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Electric Energy Storage Solution for Standalone Photovoltaic and Supercapacitor Applications in Rural Areas

Swathi Peram, V. Usha rani

Abstract— Shortage of electricity is the major issue in many areas in the world. This paper discusses a renewable standalone power system to propose the enhanced energy storage by means of Supercapacitor The enhanced storage lowers the energy shortage that gives reliable power supply in rural areas... Maximum power point tracking technique (MPPT) control algorithm is performed over the photovoltaic (PV) as the main energy source to trace the maximum power. Supercapacitor, Battery are the main energy storage devices these are not only energy storage devices which supplies the electrical energy. The system is simulated using the MATLAB/SIMULINK tool with different cases of PV, Battery and super capacitor supply. System modeling, sizing and control are discussed here and Simulation studies are presented in this paper.

Index terms—(PV) Photovoltaic panel , Maximum power point tracking(MPPT), Supercapacitor, Battery, Induction motor.

I. INTRODUCTION

Most of places in the world are surviving without electricity. If some amount of electricity is available in rural areas that are useful to some extent only. Once they use electricity for irrigation purpose. (or) for heavy loads, it will consume more amount of energy. Then further purpose they can't use because of the lack of electricity. The solar PV system has become highly competitive solutions for commercial, industrial, and residential applications. Supercapacitor and battery are used for energy storage. In this paper, the system works on a fuzzy controller. It gives the best results, compare to other controllers. To show that we are comparing the fuzzy controller system performance with PI controller. PV Panel is the combination of solar cells based on rating the number of solar cells are increased in a panel. Solar cells convert available light energy into electrical power. Photovoltaic cells (solar cells) are based on semiconductor physics. These are three layered P-N junction photodiodes,

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***Correspondence Author(s)**
Swathi Peram, Student EEE, Gokaraju Rangaraju Institute of Engineering and Technology (JNTU-H), Nizampet, Hyderabad, India.
V. Usha rani, Assit. Professor EEE, Gokaraju Rangaraju Institute of Engineering and Technology (JNTU-H), Nizampet, Hyderabad, India.

first top layer one is junction layer, second layer is core of the device and last layer is energy-conversion layer. The power of solar cell is defined as based on maximum open circuit voltage. Power can be computed by this equation

$$P=V*I.$$

A Supercapacitor is a high power density device, energy capability, and scalability, fast response, it can be charged and discharged very quickly. We have Supercapacitor with aqueous electrolyte, organic electrolyte, ionic liquid. Hybrid and Pseudo type of Supercapacitor have been extensively used. There is no risk of exploding Supercapacitor as the exposure temperature is in the range of – (40 to 65ºc) and this is very feasible range to catch fire. The voltage of it increases progressively on a constant voltage charging. progressively but the charge will be more effective and voltage rises straight at constant current charging. The voltage of a Supercapacitor decreases continuously during the period of discharge. The voltage converter is used along with it to obtain stable voltage and make use of best energy of the Supercapacitor.

Electrochemical devices are convert higher-level active materials into an alternate state during discharge are termed as batteries. The load characteristics of a battery determines the reaction rate and storage in the battery. It has good energy density and also has the ability to store energy effectively, so it is used as energy storage source for given specified weight and volume. Batteries are of two types primary batteries and secondary batteries. Primary battery can also be called as single usage batteries. These cannot be recharged as the reaction in it is irreversible that is active materials are not regenerated. Secondary batteries can be coined as rechargeable batteries These batteries can be used and gets recharged for re-use. Active materials are regenerated in the reaction of secondary battery process, this recharging is possible on supplying electric current. The recharging process reverses the chemical reactions that occur during discharge. Devices that supply the required current to recharge the battery are termed as chargers.

The data which are vague and not clear are regarded as fuzzy data. Most of the situations in everyday life are fuzzy in nature as we cannot give the accurate information with high resolution.

The Fuzzy logic provides a reasoning and valuable solution to the defined problem.

The mode of PI control has non-integrating process. This non-integrating procedure adopted by PI controller eventually returns to the same output for given the same set of inputs and disturbances.

Supercapacitor is high energy capability and commercially viable energy storage. This is for large scale implementation and also can save more energy. Supercapacitor has a high power density and so has high power consumption.

PV panel is controlled by the MPPT Technique is the main energy source, battery pack and Supercapacitor are main energy source devices.

The system is simulated using the MATLAB/SIMULINK tool with different cases of PV, Battery and super capacitor supply. simulation results are given and discussed for the proposed system

II. STRUCTURE MODELING OF SYSTEM

Block Diagram: The system connected with solar energy, battery, and Supercapacitor is shown in Fig.1.

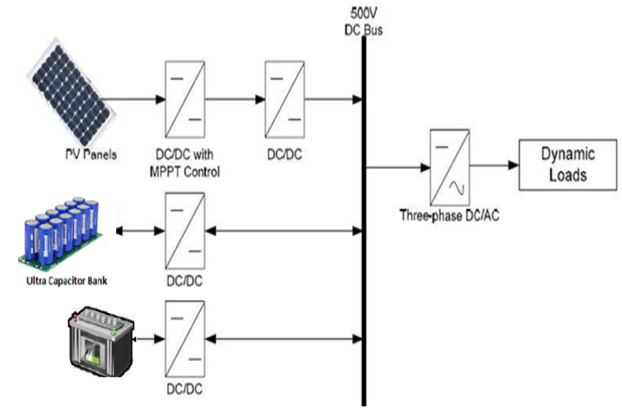

Fig. 1. Block diagram of the system

The DC coupling configuration is used for this system, and different energy storage devices and load are connected to the DC bus through appropriate power electronic converters. This kind of system has a simple control strategy.

DC/DC converter controls PV panel (with an MPPT controller) and then connected to the DC bus. The battery and Supercapacitor are connected in parallel to the DC bus. The DC bus is connected with inverter and then to AC load (Induction motor). Proposed system has a Fuzzy controlled that works on fuzzy logic.

When solar energy available the PV panel collects the light energy through MPPT and convert into electrical energy It will supply the electricity to load through an inverter which converts DC to AC and its supply to the load.

At the same time, the PV panel charges the battery and Supercapacitor.

When solar energy not available the load (Induction- motor) starts with the help of Supercapacitor for starting the purpose of Induction Motor requires more current. by using Supercapacitor the energy will save.

After starting the machine, it will run on the battery up to again sun energy available. Here Supercapacitor, battery not only for energy storage purpose. these also supply the electricity.

All the available data is considered to solve a problem using the fuzzy logic algorithm. In fuzzy logic, the best possible decision is made over the available data and input given.

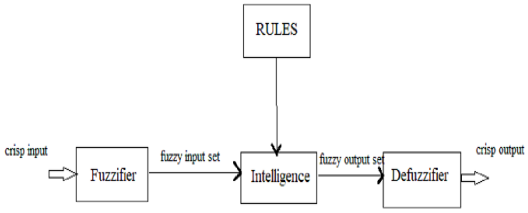

Fig.2. Fuzzy logic algorithm

Machine learning technique can be implemented easily using fuzzy logic. It allows you to deal with non- linear functions of arbitrary complexity and also a suitable method for uncertain or approximate reasoning if logic have two values that represent two possible situations.

Here a PI (proportional and integral) is a feedback control loop it works taking the error signal i.e. difference between the set point and output of a system.

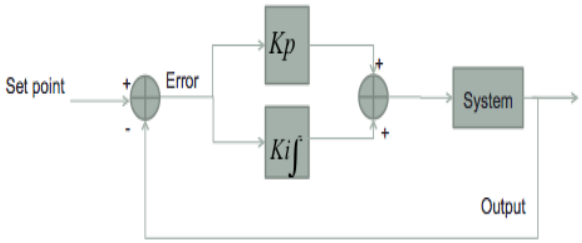

Fig.3.PI Controller

PI controller eliminates the steady state error that resulted from the P controller. However, it has a negative impact in terms of the speed of the response and overall stability of the system and so this PI controller is mostly used in areas where the speed of the system is not an issue.

III. ENERGY STORAGE SYSTEM

The energy storage system contains two energy storage devices Supercapacitor, battery.

I. Charging and Discharging mode of Supercapacitor:

Supercapacitor charges from the panel when it starts supplying the electricity to the load at the same time electrical energy receives the Supercapacitor from the panel. Supercapacitor starts discharging when electrical energy is not passing to the load from the PV panel. It starts supplying the electricity to the load then it starts discharging. For only starting of load then it remains constant. Up to solar energy available to the panel.

II. Charging and Discharging mode of Battery:

Battery charges from the panel when it starts supplying the electricity to the load, parallel charges the battery.

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Battery starts discharging when Supercapacitor becomes constant battery will supply the electricity to the load up to load gets supply from the PV panel.

The working of super capacitor and battery is same in both controllers.

A. Energy Management Strategy:

In this paper, the system is accordingly proposed so as to provide reliable power supply in rural areas. The block diagram shown in fig.4 energy management strategy using a Supercapacitor.

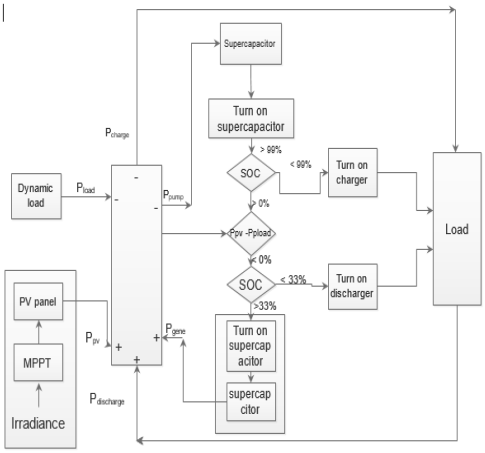


Fig.4. Flow chart of supercapacitor Energy management strategy.

The unreliable or variable feature of solar energy insists to have the energy storage sources. Here Supercapacitor and battery plays significant role in storing energy so as to achieve continuous power supply. Control strategy employed here focuses mainly on how to provide energy to load in both the cases i.e. when the solar energy is available and unavailable. The load is energized with solar power when it is sufficient and in case of insufficiency the load is powered by means of Supercapacitor or battery as defined in the proposed controller logic.

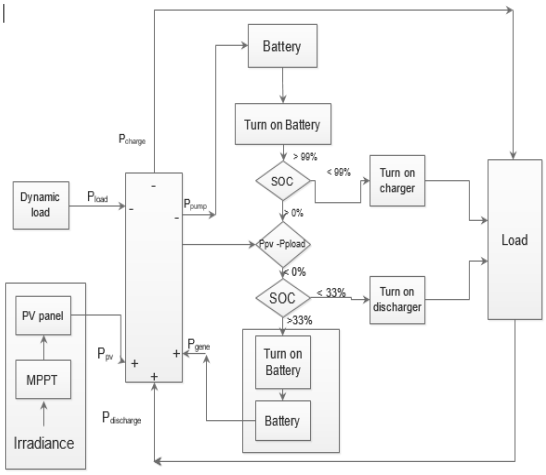


Fig.5. Flow chart of Battery Energy Management Strategy

Any control logic in controller is worked as when solar energy is not sufficient or unavailable the Supercapacitor is discharged to supply electric power and battery is turned when SOC (State of Charge) of Supercapacitor reaches a certain low-threshold value. The Supercapacitor or battery is accordingly operated based on the availability of the solar energy.

B. System Components Selection:

1. PV panel:

Power rating/panel	=305W
Cells/module	= 96
Number of modules/string	= 17*10
Total power rating	= 305*10=3kw

2. Supercapacitor:

Voltage for each cell	= 2.7V
Operating temperature	=25ºC
Rated capacitance	=99.5F
Rated voltage	=350V

3. Battery:

Rated capacitance	=150Ah
Initial state of charge	=20%
Response time	=2
Nominal Voltage	=300V

4. Inverter:

Power electronic device	= IGBT/Diode
Number of Bride arms	=3
Snubber resistance	=1000Ω

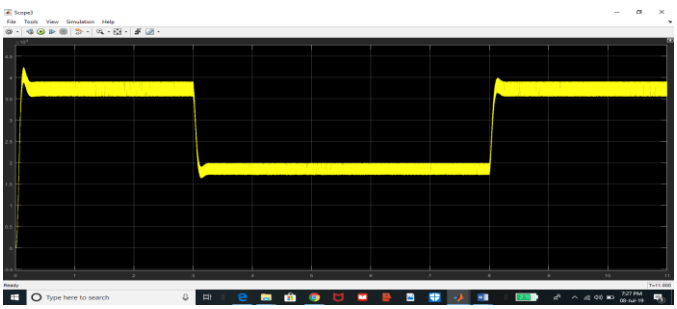
5. Induction Motor:

Nominal Power	=50HP
Nominal Voltage	=300V
Frequency	=60Hz

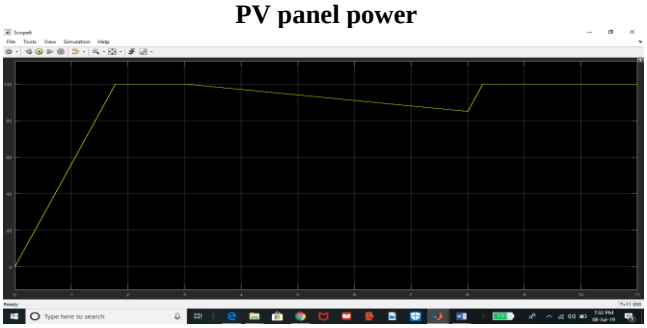
IV. SIMULATION RESULTS

Fuzzy controller results

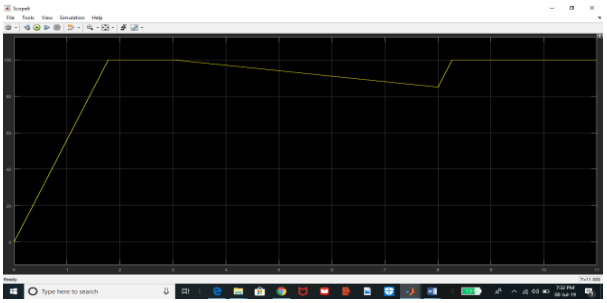
A. Charging mode:



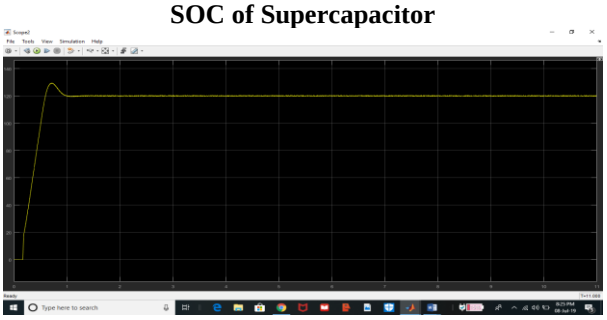
PV panel power



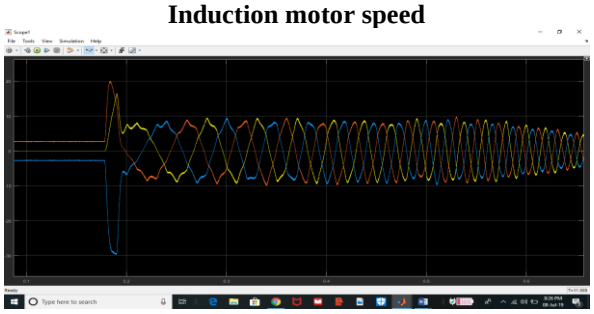
SOC of battery



SOC of Supercapacitor

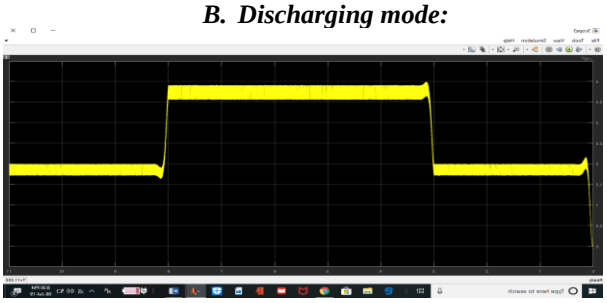


Induction motor speed

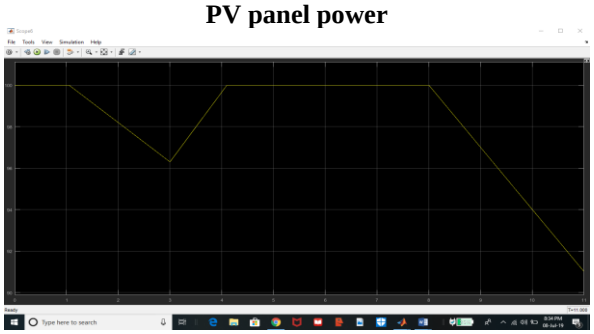


Induction motor current

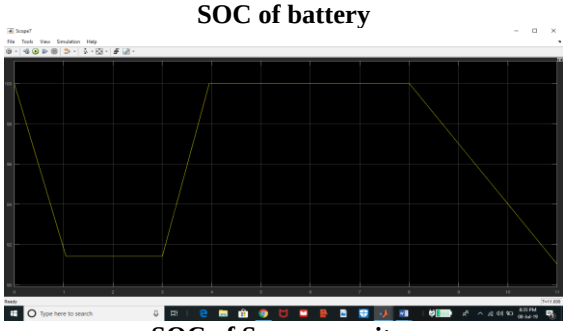
B. Discharging mode:



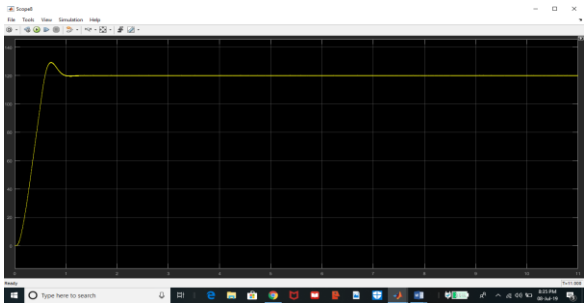
PV panel power



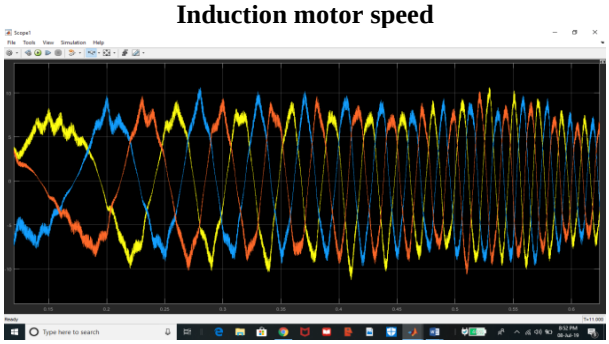
SOC of battery



SOC of Supercapacitor



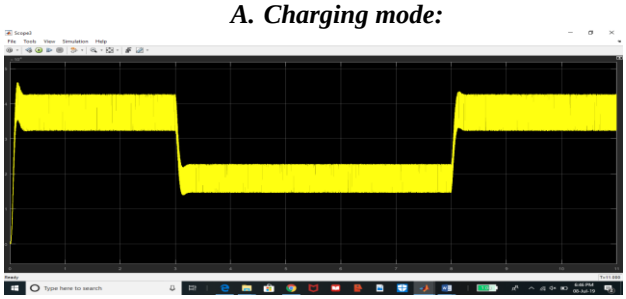
Induction motor speed



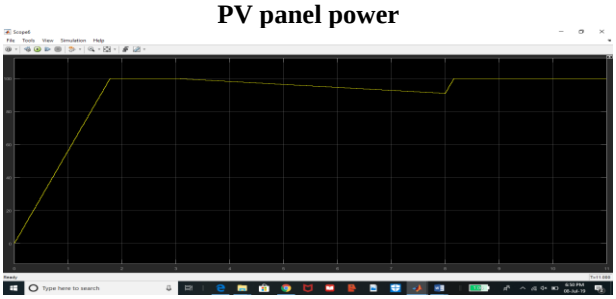
Induction motor current

PI Controller results:

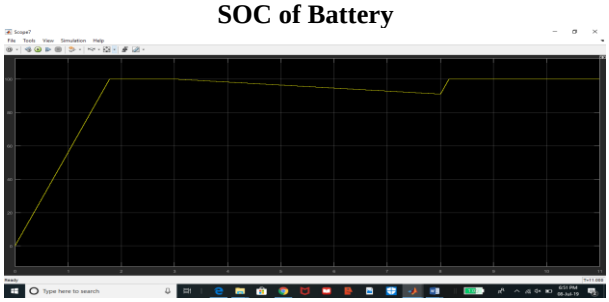
A. Charging mode:



PV panel power



SOC of Battery



SOC of Supercapacitor

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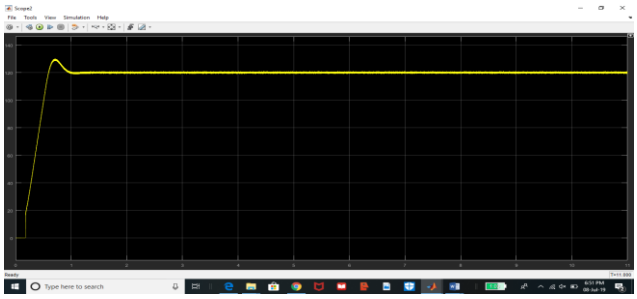
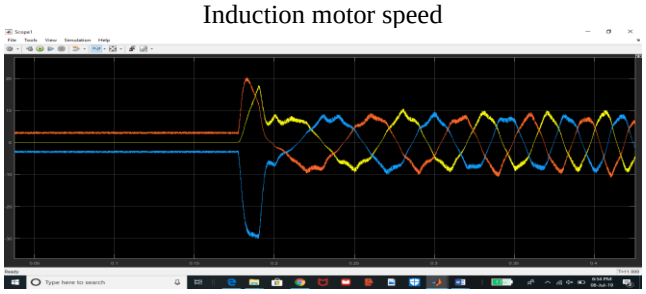
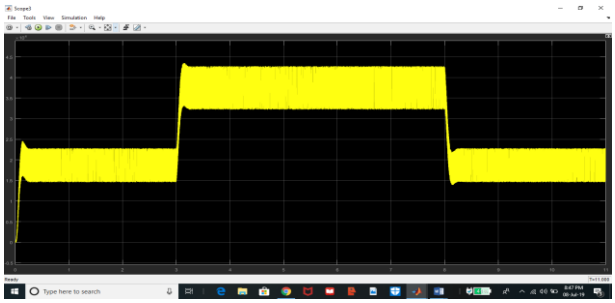


Induction motor speed

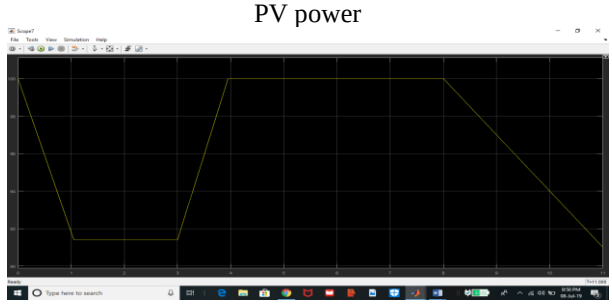


Induction motor current

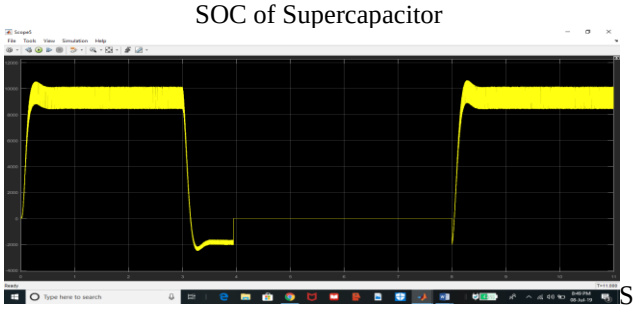
B. Discharging mode:



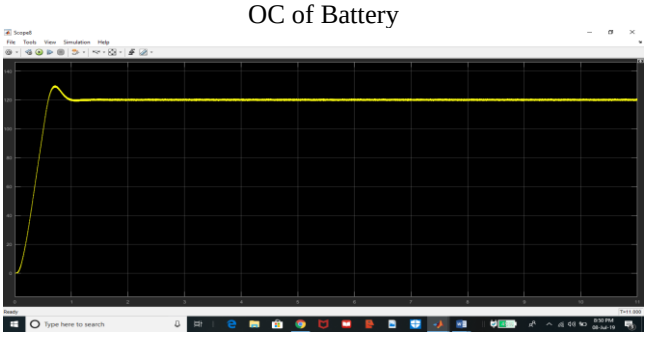
PV power



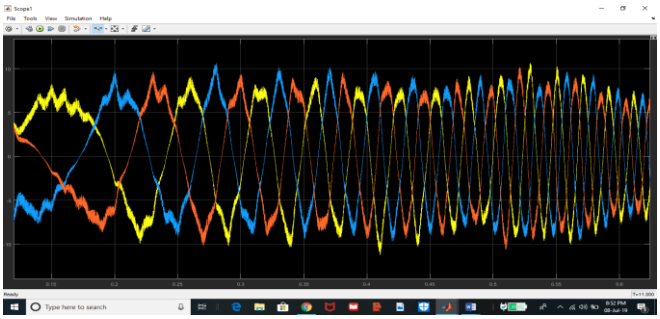
SOC of Supercapacitor



OC of Battery



Induction motor speed



Induction motor current

V. CONCLUSION

In this paper we simulated that the connected load is supplied with Photovoltaic, Supercapacitor and Battery accordingly, as per requirement and availability. The system analysis is done by both PI and Fuzzy logic controllers.
The fuzzy logic controller is a new control technique adopted for enhanced performance, it shows the better results as compare to PI controller.

REFERENCES

1. Layered porous materials indium triphosphate InP3 for high-performance flexible all –solid- state Supercapacitor journal yukai chang, Bochong Wang
2. Renewable sources of energy text book by B.H Khan.
3. A deep learning algorithm to estimate hourly global solar radiation from geostationary satellite data journal Power electronics text book by P. S Bimbhra.
4. Renewable and sustainable energy reviews journal Aoife M. Foley Modeling and simulation using matlab-simulink text book by
5. Dr. Shailendra Jain.
6. Supercapacitor Module Sizing Pdf by Prof. Francois Beguin, Prof. Elzbieta Frackowiak.
7. Research Gate State-of-the art off battery state-of-charge determination article in Measurement Science and Technology 16(4) December 2005.
8. Electric machinery test book by J.B Gupta

AUTHORS PROFILE

Swathi Peram, Student, M. Tech in power systems (EEE) from GRIET Hyderabad, B. Tech in EEE from G. Narayanamma institute of technology and science Hyderabad, GATE 2017 qualified swathyperam@gmail.com.

V Usha Rani, currently working as a Assistant professor in EEE department, GRIET -Hyderabad and doing Ph.D in KL University. She pursued B.Tech in Electrical and Electronics Engineering and M.Tech with the specialization of Power Electronics and Power Systems. She has teaching experience of 10 years. She is familiar with the softwares MATLAB, Pspice, Mi Power, Etap, PSCAD, LabView. She has published papers, Real time Web based Monitoring System for CO 2 (GWACS), Transmission Line Protection for Symmetrical and Unsymmetrical Faults using Distance Relays, Optimal Operation of Distributed Generation Unit with Micro Grid Controlling to Improve Stability and Generation Hosting Capacity, Loss Minimization and Voltage Profile Improvement with Network Reconfiguration and Distributed Generation. Her Research areas of interest are Power Systems, Renewable Energy Sources, IoT applications, Smart Grid.