes place (which means reduction of electrons), and at cathode reduction takes place (addition of electrons).

The electrolyte will also help in transportation if ions from cathode to anode. Battery has two main terminals in which the electrical output is drawn out to satisfy the load. Batteries are of two types rechargeable and non-rechargeable [3]. Some chemical reactions that occur in a battery are irreversible. So, they are used to store electro chemical energy for a long time [4]. Those batteries are used in TV remotes, Wall Clocks, smoke detectors, flashlights etc. On the other side the rechargeable can be rechargeable by injecting electric current into it.

Rechargeable batteries do not store electrochemical energy for a long time they get discharged very frequently and in a fast

manner, so in these batteries the recharging is very easy, and the chemical reactions are reversible[10]. By re injecting the electrical energy into the battery it gets recharged and can be used again. This type of batteries are used in cell phones, Laptops, smart watches etc.

MAXIMUM POWER POINT TRACKING(MPPT)

It is the common method used in wind turbine and Photovoltaic, to get the control on the power delivered from them. In the sun based photovoltaic power generation it is essential to track or observe the maximum power to analyze the efficiency of the PV module. So, in the Photovoltaic the MPPT tracks the maximum power, and that voltage is used as reference in generation of pulses to the switch used in DC-DC converter to maintain the constant output from the PV panel.

When the sun light radiation is maximum then this MPPT will track the power obtained by the PV panel.

This MPPT is utilized as calculation in control controller in which it tracks the most extreme force from the sun powered PV board under specific conditions as appeared in fig 10. The power tracked by the MPPT is the maximum power that produced by the PV module and the voltage tracked or produced is known as Peak Power Voltage (maximum voltage by PV). A typical PV module can produce maximum of 17V at normal cell temperature of $25°C$. Sometimes it reduced to 15V in a very hot day and rises to 18V in a very cold day.

Usually the MPPT is mainly used in these converters to generate pulses to the switches used in these converters by tracking maximum power and that voltage is used to generate pulses as shown in fig 9.
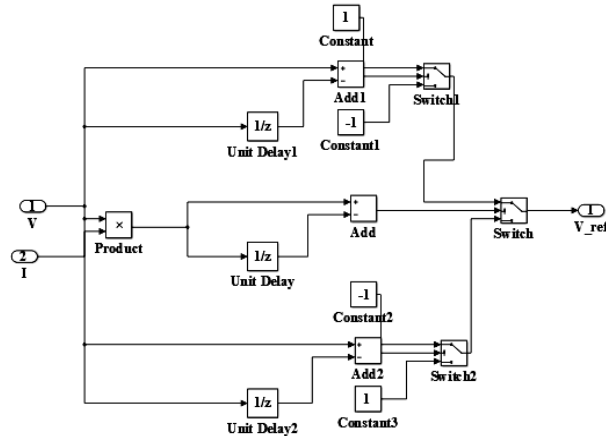

Fig. 9: Matlab model of MPPT

The essential guideline of MPPT is to follow the greatest force from PV board and to work it with better and in a proficient way. The most extreme force followed by the MPPT is fixed and noticed that it is the greatest force that PV module can convey and dependent on that it is concluded that whether the PV module is sufficient to charge the battery or not[3]. In a similar manner it is also checked that whether it can drive or meet the DC load demand. So, that this MPPT works to improve the efficiency of the module when it is charging a battery.

Normally the MPPT works better and efficiently in cold weather conditions and there it is used to track the Maximum power. Cold days, cloudy or hazy days are the most effective conditions where the MPPT can work better. On the off chance that the condition of charge of the battery brings down, at that point

MPPT can extricate more force and charge the battery[4]. The MPPT is implanted with MPPT calculation and used to expand the present that is sent into the battery from PV module. The MPPT goes about as DC-DC converter in which it accepts DC as contribution from PV module and changes over it into AC and afterward it changes over it into DC voltage and current that precisely coordinates the PV to battery [5].

Usually the MPPT is mainly used in these converters to generate pulses to the switches used in these converters by tracking maximum power and that voltage is used to generate pulses.

GA APPLIED FOR OPTIMAL SCHEDULING AND OPERATION OF ESS
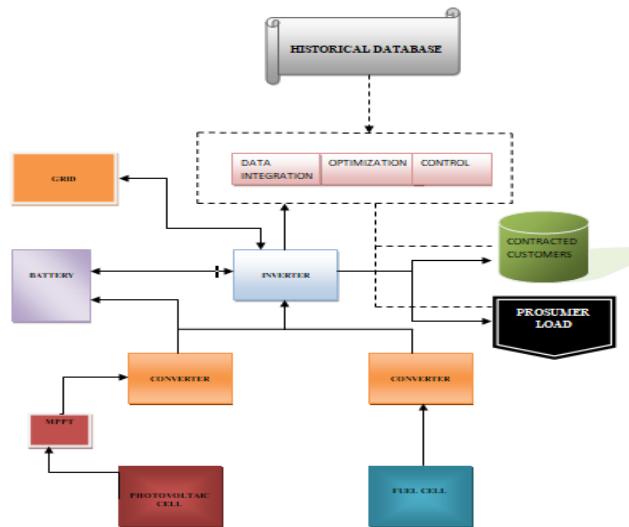

Fig. 10: Structure framework and grid functions for prosumer load demands. The prosumer owns renewable DGs, ESSs and loads.

Both are used to generate the power and the MPPT is used at the PV model to track the maximum power and the voltage is used as reference and pulses are generated using that reference voltage. The pulses are given to the switch used in the DC-DC converter so that the output from the PV model always constant (i.e. 300V). A DC-DC converter is used at Fuel cell to maintain the constant output voltage. The fig 10 represents structure framework and grid functions for prosumer load demands

These two voltages are given to the battery and to the inverter. So, the DC is converted to AC and that is given to the loads and when in surplus it is sell to the consumers or the contracts[9]. If power generated is more than the required demand then it is stored in battery and supplied to grid/utility.

The optimization is done in GA and the operation of ESS is done by EMS and the GA works here based upon the real time operation and day ahead scheduling. The GA gives the best parent child from the number of parent chromosomes as in the same manner it gives the best output result by day ahead schedule and by tuning the values to PI controller. The switch will be on set by PV if the value is 1 and the supply continues given with a unit delay. In the same manner the FC switch will turn on if the value is 1.

The irradiance and temperature is given summation and then it is connected to Id and Vd, product of those given to PI controller. In the GA the values will be read through binary language.

TABLE I Pv output power at different intervals of time

S.no	Time(*hrs*)	Power(*kw*)
1	0-11	45
2	11-12	55
3	12-13	60
4	13-14	65
5	14-15	66
6	15-16	70
7	16-17	65
8	17-18	60
9	18-19	55
10	19-24	45

The above Table I represents the PV output power at different intervals of time. As clearly show that the maximum output power of PV is 70kw and minimum power is 45kw. The output power will be more in noon time because of irradiance and temperature the power varies as it goes on increasing up to noon time and after that it decreases and comes to initial value. The power will be varies every hourly and with respective of temperature that it is supplied to prosumer load

Table II Fc output power at different intervals of time

S.no	Time(*hrs*)	Power(*kw*)
1	0-4	35
2	4-5	37.5
3	5-6	45
4	6-12	35
5	12-13	45
6	13-17	50
7	17-18	45
8	18-24	35

The above TABLE II represents of a FC output power at different intervals of time. The output power varies time to time, as it is clearly shown that the power is increasing up to noon time and decreasing after that. This means the power consumption is more in noon time and in TABLE I also it is showing the noon time requires maximum power supply to the prosumer load. The maximum output power for FC is 50kw and the minimum power is 35kw the output power varies hourly depending upon the prosumer load.

Table III Test bed system parameters

PARAMETERS	VALUE
Ps_{max}	2.2 *MW*
Ps_{min}	-2.2 *MW*
PV RATED POWER	70 *kW*
FC RATED POWER	50 *kW*
E^{ES}	100 *kWh*
SOC_{max}	90 %

SOC$_{min}$	10 %
SOC$_o$	70 %

The above TABLE III is showing the maximum and minimum output power delivered to prosumer load from each subsystem.

Table IV Active power of prosumer load at different intervals of time

S.no	Time(hrs)	Power(kw)
1	0-4	25
2	4-5	35
3	5-6	45
4	6-11	25
5	11-12	18
6	12-13	35
7	13-14	39
8	14-15	35
9	15-16	30
10	16-17	39
11	17-18	30
12	18-19	20
13	19-24	25

The above TABLE IV represents the prosumer active power load shows how much power is required to contracted customer at each interval time. The power is varying hourly depending upon load.

The target work is defined, from the prosumer's point of view, to limit activity costs, which are mostly power cost to be paid to utility. Not with standing the costs, it is additionally important to consider the pace of progress of SOC inside an hourly time interim since the sudden changes of SOC may cause disintegration of battery cycle life.

$$F = \min (x, u) \sum_{t=1}^{24} \{K_t P_t^S + W(SOC_t - SOC_{t-1})^2\} \quad (1)$$

Subjected to
$$P_t^S + P_t^{FC} + P_t^{PV} + P_t^{ES} = P_t^D + P_t^C \quad (2)$$

$$P_{min}^S \leq P_t^S \leq P_{max}^S \quad (3)$$

$$\frac{SOC_{t-1} + SOC_{max}}{100} E^{ES} \leq P_t^{ES} \quad (4)$$

$$P_t^{ES} \leq \frac{SOC_{t-1} + SOC_{min}}{100} E^{ES} \quad (5)$$

$$SOC_t = SOC_{t-1} - \frac{100 \times P_t^{ES}}{E^{ES}} \quad (6)$$

$$SOC_{min} \leq SOC_t \leq SOC_{max} \quad (7)$$

$$SOC_{24} = SOC_0 \quad (8)$$

$$\overline{x} = [P_1^S, \dots, P_{24}^S, \dots, SOC_0, \dots, SOC_{24}]^T$$

$$\overline{u} = [P_1^{ES}, \dots, P_{24}^{ES}]^T$$

1. By solving equation (1), the well-known genetic algorithm is used.
2. To take care of the enhancement issue, the hereditary calculation of MATLAB with a resilience of 10−8 is utilized.
3. The after subsections clarify the requirements depicted as (2) to (8).
4. It is important to take note of that the size of a modern complex is generally little as contrasted and ordinary dispersion frameworks, so arrange imperatives, for

example, voltage and current points of confinement are precluded for straightforwardness in the paper.
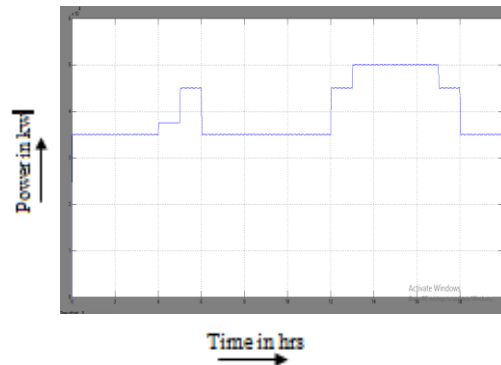
RESULTS

Fig. 12: FC output power to meet prosumer load

The above fig 12 output shows the FC power delivered to prosumer load the power is varying depending upon temperature and the peak time is at noon having maximum power of 50kw
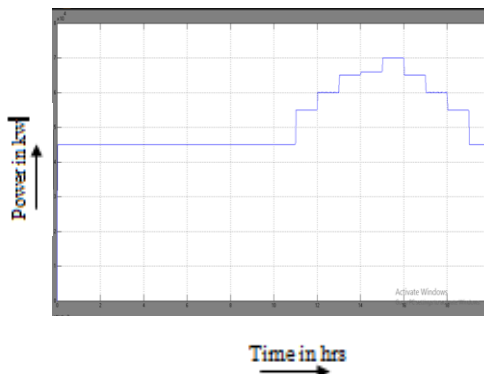

Fig. 13: PV output power to meet prosumer load

The above fig 13 shows the PV output power deliver to prosumer load. The maximum power is delivers at noon because the consumption is more at that time and the maximum power is delivered from PV is 70kw.
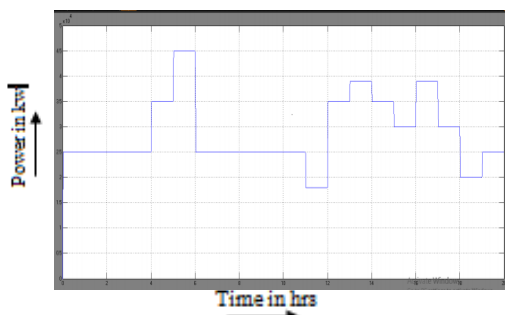

Fig. 14: Active power of Prosumer load

The above fig 14 shows the prosumer load and active power of a contracted customer requires power at respective intervals depending upon the load.
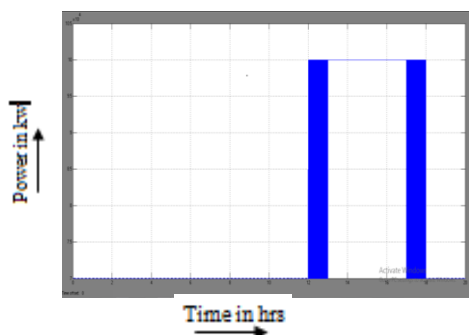

Fig. 15: Ess output when there is a no supply from source

The above fig 15 shows the output power from the battery when there is a need of supply for prosumer load when the PV and FC is not meeting the load requirements of the load and it acts as a secondary supply.

CONCLUSION

In this paper the limitations of power generation and controlling of energy sources using quadratic programming are analyzed. So, in this project quadratic programming is replaced with the advanced Artificial Intelligence (AI) technique called GA. The simulation results proves, that the output power from the PV module and Fuel cells are improved and better when correlate with the existing ones. It is observed that the SOC of the battery is also maintained in a better way when GA is used. Since the energy sources are operated automatically based on weather conditions the production cost is reduced as well as the maintenance costs were minimized.

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