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Modelling A Standalone Hybrid Micro Grid and Analyzing its Voltage Control Capabilities

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***Abstract*—**Electrical energy is one of the most important component in the development of any society. Electrical energy is primarily generated from fossil fuels, nuclear power or hydro but an increasing gap between demand and generation is leading is to find an alternative energy sources that produce clean energy and meet our increasing needs while maintaining the secure and reliable operation of power system. Presently Pakistan is facing extreme energy crisis and the situation is even worse in remote areas that are deprived from basic facility of electrical energy. These areas are normally gifted from natural resources that can play a key role in overcoming this problem. Run on River hydro generating units, solar Photovoltaic cells and Biomass generating units are able to generate clean electrical energy and meet the local demands; however, it is important that the frequency and voltage of that area is maintained within in the specified for the secure operation of power system. The voltage control plays important role in stable and reliable power supply. This research project will model a standalone micro grid where electrical energy will be generated from alternative sources of energy that are renewable i.e. hydro, solar irradiations and biomass resources, and then will employ specific technique for voltage control. This study will analyze the system behavior in different seasons when the load demand varies.

***Keywords*—** Micro grid, Micro Hydro power plant, Photovoltaic, Resources, Diesel Generator, Biomass, Super capacitor

I. INTRODUCTION

In 1880's amongst the most profitable economic business was supply of electrical power to the consumers. As time passed, electrical networks at state level were interconnected with the installation of bigger electricity generating stations and these were connected by long transmission networks, under supervision of the state. The increased demand for the electrical energy by consumers reinforced the idea of improving the centralized power production with bigger hydro electrical, nuclear, thermal generating stations during twentieth century. However, due to shortage of electricity during 1970s, concern about environmental issues rose in eighties, deficiency of fossil fuel reserve and were some of the factors to change the strategy and policy regarding energy.

Electrical network at start were Direct current networks, voltage levels and the distance were limited between generation and load point. The difference between generation and demand was gradually gained because of using some sort of domestic power storage devices, like batteries. As the electrical networks were expanded, the DC grid stations converted into ac. High voltage levels were used for the sake of achieving greater capacity and transmit electrical power overlong distances. However during the last years though, advancement in technology has played an important role in the integration of distributed power systems integrated with the utilization of alternative sources of energy i.e. renewable, due to which grids had became complex, but it has also provided different opportunities in order to avail electricity in most of faraway areas, where till now it was very complicated to supply electricity to them. Standalone hybrid electrical system including diverse electrical resources and storage devices have been manufactured and used in different applications. These appliances improve day by day and fulfilling the requirements.

A. Goals and Objectives:

This thesis investigates the implementation of a hybrid microgrid to electrify one of the rural village near Mardan district in Pakistan. Several cases have been searched out and these include a PV system, a micro hydro system, biomass system, diesel system and connection of hybrid micro grid with National grid. Energy from renewable resources are very unpredictable and dependent on climatic conditions [15]. The goal of the project is to gain a reliable and efficient operation of the microgrid system and search for the best possible optimized model.

An efficient, reliable, efficient and valid form provides the foundation for assessing system's function like detecting its flaws, implementation of various techniques and making the essential adjustments in order to set up a system contributing a good quality service to the consumer.

B. What is Micro Grid?

"In Micro grid it is supposed that a cluster of electrical loads and Power generation sources are working as a unity controllable system which supplies electricity to its local consumer." - This idea gives a new prototype for operating distributing generation systems. These small energy generating sources are having much lower expenditure, greater reliability are laid out at consumer side.

C. Micro Grid Types

Micro grids are basically classified into three types:

Residential Micro grid, Remote Microgrid, Mobile Microgrid.

1) Background

Hybrid Micro Grid technology mainly consist of renewable energy resources. These renewable sources are accessible in abundance and can be utilized up to utmost extent possible. These micro grid technologies earlier comprised of only Batteries, wind turbines and diesel generators in order to deliver power to the load, but there wasn't a better balance between generation and demand as the system was not secure in most of situations. Therefore to solve this issue, controller is used along with PV module. Output of the PV solar arrays depends on the solar irradiation and it varies from place to place depending upon the location. Thus, this thesis defines solar irradiance for Mardan Region located in Khyber Pakhtunkhwa Pakistan to find out the effects on the power flow of system. Biomass is also available in greater amount at the desired site. Along with Biomass we have Micro hydro availability too. Therefore we have multiple renewable energy sources to get benefit from. It is necessary to look out for the best possible combination of these Distributed Energy Resources (DER's). Voltage stability study will facilitate in verifying the stability and reliability of the system through the incident of fault or variation in load in the system. So we have to deal with simulation software to get the best results.

D. Photovoltaic System

Sun is the greatest source of energy and the energy can be directly extracted via photovoltaic cells. There are many areas in the world which are not connected with grid and there is no electricity but the electricity in these areas can be generated using solar power. Solar energy is clean energy source and is not dangerous for climate change. The energy generated by photovoltaic cell is given by formula.

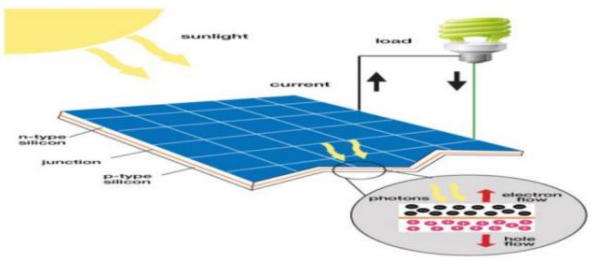


Figure 1. PV Working Principle

E. Solar Resource for Mardan Region:

. Solar radiation potential in Mardan region are estimated having solar radiation of 2.86 KWH/m2/day (minimum value)in the month of December and 7.88 KWH/m2/day (Peak value) in month of June. Similarly the Clearance index value for the region varies between 0.57 (in month of March) and 0.71 (in month of October).

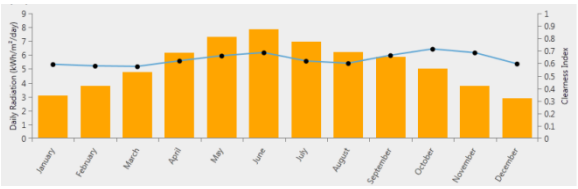


Figure 2. Solar Resource Available at the Site

1) Inverters:

An inverter is a circuit that converts the direct current (DC) electrical energy generated by sources like batteries, Photovoltaic arrays, or wind turbine system to alternating current electricity. The (AC) electrical energy is then utilized to drive AC appliances similar to the ones those are installed in majority of the household electrical outlets. The resulted AC waveform at the inverter output is a sine wave having frequency of 50Hz or 60Hz depending upon power system at different regions of the world. In Pakistan the required frequency for electrical appliances is 50Hz.

2) Micro Hydro System:

Hydropower is the production of electricity by utilizing kinetic energy of water produced by gravity. The water's kinetic energy in hydro power system dependent on two factors, available head and its flow. Small hydro system converts the potential energy due to head and kinetic energy of flowing water into electrical energy through turbine that drives an electrical generator. Every dissimilar site needs its own estimation in order to conclude the energy that is obtained at the output. This type of system is basically implemented in regions where a lesser stream of water can be utilized for power generation.

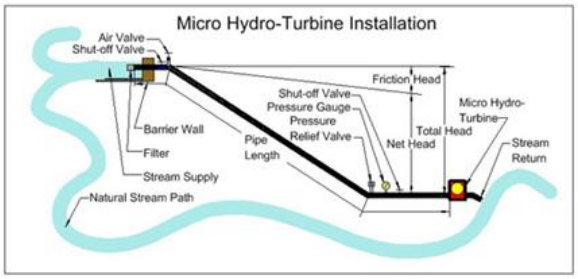


Figure 3. Micro Hydro Schematic

3) Hydro Resources available:

The flow data has been collected for the last six year from 2011 to 2016 on the proposed location from provincial irrigation department Mardan. The total flow of disty katlang at the proposed location has been calculated as 1.89m3/sec full supply discharge (FSD) in the peak summer season. Discharge data at Disty Katlang was collected for the last six years (2011-2016) from the office of irrigation department, Government of Khyber Pakhtunkhwa province.

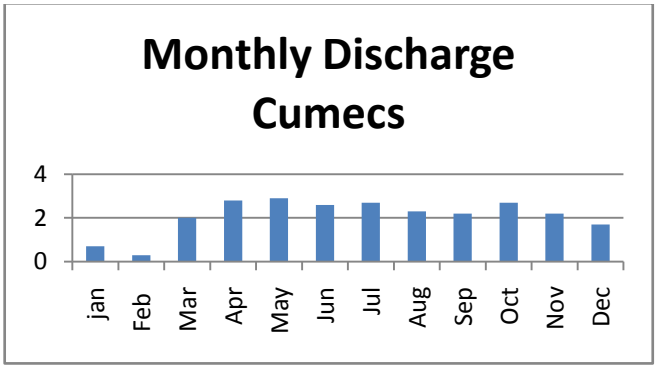


Figure 4. Monthly Stream Flow

F. *Biomass Energy:*

Organic matter is the biggest source of obtaining Biomass energy. This organic matter is derived from plants, animals, humans and marine life. Plants, dry grass, animals waste, garbage, wood pieces and municipal wastes are the examples of biomass. Biomass is another alternative and renewable energy source. Different processes are used to convert biomass to various other forms of energy. Thermo chemical and biochemical conversion are the two main conversion techniques.

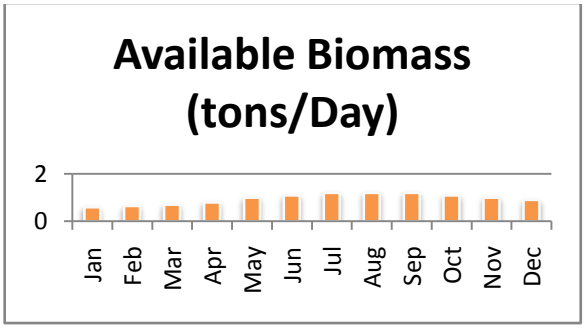


Figure 5. Monthly average biomass available at site

G. *Diesel Generator:*

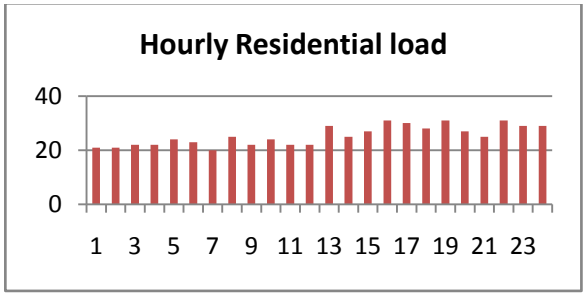
A diesel generator is comprised of a diesel engine with an electric generator to produce electrical energy. A diesel generator is chosen in simulation software to search out for the best optimized model in a micro grid; as it is of a higher power capacity in order to support the grid in emergency conditions. Emergency stand by diesel generators like those used in hospitals, shopping plazas, are, as a secondary function, widely used in various countries of the world (Short Term Operating Reserve) in order to support the respective national grids at times for a variety of reasons as well as in emergency conditions.

H. *Area Load Profile*

The total electrical load of the area for the listed appliances above was obtained to be supplied by the hybrid system.

1) *Types of Loads:*

Two types of electrical loads have been used for the selected site. One is the residential load and the other is the commercial load.



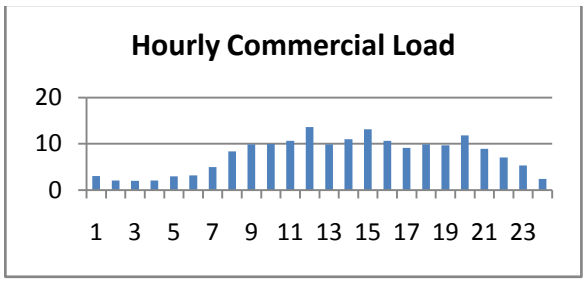


Figure 6. Hourly Commercial and residential load Profile

Cost Function For Photovoltaic:

$$PV_{NPC} = PV_{CC} + PV_{ins} + \sum_{1}^{n} PV_{O\&M} * T_{lifeTime} + PV_{rep} * N_{rep} \quad (5.1)$$

Biomass Cost Function:

$$BM_{NPC} = BM_{CC} + BM_{ins} + \sum_{n=1}^{8760} BM_{O\&M} * T_{lifetime} + BM_{rep} * N_{rep} + \sum_{n=1}^{8760} BM_{fuel} * T_{lifetime} \quad (5.2)$$

Micro-Hydro Cost Functions:

$$MH_{NPC} = MH_{CC} + MH_{ins} + \sum_{1}^{n} MH_{O\&M} * T_{lifeTime} + MH_{rep} * N_{rep}$$

Converter Cost Function:

$$CON_{NPC} = CON_{CC} + CON_{ins} + CON_{O\&M} * T_{lifeTime} + CON_{rep} * N_{rep} \quad (5.4)$$

System NPC & Objective Function:

$$RES_{NPC} = PV_{NPC} + MH_{NPC} + BM_{NPC} + CON_{NPC} + BB_{NPC} \quad (5.5)$$

II. Simulation & Results

The software used for the simulation of hybrid microgird project is Homer. All the required data was put in the software. Hydro, Diesel, Biomass, Photovoltaic and Grid connection and isolated system has been optimized. So the following cases have been obtained.

Case 1:A Standalone Hydro and Biomass Hybrid Model

The optimized results show that Hydro System has a maximum generated power of 24 kilowatts. Power produced by Biomass resources is 30 kilowatts. So these two generating

systems are the best two in terms of cost of electricity. So no Photovoltaic panels are required because of having greater cost. . The net present cost of complete system is $476,233 while operating cost is $29,208. The cost of electricity is $0.17.

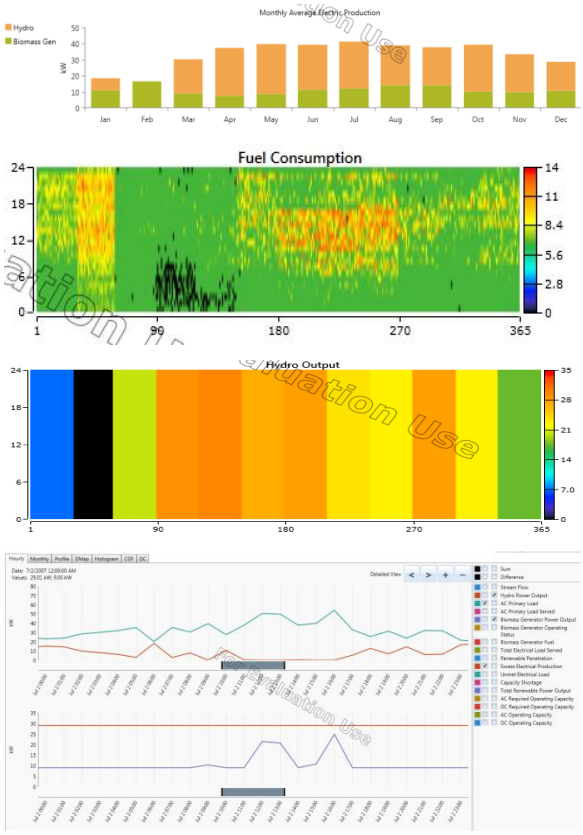
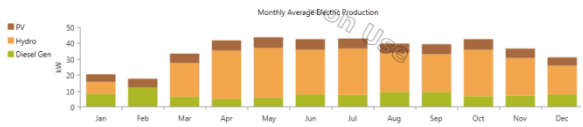


Figure 7. Case 1 System Complete Profile

The results from this model indicates that the cost of electricity and net present cost of Model is very high and secondly that Biomass will not be available for longer time period from area. So this model is not feasible and Biomass Power Generating Unit may be excluded from the model.

Case 2: A Standalone Hydro, Diesel Generator and PV Hybrid Model

In this case the generating units considered are Hydro, Photovoltaic and Diesel generator. The biomass resource is not considered in this case because the initial capital cost of Biomass gasifier generating unit is very high so it will be very economical if we use diesel generator set instead of biomass gasifier set.



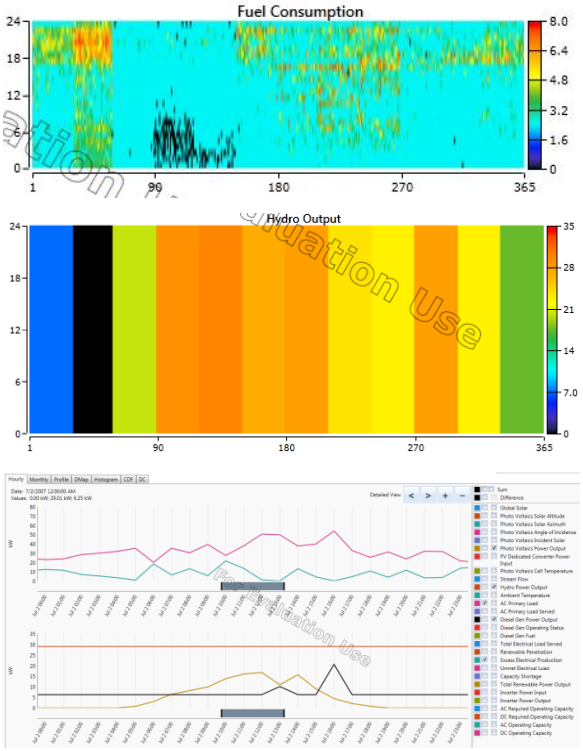
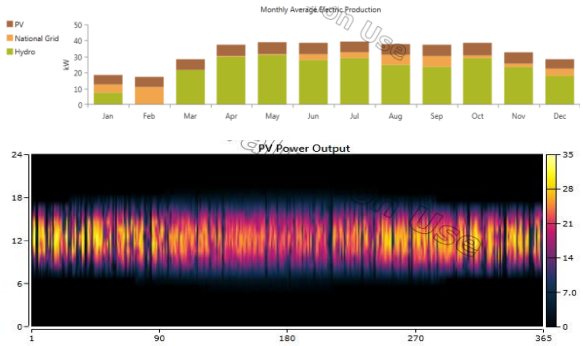


Figure 8. Case 2 System Complete Profile

The results show that we have to install 35 kilowatts of PV, 25 Kilowatts of Diesel Generator and 24 kilowatts of Hydro power generating system. The size of the inverter should be 20 kilowatts. The net present cost of the model is $344,562 while Operating and maintenance cost is $27,027. The cost of energy is $0.127 which is much lower than above case (Biomass and Hydro hybrid i.e $0.17).

Case 3: Hybrid Model with Grid Connected

In this case Hydro, Diesel and PV hybrid model is connected with the national grid. It has been concluded from the results that excess electricity is generated by hybrid model. It will be much economical to sell back this excess electricity to the grid.



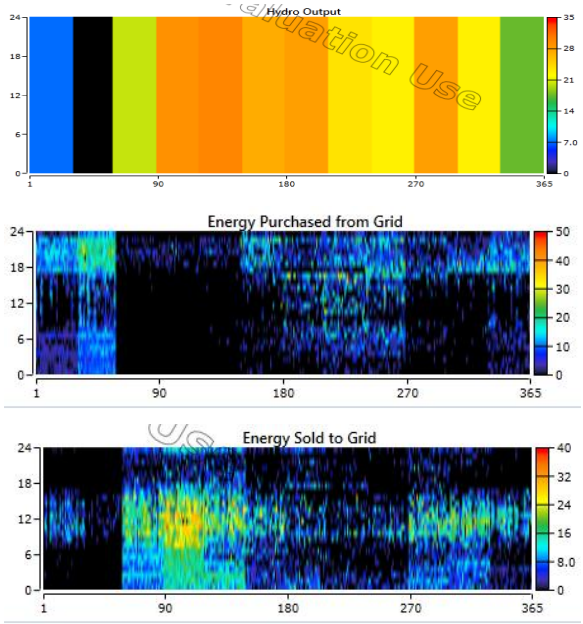


Figure 9. Case 3 System Complete Profile

A. *Voltage Controlling Micro grid system*

The point of common coupling is the point where Micro grid is connected to national grid, which during fault will be disconnected from main grid, after that operation of Micro grid comes under standalone mode. When a micro grid is operated in a grid connected mode a defined voltage value have to be ensured for its successful operation.

B. *Modeling of the Super Capacitor*

The rate of energy density in s Super Capacitors is extremely higher in contrast to ordinary capacitors, because plates are used instead of dielectric material in super capacitors. It has been proved that super capacitors have non linear behavior and its capacitance has invariable value if the parameters such as temperature, voltage and current are not having significant variations.

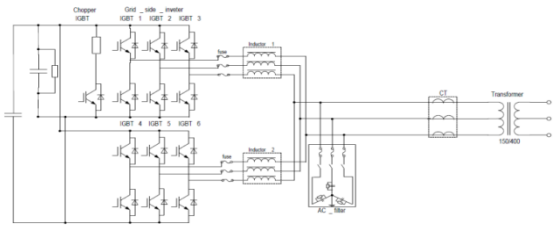


Figure 10. Bi-directional converter topology for SCESS.

C. *Transient Response of Micro-Grid under Load Increase of 12 KVA:*

The transient response of the grid is experimentally calculated with and without the super capacitor. 12KVA of inductive load was further added to already present resistive load at time t=80 ms for the reason to verify the super capacitors on grid.

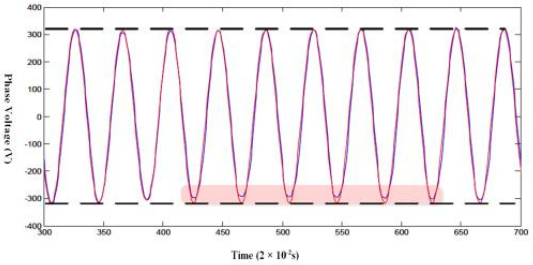


Figure 11. Phase Voltage of system when12 kVA load is added at t = 80 ms ("Blue" without SCESS and "Red" with SCESS).

It is proved from Figure that as soon as the load varies at t = 80 ms, the system takes round about 50 milliseconds to get better voltage sag without super capacitor whereas the voltage transient response has been improved rapidly with super capacitor has rapidly.

D. *Transient Response of Micro-Grid under Load Increase of 20 KVA:*

In this part of experiment the load is increased twice i.e 20 KVA with the intention to verify system reaction experimentally under the control of super capacitor, and Figure shows the voltage transient response.

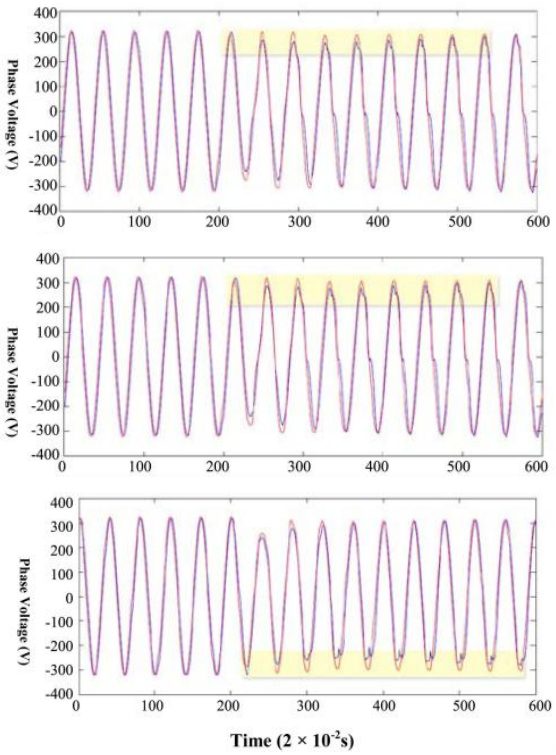


Figure 12. Phase Voltages of the system when load 20 kVA load is added at t = 40 ms ("Blue" without SCESS and "Red" with SCESS) (a) Phase voltage 1; (b) Phase voltage 2; (c) Phase voltage 3.

E. *Transient Response of Micro-Grid Due to Sudden Start-Up of an Induction Motor*

The induction motor draws greater current during starting, so it has regularly a very high initial current value, keeping in

view this point the effect of impulsive start of an induction motor on system with and without super capacitor is studied.

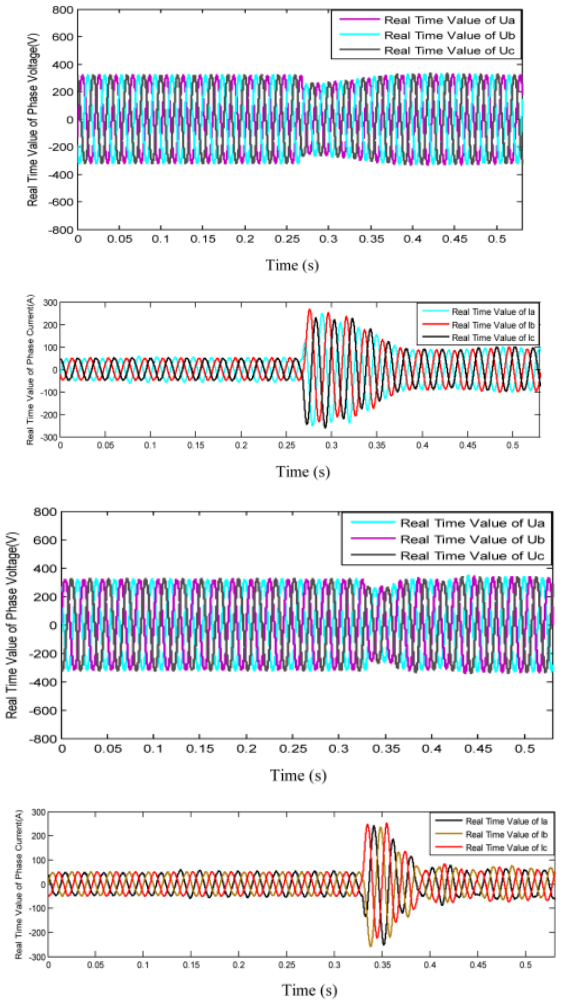


Figure 13. Phase voltages of the system when an induction motor start-ups (a) Three Phase Voltages (without SCESS); (b) Three Phase Currents (without SCESS); (c) Three Phase Voltage (with SCESS); (d) Three Phase Currents (with SCESS).

It can be concluded that when induction motor suddenly starts up at time t=0.27s approx for the system without super capacitor, voltage sags till t = 0.45s and then voltage is stabilized in about 180 ms but in case when inductor motor starts up at time t=0.33s for system with super capacitor, the voltage comes to its normal value and get stabilized in very short period of about 70ms. In the same way, the three phase current's amplitude boosts up when the induction motor is allied and with the help of super capacitors less time is taken by current to get stabilized.

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CONCLUSION

This research work provides an optimized solution for standalone and interconnected micro grid systems having different energy resources. The sensitivity analysis displays the intermittent nature of renewable resources. It can be concluded from results that an optimized model with mix energy sources help in making the power system operation reliable by maintaining the voltage and frequency at their normal level. Second Portion of research shows that the Transient study of the system is very significant in this observation for its flourishing and stable process. Some of the important factors like upper and lower limits of voltage of system should be taken into account, and a comprehensive study is required to make sure the system's transient response under different load conditions because the hybrid micro-grid must develop a robust system that can operate stably and reliably both in islanded as well as grid-connected mode. It has been proved from simulations that during particular load variations in micro grid system, the transient voltage response of the system is disturbed for some cycles. Therefore super capacitor will facilitate the system to improve and stabilize three phase voltages rapidly.

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